Alaska Fisheries Technical Report Number 10

DISTRIBUTION AND QUANTIFICATION OF WATER WITHIN THE LAKES OF THE 1002 AREA, ARCTIC NATIONAL WILDLIFE REFUGE, ALASKA

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Distribution and Quantification of Water Within the Lakes of the 1002 Area, Arctic National Wildlife Refuge, Alaska

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Abstract

An inventory of lake basins in the 1002 area of the Arctic National Wildlife Refuge was conducted as part of an effort to develop a hydrologic data base, map sources of water, and quantify water availability.

Using a recording fathometer, depth profile measurements were taken on 119 lakes within the 1002 area during the summer months of 1988, 1989, and 1990. Fathometer output was used to construct lake contour maps, calculate volumes, and estimate winter water volumes beneath ice cover.

Total estimated volume of the study lakes ranged from 55,382 acre-ft when free of ice to 3,366 acre-ft beneath seven feet of ice, the maximum ice thickness. In April, when ice thickness is at maximum, 90 percent of the available water is contained in nine of the 119 lakes surveyed. The lakes are not evenly distributed across the 1002 area. A large number of lakes are congregated near the mouth of the Canning River, and only two lakes are located in the region between the Katakturuk and Sadlerochit Rivers.

During the winter months, winter water is more abundant in lakes than in pools located beneath ice hummocks along major river drainages of the 1002 area.

Observation of fish presence in lakes was more frequent and widespread than previously suspected. Ninespine stickleback (Pungitius pungitius) were found in 34 of the 52 lakes (65%) surveyed in 1989.

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Introduction

The location and quantity of water from natural lakes in the 1002 area of the Arctic National Wildlife Refuge (ANWR) were evaluated to identify water availability throughout the year (Figures 1 and 2). Information on the spatial and temporal distribution of potential water sources is required to make informed decisions concerning the management of potential oil and gas development so as to best protect aquatic habitats and the fish and wildlife species that use them.

The availability of water during winter months is influenced by extremely low air temperatures and short, cool summers. Total annual precipitation averages 6.2 inches on Barter Island (Arctic Environmental Information and Data Center 1986). Ninety-nine percent of the 1002 area is classified as wetlands. However, water is limited and confined to the shallow zone above permafrost (Clough et al. 1987). Lake depth also influences winter water availability. Clough et al. (1987) reported that most lakes have basins less than 7 ft deep and freeze to the bottom by late winter. Wilson et al. (1977) reported that maximum ice thickness in Arctic lakes normally does not exceed 6.6 ft except in extremely severe winters.

Winter water availability and distribution within the 1002 area is an important factor to consider with respect to the potential large scale oil and gas exploration activities being considered in the 1002 area. Wilson et al. (1977) and Clough et al. (1987) reported that the average water demands in the Prudhoe Bay area for oil and gas exploration were:

Geophysical exploration.....	0.003 acre-ft/day/crew
Exploratory drilling.....	0.09 acre-ft/day/crew
Base camp (75 men).....	0.02 acre-ft/day
Ice road construction and maintenance.....	4.1 acre-ft/mi
Ice airstrip construction and maintenance...	21.5 acre-ft

According to Clough et al. (1987), it is estimated that 46 acre-ft of water would be required to build and support a single exploratory well. Note that ice road construction is the largest consumer of available winter water should oil and gas exploration occur.

Few lakes in the 1002 area have been measured to determine their depth or volume. West and Fruge (1989) estimated the depth of nine study lakes based on fetch along the direction of prevailing winds (Carson and Hussey 1962). Three of the nine lakes were estimated to be deeper than 5.9 ft; two of these lakes are located on Kaktovik Inupiat Corporation lands. Childers et al. (1977) reported water depth and ice thickness for six lakes within the 1002 area. The total depth, including ice thickness, ranged from 6.2 to 10.0 ft. Three of these lakes are on Kaktovik Inupiat Corporation lands.

Water depth is thought to restrict the presence of fish in Arctic lakes during the winter. Hobbie (1984) found fish only to be present in lakes with depths greater than 5.6 ft. Within the 1002 Area, Ward and Craig (1974) sampled 14 lakes along the Canning River and found fish present in six of the lakes, including broad whitefish (Coregonus nasus), round whitefish (Prosopium cylindraceum), Arctic grayling(Thymallus arcticus), Arctic char (Salvelinus

