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UNITED STATES
GEOLOGICAL SURVEY
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GROUND WATER AVAILABILITY IN ACADIA NATIONAL PARK AND VICINITY, HANCOCK AND KNOX COUNTIES, MAINE

Open-File Report 80-1050

Prepared in cooperation with the

WATER RESOURCES PROGRAM
OFFICE OF SCIENTIFIC STUDIES
NATIONAL PARK SERVICE
NORTH ATLANTIC REGION

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1980

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ILLUSTRATIONS

CONVERSION FACTORS AND ABBREVIATIONS

The following table may be used to convert inch-pound units to International System Units (SI).

Multiply inch-pound units	By	To obtain SI Units
	Length	
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.4047	