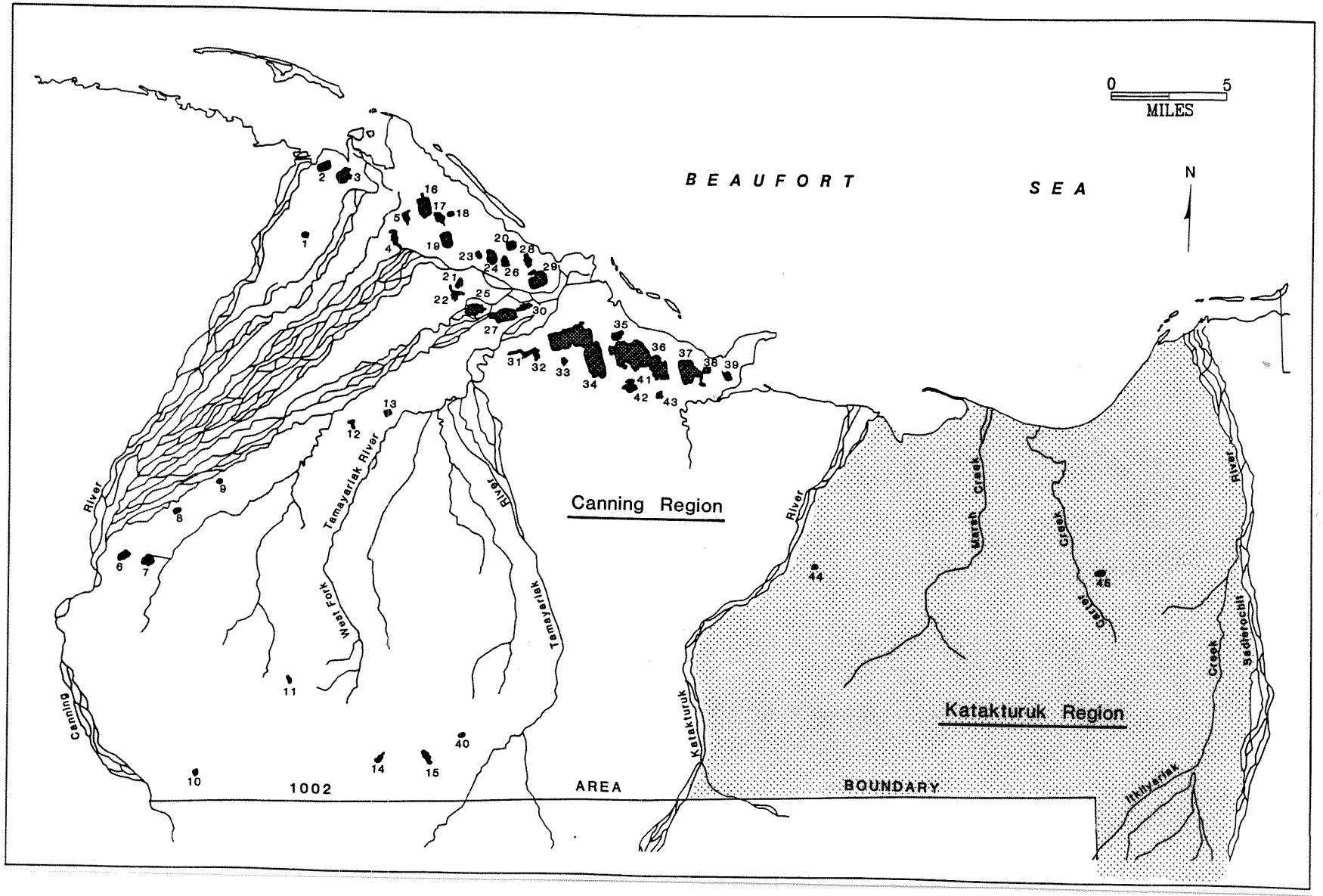

Figure 1.-Map of lakes on the western portion of the 1002 area, Arctic National Wildlife Refuge.

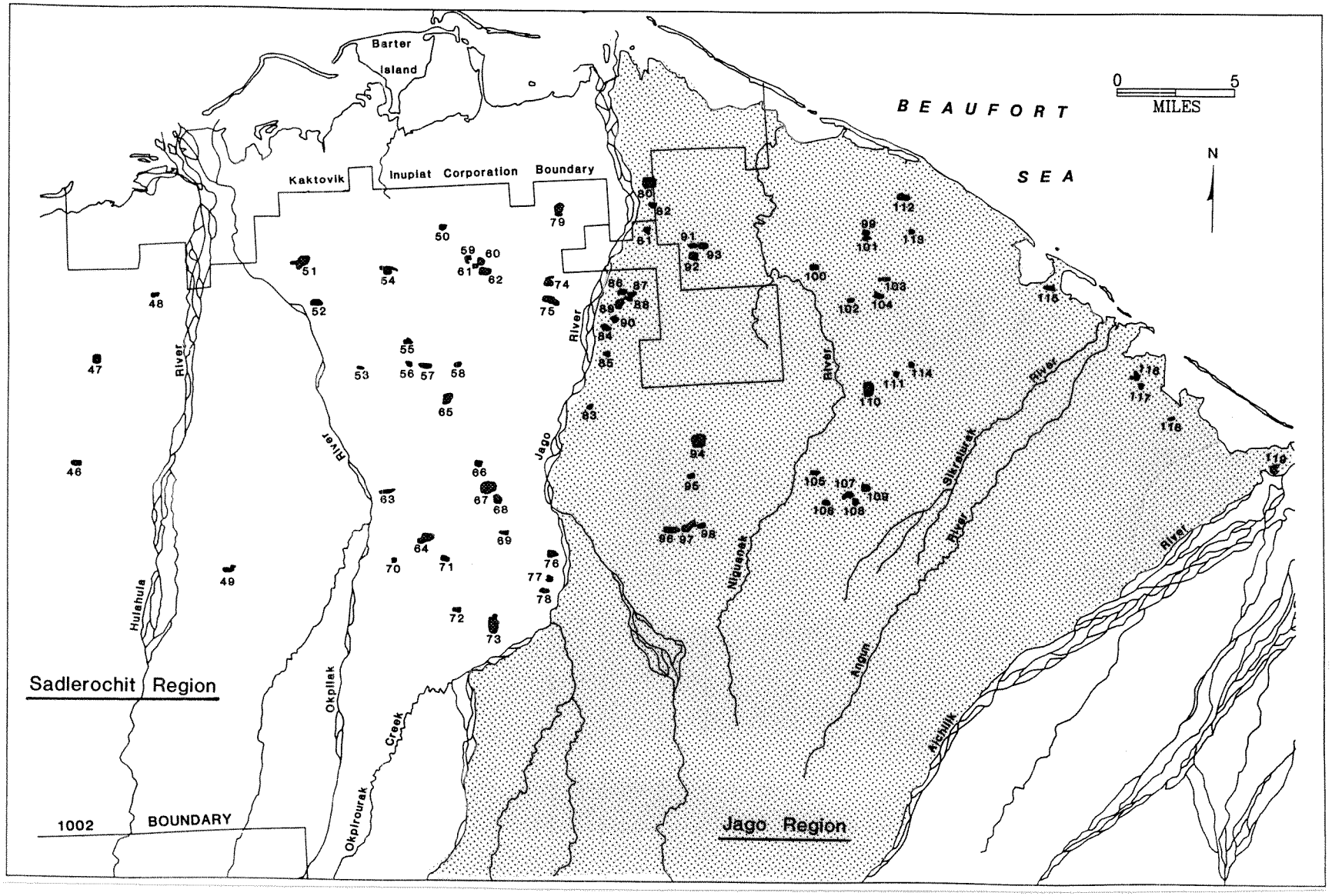

Figure 2.-Map of lakes on the eastern portion of the 1002 area, Arctic National Wildlife Refuge.

alpinus), ninespine stickleback (Pungitius pungitius), and Arctic flounder (Liopsetta glacialis). West and Fruge (1989) found ninespine stickleback present in three of nine lakes sampled within the 1002 Area.

The objectives of this study were to quantify the volume of water, including winter water, in lakes of the 1002 area with surface areas near or greater than 25 acres. Winter water is defined as water in its liquid phase. The second objective was to examine the distribution of these lakes. This final report summarizes the data collected during 1988-1990.

Methods

One hundred and nineteen lakes were studied within the 1002 area of the ANWR. Lakes were identified from U.S. Geological Survey (1:63,360) maps. These 119 lakes are the largest lakes within the 1002 Area. Lakes that were not surveyed were considered to be to small or to shallow to be included in the study. Transect data was collected on the two largest lakes in 1988. In 1989, transect data were collected on 52 of the larger lakes and the remaining 65 lakes were surveyed in 1990. Because the lakes in the 1002 area are unnamed, they are identified by legal locations and latitude-longitude map coordinates (Appendix A). Note that lake numbers identified in Elliott (1990) have been changed to include the lake transect data from 1990, thus allowing lakes to be grouped by geographic location.

Water depth was measured along a minimum of 6 transects across each lake, using a recording fathometer mounted on the back of an inflatable boat. A constant throttle setting was used for each transect. The goal was to run three parallel transects dividing the lake into quarters along one axis. Then three more transects were run perpendicular to the original transects, also splitting the lake into quarters. Transect configuration was often altered because of irregular shape or size of the lake.

In 1989, several soundings were taken at each lake using a weighted line to develop a calibration factor for the depth recorded by the fathometer. Sounding depths were read to the nearest 0.1 ft. The depths recorded on the fathometer strip charts were adjusted to true depth soundings using a mylar overlay scribed with the strip chart scale. The overlay scale was placed over the strip chart records and aligned to calibration depth records marked on the strip chart. The location of each 1 ft depth contour interval was then identified along each transect using the overlay scale (Elliott 1990).

In 1990, several depth measurements were taken to the nearest 0.1 ft at the beginning of each set of transects using a weighted line. Soundings taken by the fathometer were then calibrated to the measurements of the weighted line. Calibration information was recorded on the strip chart before any transects were run. Lakes with maximum depths less then 2.5 ft were not measured in the field. The volumes of these shallow lakes were estimated using surface area measurements from enlarged U.S. Geological Survey maps and maximum depth estimates made by the surveyors.

Lake shoreline maps were made from approximately 9X enlargements of 1:63,360 scale U.S. Geological Survey topographic maps. Contour interval locations were placed on lake maps using the proportion of chart transect length to map transect length. Contour lines were drawn on each lake map through corresponding points of depth. The area within each 1 ft contour was read to the nearest 0.001 in^2 using a planimeter. The planimeter reading was then converted to the nearest 1 acre based on the lake map scale. Lake volume was calculated using the formula (Welch 1948):

$$V = \Sigma [h/3 \ (a_1 + a_2 + \sqrt{a_1 a_2})]$$

where, V = lake volume (acre-ft)
h = strata height (ft)
a_1 = area of top surface of strata (acres)
a_2 = area of bottom surface of strata (acres)

Water volumes during winter were calculated by subtracting 1 ft strata volumes from the ice-free volume to estimate volume of water beneath successive 1 ft layers of ice. Dates that ice thickness reached the 1 ft intervals were approximated from averaged data of ice thickness over time for Barter Island Lake reported by Bilello and Bates (1969, 1971, 1972, and 1975), representing eight years of record.

For the purpose of analysis the 1002 area was broken into four geographic regions. Summarizing the data by geographic region illuminates the uneven distribution of lakes across the coastal plain. All lakes surveyed between the Canning and Katakturuk Rivers (lake #1-43) make up the Canning region. Lakes located between the Katakturuk and Sadlerochit Rivers comprise the Katakturuk region (lake #44-45). The Sadlerochit region (lake #46-79) is located between the Sadlerochit and Jago Rivers. The Jago region extends east from the Jago River, to the eastern boundary of the 1002 area (lake #80-119).

In 1989, each lake was examined for the presence of fish during August. The margins of several lakes were visually inspected to determine the most heavily used shoreline habitat type. All of the lakes were then sampled along selected shoreline areas using a long handled dip net. All fish captured were identified to species (Elliott 1990). No fish sampling was conducted on lakes during 1990.

In 1989, the maximum fetch distance parallel to prevailing wind direction (approximately WSW-ENE) was measured to the nearest 100 ft from enlargements of 1:63,360 scale topographic maps. The relationship between lake depth and maximum fetch distance was determined using simple linear regression (Elliott 1990).

Results

Of the 119 lakes surveyed, surface areas averaged 90 acres and ranged from 0 to 1,533 acres (Appendix B). Maximum depths recorded for individual lakes ranged from 0 to 24.8 ft with an average of 6.7 ft. Fifty-nine of the lakes

surveyed had a maximum depth that exceeded 7.0 ft. Four of the 119 lakes identified on the U.S. Geological Survey maps were either dry or contained less than one foot of water. These dry lakes have been included in the data base and account for areas and volumes equal to zero.

Individual lake volumes during ice-free conditions ranged from 0 to 9,285 acre-ft. Total lake volume for the 119 lakes measured was 55,379 acre-ft. In early January, when ice thickness is approximately four feet, lake water volume totaled 17,755 acre-ft from 85 lakes. By mid-April, when ice thickness reaches its maximum of 7 ft, 60 of the 119 lakes will freeze to bottom. The remaining 59 lakes contain a total water volume of 3,365 acre-ft. At maximum ice development of 7 ft, only nine lakes (lake #s 2, 6, 14, 27, 34, 36, 76, 80, and 119) contain at least 50 acre-ft of winter water, the approximate minimum volume required to support a exploratory well site. These nine lakes comprise 90 percent of the available winter water in lakes.

Canning Region: The distribution of winter water in lakes is heavily skewed in the 1002 area. The largest volume of winter water, 64 to 80 percent, depending on ice thickness (Table 1), is located in the Canning region (lakes #1-43). Within the Canning region lakes tend to be clustered near the mouth of the Canning River. At an ice thickness of 7 ft, 48 percent of the available water in the Canning region is located in one lake, while 92 percent is in only five lakes. With ice thicknesses of 0, 4, and 7 ft there are 39, 20, and 6 lakes respectively that contain 50 acre-ft of water or more.

Katakturuk Region: There were only two lakes (lake #44 and #45) between the Katakturuk and Sadlerochit Rivers (Katakturuk region) with surface areas great enough to be included in this survey. These two lakes contained less then one percent of all the available water regardless of ice presence and thickness. Only one lake contained more than 50 acre-ft of water, and with an ice thickness of 7 ft, this region contains less than 10 acre-ft of winter water.

Table 1.--Volume and percent of total 1002 Area lake water surveyed, by region, at ice thicknesses of zero, four, and seven feet. The date of average ice-thickness is in parenthesis.

		0 ft Ice		4 ft Ice (Jan 4)		7 ft Ice (Apr 16)	
Region	No. Lakes	Volume (acre-ft)	Percent of Total	Volume (acre-ft)	Percent of Total	Volume (acre-ft)	Percent of Total
Canning	43	35,541	64.2	12,378	69.7	2,669	79.3
Katakturuk	2	339	0.6	93	0.5	6	0.2
Sadlerochit	34	9,959	18.0	2,504	14.1	186	5.5
Jago	40	9,543	17.2	2,783	15.7	505	15.0
Totals	119	55,382	100.0	17,758	100.0	3,366	100.0

Sadlerochit Region: Five to 18 percent of the water surveyed was located in the 34 surveyed lakes in the Sadlerochit region (lake #46-79). The lakes in this region are concentrated and well distributed in the northern half and east of the Okpilak River. All lakes along the coast in this section are on Kaktovik Inupiat Corporation land and were not surveyed. Again, the water is not evenly distributed within the Sadlerochit region. With 0, 4, and 7 ft of lake ice, there are 33, 15, and 1 lakes, respectively, that contain 50 acre-ft of water or more.

Jago Region: A total of 9,543 acre-ft of water was found in the 40 lakes surveyed in the Jago region. The largest concentrations of lakes were found along the Jago and Niguanak Rivers. In the Jago region, with four feet of lake ice, there is 2,783 acre-ft of water available and only 10 lakes with greater than 50 acre-ft of winter water. With 7 ft of lake ice there are only two lakes with more than 50 acre-ft of water volume required to support an exploratory well site.

Additional Results: Ninespine stickleback were captured in 34 of the 52 lakes surveyed in 1989. No other species were captured. Fish were not sampled during the 1990 survey, but fish were observed in lake numbers four and five. Fish captured in 1989 were limited to two areas, between the Canning and Katakturuk Rivers and between the Okpilak and Aichilik Rivers. No fish were found in the central portion of the 1002 area between the Katakturuk and Opilak Rivers. Fish were found in 83 percent of the lakes with depths greater than 7 ft and in 43 percent of the lakes with depths less than 7 ft deep (Elliott 1990).

Of the 54 lakes inventoried in 1989, 45 lakes were within the range of the fetch distances reported by Carson and Hussey (1962) illustrating "the ideal depth-fetch relationship." However, the depth of 41 of the 45 lakes was underestimated by this relationship. Only 14, or 31 percent, of the 45 lakes were within $\pm$ 2 ft of the ideal relationship. Elliott (1990) found that there was no relationship (r^2=0.05) between lake depth and maximum fetch distance (n=45) in the 1002 Area.

Discussion

Lake depths measured during this study were consistently greater than depths estimated and measured for the same lakes investigated during previous studies. Childers et al. (1977) measured ice surface to lake bottom depths of 6.2, 7.3, and 7.5 ft in three lakes for which maximum depths of 6.4, 9.0, and 8.5 ft, respectively, were measured during this inventory. However, measurements by Childers et al. (1977) were taken at only a single point in each lake.

Lakes provide a more abundant source of winter water than naturally occurring water pools found in rivers (Elliott and Lyons 1990). The total estimated volume of water beneath ice hummocks in the 1002 area during 1989 was estimated to be 27 acre-ft (Elliott and Lyons 1990). Winter water availability in lakes ranges from 55,379 acre-ft in October to 3,366 acre-ft

in April. The only other naturally occurring winter water source available are perennial springs. The largest spring in the 1002 area, Sadlerochit Spring, discharges 35 cfs or 70 acre-ft per day during winter months (Lyons 1990).

Timing and distribution of water in the 1002 area is a critical factor to consider in regard to oil and gas exploration. In an average year, ice begins forming on lakes by early October; by mid-December more than half the available water volume has been frozen, reducing the winter water from approximately 55,000 acre-ft to approximately 25,000 acre-ft (Figure 3).

Wilson et al. (1977) and Clough et al. (1987) estimated that a single exploratory well site would require a minimum of 46 acre-ft of water. Ice road construction also requires large volumes of winter water, 4.1 acre-ft per mile (Wilson et al. 1977; Clough et al. 1987; and Elliott and Lyons 1990). Since lakes in the 1002 area are unevenly distributed, winter water that might be used for ice road construction is not uniformly available. A large concentration of lakes occur near the mouth of the Canning River and a fairly good distribution of lakes occur within 20 miles of the coast between the Hulahula and Niguanak Rivers (Figures 1 & 2). Distribution of lakes in the remaining regions of the 1002 area is sparse and widespread.

Water quality of lakes in the Arctic is generally good during summer months (Sloan 1987) with the exception of shallow lakes and lakes located along the coast. Shallow lakes are often turbid because of the continual disturbance of bottom sediments caused by wave action (Sloan 1987). Lakes located near the coast are subject to high concentration of dissolved solids due to sea spray or salt water intrusions (Sloan 1987). Clough et al.(1987), Sloan (1987), and Wilson et al. (1977) reported that as ice thickness increases, there is an increase in the concentrations of dissolved ions and organic matter, and that dissolved oxygen concentrations are depressed due to the lack of aeration and limited photosynthesis during winter months. Clough et al. (1987) noted that changes in water quality are dependent on the ratio of water to ice and that shallow lakes that freeze nearly to the bottom are unpotable.

Carson and Hussey (1962) estimated lake depth based on fetch along the direction of prevailing winds. The Arctic Coastal Plain province is divided into two sections, the Teshekpuk section which is characterized by flat topography, and the White Hills section which is characterized by scattered groups of low hills (Wahrhaftig 1965). The "oriented lakes" discussed by Carson and Hussey (1962) are found in the Teshekpuk section, which extends into the 1002 Area only near the mouth of the Canning River. Most of the lakes in the 1002 Area are within the White Hills section of the Arctic Coastal Plain province and their shape is defined more by topography than prevailing wind direction.

Fish distribution in 1002 area lakes is much more widespread than previously reported. Elliott (1990) reported capturing ninespine stickleback in 34 of the 52 lakes surveyed in 1989. These fish were found in lakes throughout the 1002 area with the exception of the region between the Katakturuk and Okpilak Rivers. Fish were captured in 30 and observed in two lakes for which there was no previous record of fish presence.

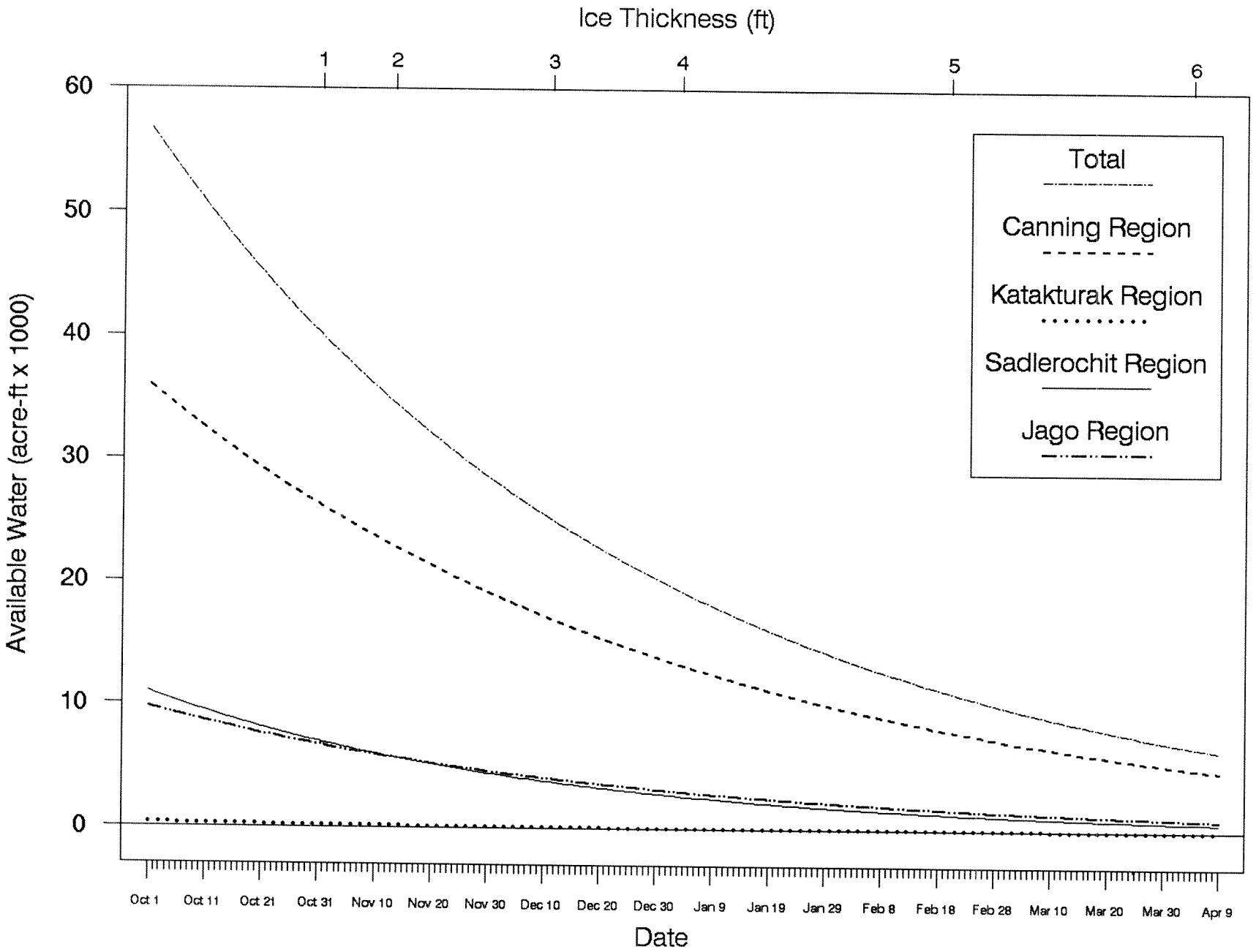

Figure 3.-Volume of available water from lakes within the 1002 area of the Arctic National Wildlife Refuge during winter months.

Conclusions

Lakes deeper than 7 ft can serve as winter habitat for fish (Elliott 1990). The withdrawal of water from lakes inhabited by fish should be considered on a case by case basis, taking into account the amount of water necessary for overwinter survival. If there are no environmental concerns with a lake freezing to the substrate, larger volumes of water are available by removing the water prior to maximum ice development. For example, 152 acre-ft instead of 29 acre-ft could be obtained from lake #46 prior to January 4, before ice thickness reaches 4 ft (Table 1). Using this criterion, lakes shallower than 7 ft, which do not support fish, could also be used as a winter water source.

Since fish sampling was limited to dipnets and no sampling was conducted in 1990, it is recommended that all lakes be surveyed for fish presence prior to using the lake as a winter water source.

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Appendix A

Legal descriptions of study lake locations

Appendix A.--Legal descriptions of study lake locations.

Lake Number	Map Location	Latitude	Longitude
	Flaxman Island (A-4)*		
1	NE¼ SW¼ Sec. 34, T.9N., R.24E.	70°05'54"	146°56'36"
2	NE¼ SW¼ Sec. 14, T.9N., R.24E.	70°08'00"	145°57'18"
3	SW¼ SW¼ Sec. 13, T.9N., R.24E.	70°07'36"	145°56'36"
4	NE¼ SW¼ Sec. 32, T.9N., R.25E.	70°05'24"	145°51'12"
5	NW¼ SE¼ Sec. 29, T.9N., R.25E.	70°06'06"	145°50'00"
	Mt. Michelson (D-4)*		
6	SW¼ NW¼ Sec. 11, T.6N., R.23E.	69°53'30"	146°20'28"
7	NW¼ SW¼ Sec. 12, T.6N., R.23E.	69°53'20"	146°17'58"
8	SW¼ NW¼ Sec. 31, T.7N., R.24E.	69°55'08"	146°14'55"
9	NW¼ NW¼ Sec. 28, T.7N., R.24E.	69°56'14"	146°10'08"
10	SE¼ SE¼ Sec. 30, T.5N., R.24E.	69°45'21"	145°12'57"
11	NW¼ SW¼ Sec. 1, T.5N., R.24E.	69°48'51"	146°02'57"
12	NE¼ SE¼ Sec. 8, T.7N., R.25E.	69°58'22"	145°55'55"
13	NE¼ NW¼ Sec. 10, T.7N., R.25E.	69°58'46"	145°52'10"
14	NW¼ NE¼ Sec. 28, T.5N., R.25E.	69°45'58"	145°53'40"
15	SW¼ SE¼ Sec. 23, T.5N., R.25E.	69°46'00"	145°48'36"
	Flaxman Island (A-3)*		
16	SW¼ NE¼ Sec. 28, T.9N., R.25E.	70°06'30"	145°48'00"
17	NW¼ SW¼ Sec. 27, T.9N., R.25E.	70°06'12"	145°46'06"
18	NW¼ SW¼ Sec. 27, T.9N., R.25E.	70°06'18"	145°44'54"
19	NE¼ SW¼ Sec. 34, T.9N., R.25E.	70°05'18"	145°45'18"
20	SE¼ SW¼ Sec. 31, T.9N., R.26E.	70°04'30"	145°39'12"
21	NW¼ SE¼ Sec. 7, T.8N., R.26E.	70°03'42"	145°44'06"
22	NE¼ NW¼ Sec. 18, T.8N., R.26E.	70°03'18"	145°44'30"
23	SE¼ NW¼ Sec. 5, T.8N., R.26E.	70°04'42"	145°41'54"
24	SE¼ NE¼ Sec. 5, T.8N., R.26E.	70°04'36"	145°40'36"
25	NW¼ SW¼ Sec. 17, T.8N., R.26E.	70°02'41"	145°42'45"
26	NW¼ SE¼ Sec. 4, T.8N., R.26E.	70°04'30"	145°39'12"
27	SE¼ SW¼ Sec. 16, T.8N., R.26E.	70°02'27"	145°39'30"
28	NW¼ SE¼ Sec. 3, T.8N., R.26E.	70°04'30"	145°36'48"
29	NE¼ SE¼ Sec. 10, T.8N., R.26E.	70°03'48"	145°35'48"
30	NE¼ SW¼ Sec. 15, T.8N., R.26E.	70°02'48"	145°37'12"
31	NE¼ SW¼ Sec. 27, T.8N., R.26E.	70°58'00"	145°37'28"
32	SW¼ SE¼ Sec. 27, T.8N., R.26E.	70°00'54"	145°36'06"
33	NW¼ NE¼ Sec. 35, T.8N., R.26E.	70°00'42"	145°33'06"
34	SE¼ SE¼ Sec. 24, T.8N., R.26E.	70°01'35"	145°31'15"
35	NE¼ SW¼ Sec. 20, T.8N., R.27E.	70°01'48"	145°27'30"
36	NW¼ SW¼ Sec. 28, T.8N., R.27E.	70°01'05"	145°22'55"

Appendix A.--Continued

Lake Number	Map Location	Latitude	Longitude
	Flaxman Island (A-3)*		
37	SW¼ NW¼ Sec. 35, T.8N., R.27E.	70°24'00"	145°20'00"
38	SW¼ NW¼ Sec. 36, T.8N., R.27E.	70°00'10"	145°18'00"
39	SE¼ SE¼ Sec. 36, T.8N., R.27E.	70°00'00"	145°15'42"
	Mt. Michelson (D-3)*		
40	NE¼ NW¼ Sec. 19, T.5N., R.26E.	69°46'48"	145°44'45"
41	SE¼ SE¼ Sec. 32, T.8N., R.27E.	70°00'00"	145°26'18"
42	NE¼ NE¼ Sec. 5, T.7N., R.27E.	69°59'43"	145°26'20"
43	SW¼ NW¼ Sec. 3, T.7N., R.27E.	69°59'24"	145°23'06"
	Mt. Michelson (D-2)*		
44	SW¼ SE¼ Sec. 10, T.6N., R.28E.	69°52'54"	145°06'48"
45	SW¼ NE¼ Sec. 15, T.6N., R.30E.	69°52'33"	144°36'18"
	Mt. Michelson (D-1)*		
46	NE¼ NE¼ Sec. 13, T.6N., R.31E.	69°52'50"	144°15'40"
47	SW¼ SW¼ Sec. 20, T.7N., R.32E.	69°56'34"	144°13'08"
48	NW¼ NE¼ Sec. 10, T.7N., R.32E.	69°58'48"	144°06'42"
49	SW¼ SW¼ Sec. 6, T.5N., R.33E.	69°48'36"	144°20'00"
	Barter Island (A-5)*		
50	NE¼ SE¼ Sec. 27, T.8N., R.34E.	70°00'54"	145°35'42"
	Demarcation Point (D-5)*		
51	NE¼ NE¼ Sec. 3, T.7N., R.33E.	69°59'52"	143°50'52"
52	SE¼ SW¼ Sec. 11, T.7N., R.33E.	69°58'18"	143°49'43"
53	NW¼ SW¼ Sec. 30, T.7N., R.34E.	69°55'54"	143°45'18"
54	NE¼ SE¼ Sec. 5, T.7N., R.34E.	69°59'24"	143°41'55"
55	NW¼ SW¼ Sec. 21, T.7N., R.34E.	69°56'48"	143°40'06"
56	SW¼ NW¼ Sec. 28, T.7N., R.34E.	69°56'00"	143°40'00"
57	NE¼ SE¼ Sec. 28, T.7N., R.34E.	69°55'54"	143°38'30"
58	NW¼ SW¼ Sec. 26, T.7N., R.34E.	69°55'54"	143°34'54"
59	SE¼ NE¼ Sec. 2, T.7N., R.34E.	69°59'42"	143°33'12"
60	SW¼ NE¼ Sec. 1, T.7N., R.34E.	69°59'36"	143°31'54"
61	NE¼ SW¼ Sec. 1, T.7N., R.34E.	69°59'24"	143°32'30"
62	SW¼ SE¼ Sec. 1, T.7N., R.34E.	69°59'11"	143°31'30"
63	SE¼ SE¼ Sec. 19, T.6N., R.34E.	69°51'24"	143°43'06"

Appendix A.--Continued

Lake Number	Map Location	Latitude	Longitude
	Demarcation Point (D-5)*		
64	SW¼ SE¼ Sec. 33, T.6N., R.34E.	69°49'34"	143°39'22"
65	NE¼ NE¼ Sec. 3, T.6N., R.34E.	69°54'40"	143°36'13"
66	SE¼ SE¼ Sec. 14, T.6N., R.34E.	69°52'12"	143°33'12"
67	SE¼ SW¼ Sec. 24, T.6N., R.34E.	69°51'20"	143°32'30"
68	SW¼ NE¼ Sec. 25, T.6N., R.34E.	69°50'51"	143°31'32"
69	SE¼ SE¼ Sec. 36, T.6N., R.34E.	69°49'36"	143°31'06"
70	SW¼ SW¼ Sec. 5, T.5N., R.34E.	69°48'48"	143°42'54"
71	SE¼ SW¼ Sec. 3, T.5N., R.34E.	69°48'48"	143°37'30"
72	NW¼ NE¼ Sec. 22, T.5N., R.34E.	69°46'54"	143°36'36"
73	NW¼ SW¼ Sec. 24, T.5N., R.34E.	69°46'14"	143°32'50"
74	SE¼ NW¼ Sec. 9, T.7N., R.35E.	69°58'40"	143°24'50"
75	NE¼ NW¼ Sec. 16, T.7N., R.35E.	69°58'00"	143°24'40"
76	SW¼ SE¼ Sec. 5, T.5N., R.35E.	69°48'45"	143°26'22"
77	SW¼ SE¼ Sec. 8, T.5N., R.35E.	69°47'54"	143°26'36"
78	SE¼ NW¼ Sec. 17, T.5N., R.35E.	69°47'24"	143°27'18"
	Barter Island (A-4)*		
79	NE¼ NE¼ Sec. 28, T.8N., R.35E.	70°01'23"	143°23'20"
80	SE¼ NE¼ Sec. 19, T.8N., R.36E.	70°02'11"	143°13'25"
81	SW¼ NW¼ Sec. 31, T.8N., R.36E.	70°01'24"	143°14'06"
82	SW¼ NW¼ Sec. 29, T.8N., R.36E.	70°01'24"	143°13'18"
	Demarcation Point (D-4)*		
83**	NE¼ SE¼ Sec. 3, T.6N., R.35E.	69°54'06"	143°21'18"
84	SW¼ NE¼ Sec. 23, T.7N., R.35E.	69°57'13"	143°19'08"
85	SW¼ NE¼ Sec. 26, T.7N., R.35E.	69°56'00"	143°19'12"
86	SE¼ SW¼ Sec. 12, T.7N., R.35E.	69°58'11"	143°17'08"
87	NE¼ NE¼ Sec. 13, T.7N., R.35E.	69°58'06"	143°16'00"
88	SW¼ NE¼ Sec. 13, T.7N., R.35E.	69°57'54"	143°16'30"
89	SE¼ NW¼ Sec. 13, T.7N., R.35E.	69°57'46"	143°17'32"
90	NW¼ NW¼ Sec. 24, T.7N., R.35E.	69°56'56"	143°18'10"
91	NW¼ NE¼ Sec. 4, T.7N., R.36E.	69°59'48"	143°09'06"
92	NW¼ SE¼ Sec. 4, T.7N., R.36E.	69°59'12"	143°09'06"
93	NW¼ NW¼ Sec. 3, T.7N., R.36E.	69°59'42"	143°08'08"
94	SE¼ NW¼ Sec. 16, T.6N., R.36E.	69°52'40"	143°10'05"
95	SE¼ SE¼ Sec. 20, T.6N., R.36E.	69°51'18"	143°10'54"
96	NE¼ NE¼ Sec. 6, T.5N., R.36E.	69°49'26"	143°13'20"
97	SW¼ SE¼ Sec. 32, T.6N., R.36E.	69°49'28"	143°11'40"
98	SW¼ SW¼ Sec. 33, T.6N., R.36E.	69°49'30"	143°10'06"
99	SE¼ SE¼ Sec. 34, T.8N., R.37E.	69°59'36"	142°50'36"

Appendix A.--Continued

Lake Number	Map Location	Latitude	Longitude
	Demarcation Point (D-4)*		
100	SW¼ NE¼ Sec. 8, T.7N., R.37E.	69°58'32"	142°56'32"
101	SE¼ NE¼ Sec. 3, T.7N., R.37E.	69°59'54"	142°50'36"
102	SW¼ SW¼ Sec. 15, T.7N., R.37E.	69°57'24"	142°52'42"
103	SE¼ SE¼ Sec. 11, T.7N., R.37E.	69°58'06"	142°49'06"
104	NE¼ SW¼ Sec. 14, T.7N., R.37E.	69°57'30"	142°49'53"
105	SW¼ SW¼ Sec. 20, T.6N., R.37E.	69°51'12"	142°57'48"
106	SW¼ NE¼ Sec. 32, T.6N., R.37E.	69°50'06"	142°57'00"
107	SE¼ SW¼ Sec. 28, T.6N., R.37E.	69°50'21"	142°54'40"
108	SW¼ NE¼ Sec. 33, T.6N., R.37E.	69°50'06"	142°53'48"
109	NW¼ SE¼ Sec. 3, T.6N., R.37E.	69°54'07"	142°51'35"
110	NW¼ SW¼ Sec. 27, T.6N., R.37E.	69°50'34"	142°52'45"
111	NE¼ NE¼ Sec. 2, T.6N., R.37E.	69°54'36"	142°48'30"
	Barter Island (A-3)*		
112	NW¼ SE¼ Sec. 25, T.8N., R.37E.	70°01'05"	142°46'35"
	Demarcation Point (D-3)*		
113	NE¼ NE¼ Sec. 1, T.7N., R.37E.	69°59'48"	142°45'48"
114	NE¼ SW¼ Sec. 36, T.7N., R.37E.	69°54'54"	142°46'54"
115	SW¼ SE¼ Sec. 13, T.7N., R.38E.	69°57'24"	142°31'35"
116	SW¼ SW¼ Sec. 3, T.6N., R.39E.	69°54'00"	142°23'07"
117	NW¼ NW¼ Sec. 10, T.6N., R.39E.	69°53'37"	142°22'41"
118	NE¼ SW¼ Sec. 14, T.6N., R.39E.	69.52'18"	142°19'48"
	Demarcation Point (D-2)*		
119	NW¼ NE¼ Sec. 33, T.6N., R.40E.	69°50'10"	142°09'20"

* Map names refer to U.S. Geological Survey 1:63,360 topographic maps.

** Lake has merged with a small lake in the northeast quarter and both lakes are now treated as a single lake.

Appendix B

Volume of water of lakes in the 1002 area
at various ice thicknesses

Appendix B.--Volume (acre-ft) of water of lakes in the 1002 area at various ice thicknesses. Average date of ice thickness is shown in parentheses.

Lake ID No	Surface Area (acres)	Max Depth (ft)	Ice Thickness (ft) 0	1 (Oct 31)	2 (Nov 13)	3 (Dec 11)	4 (Jan 4)	5 (Feb 20)	6 (Apr 5)	7 (Apr 16)[a]	Fish Observed
1[b]	33	1.5	57	24	0	0	0	0	0	0	NS[c]
2	131	13.1	912	784	668	564	465	372	284	204	NS
3[d]	0	0	0	0	0	0	0	0	0	0	NS
4	100	4.8	235	143	67	16	1	0	0	0	NS
5	58	6.8	279	222	167	117	72	34	9	0	NS
6	94	12.1	824	730	637	543	449	358	272	196	Yes
7	113	10.0	720	607	494	381	273	171	89	35	Yes
8	44	3.8	93	55	25	4	0	0	0	0	Yes
9	23	2.9	44	22	4	0	0	0	0	0	No
10	32	5.1	120	89	57	29	8	<1	0	0	No
11	22	4.3	75	53	31	11	<1	0	0	0	No
12	31	7.7	122	91	60	34	17	8	3	<1	Yes
13	40	3.1	85	45	11	<1	0	0	0	0	Yes
14	46	13.4	328	282	236	190	146	111	79	51	No
15	96	8.2	379	283	187	97	37	9	3	<1	No
16	257	3.8	668	427	221	67	0	0	0	0	NS
17	100	7.4	342	246	162	95	46	16	2	0	NS
18[b]	32	2.0	74	42	18	0	0	0	0	0	NS
19[b]	181	2.0	419	238	102	0	0	0	0	0	NS
20	81	9.2	457	377	301	230	167	110	59	18	NS
21	56	4.2	128	77	37	10	0	0	0	0	NS

Appendix B.-Continued

Lake ID No	Surface Area (acres)	Max Depth (ft)	Ice Thickness (ft) 0	1 (Oct 31)	2 (Nov 13)	3 (Dec 11)	4 (Jan 4)	5 (Feb 20)	6 (Apr 5)	7 (Apr 16)	Fish Observed
22	77	9.3	352	276	206	145	95	54	20	3	NS
23	35	10.7	240	206	173	142	112	85	61	40	NS
24	133	7.5	709	578	457	345	240	141	50	7	NS
25	131	2.3	182	67	3	0	0	0	0	0	Yes
26	64	8.3	321	258	199	144	94	50	13	0	NS
27	303	17.9	3212	2009	1706	1414	1138	878	639	432	Yes
28	79	3.4	216	141	72	14	0	0	0	0	NS
29	300	7.5	1190	914	688	497	321	162	36	<1	NS
30[b]	0	0	0	0	0	0	0	0	0	0	NS
31	104	8.7	557	452	348	249	161	90	39	10	Yes
32	34	10.9	208	174	142	112	84	59	36	18	NS
33	29	6.3	94	66	39	17	5	1	0	0	NS
34	1533	9.0	9285	7753	6220	4756	3416	2220	1169	340	NS
35	89	8.4	523	435	351	273	200	131	69	18	NS
36	1316	11.0	9198	7882	6565	5305	4138	3067	2097	1282	NS
37	342	8.3	1804	1462	1120	793	500	245	70	10	Yes
38	44	7.8	250	206	164	124	85	50	19	3	NS
39	58	4.9	224	167	112	62	23	0	0	0	NS
40	26	3.5	58	33	9	<1	0	0	0	0	No
41	30	5.9	116	85	56	28	2	0	0	0	NS
42	96	5.9	441	346	250	159	79	20	0	0	No
43[b]	0	0	0	0	0	0	0	0	0	0	NS
44	21	2.7	44	25	8	0	0	0	0	0	NS

Appendix B.-Continued

Lake ID No	Surface Area (acres)	Max Depth (ft)	Ice Thickness (ft) 0	1 (Oct 31)	2 (Nov 13)	3 (Dec 11)	4 (Jan 4)	5 (Feb 20)	6 (Apr 5)	7 (Apr 16)	Fish Observed
45	51	8.0	295	244	193	142	93	55	27	6	No
46	56	8.8	373	317	260	205	152	104	62	29	No
47	75	4.6	274	199	124	54	7	0	0	0	No
48	32	8.4	155	124	95	69	47	29	15	6	NS
49	53	5.7	195	142	92	48	17	2	0	0	No
50	36	7.2	181	145	111	78	48	23	7	0	NS
51	155	6.4	624	469	325	203	101	31	1	0	Yes
52	69	7.9	417	348	280	212	148	88	33	4	Yes
53	17	6.7	89	72	56	40	25	12	3	0	NS
54	83	4.1	263	180	97	28	<1	0	0	0	No
55	36	5.9	166	131	96	64	36	12	0	0	NS
56[b]	28	2.5	65	37	17	0	0	0	0	0	NS
57	59	6.9	304	246	189	136	87	43	13	0	NS
58	31	8.4	156	126	98	73	50	29	12	2	NS
59	24	10.5	117	94	72	53	37	23	11	3	NS
60	50	7.9	280	231	183	137	92	52	20	3	NS
61	24	7.8	125	102	80	59	40	23	8	1	NS
62	84	3.9	248	164	83	17	0	0	0	0	Yes
63	48	7.7	269	222	177	137	95	58	25	5	NS
64	128	8.1	766	638	510	382	259	151	66	13	Yes
65	87	8.6	477	390	302	215	141	89	49	16	Yes
66	43	6.5	193	150	109	70	34	7	0	0	NS

Appendix B.-Continued

Lake ID No	Surface Area (acres)	Max Depth (ft)	Ice Thickness (ft) 0	1 (Oct 31)	2 (Nov 13)	3 (Dec 11)	4 (Jan 4)	5 (Feb 20)	6 (Apr 5)	7 (Apr 16)	Fish Observed
67	190	3.6	530	340	168	21	0	0	0	0	Yes
68	65	8.9	393	327	262	197	137	82	38	8	Yes
69	33	8.1	173	140	109	80	52	28	7	0	NS
70[b]	20	2.0	46	26	11	0	0	0	0	0	NS
71	43	8.2	190	147	106	69	40	19	4	0	NS
72	33	9.1	68	41	22	12	7	4	2	1	NS
73	168	8.6	788	620	453	299	174	76	25	7	Yes
74	69	11.0	429	361	292	223	158	98	46	11	Yes
75	102	8.7	679	576	474	371	270	174	88	23	Yes
76	63	11.6	454	392	329	267	206	149	98	53	Yes
77	26	8.7	105	80	56	35	19	8	2	0	NS
78	36	8.7	149	113	79	49	24	9	2	1	NS
79	97	3.3	216	119	31	<1	0	0	0	0	Yes
80	164	8.5	1045	881	717	558	412	280	159	53	Yes
81	41	6.7	155	115	77	44	19	5	1	0	NS
82	32	5.5	96	65	35	12	2	0	0	0	NS
83	32	7.9	184	153	122	92	64	39	16	3	NS
84	46	7.5	262	215	169	127	90	57	28	4	Yes
85	31	8.2	140	109	80	53	28	8	1	0	NS
86	41	7.1	226	185	144	106	70	36	10	<1	Yes
87	33	6.8	128	96	66	41	19	4	0	0	NS
88	27	5.6	75	49	26	10	2	0	0	0	NS
89	60	7.8	375	315	254	196	141	91	48	10	Yes

Appendix B.-Continued

Lake ID No	Surface Area (acres)	Max Depth (ft)	Ice Thickness (ft) 0	1 (Oct 31)	2 (Nov 13)	3 (Dec 11)	4 (Jan 4)	5 (Feb 20)	6 (Apr 5)	7 (Apr 16)	Fish Observed
90	36	6.9	187	151	115	81	50	24	5	0	Yes
91[b]	77	1.5	77	33	0	0	0	0	0	0	NS
92	68	3.6	148	81	20	0	0	0	0	0	NS
93	58	8.2	261	203	145	92	50	20	6	1	Yes
94	181	7.7	1003	823	642	475	330	200	79	8	No
95	29	3.5	79	50	24	4	0	0	0	0	NS
96	89	5.9	284	195	112	49	15	2	0	0	Yes
97	99	7.8	610	511	412	313	218	131	56	7	Yes
98	33	8.3	165	132	101	71	44	20	6	1	NS
99	38	7.9	195	157	121	88	58	32	12	2	NS
100	43	1.7	25	2	0	0	0	0	0	0	No
101	29	5.7	130	100	73	47	24	6	0	0	NS
102	30	7.4	131	101	73	47	23	7	1	0	NS
103	35	6.8	147	113	81	52	29	13	4	0	NS
104	50	6.2	226	176	127	80	41	11	<1	0	No
105	34	5.8	112	81	53	29	9	2	0	0	NS
106	36	5.7	84	52	26	10	2	0	0	0	NS
107	55	6.8	207	152	102	62	33	11	1	0	No
108[b]	20	2.0	46	26	11	0	0	0	0	0	NS
109	142	9.2	952	810	669	527	390	262	147	49	Yes
110	54	4.8	179	125	71	24	<1	0	0	0	No
111	25	4.8	76	52	29	9	1	0	0	0	NS
112	88	3.3	189	102	34	2	0	0	0	0	No

Appendix B.-Continued

Lake ID No	Surface Area (acres)	Max Depth (ft)	Ice Thickness (ft) 0	1 (Oct 31)	2 (Nov 13)	3 (Dec 11)	4 (Jan 4)	5 (Feb 20)	6 (Apr 5)	7 (Apr 16)	Fish Observed
113	26	3.8	75	50	27	8	0	0	0	0	NS
114[b]	0	0	0	0	0	0	0	0	0	0	NS
115	41	7.5	221	180	139	99	64	33	11	<1	Yes
116	45	7.9	148	103	58	22	6	3	1	<1	Yes
117	25	3.1	48	24	6	<1	0	0	0	0	Yes
118	18	2.7	32	15	4	0	0	0	0	0	NS
119	68	24.8	819	751	683	615	548	484	422	363	Yes
Total			55,379	43,959	33,962	25,061	17,755	11,702	6,797	3,366	

a. Seven feet of ice was reported only during one year of record.

b. Lake was too shallow for fathometer readings. Volumes are estimates based on surface area from U.S.G.S. topographic maps and maximum depth estimates.

c. Lake was not sampled for fish.

d. Lake is directly connected to the Beaufort Sea.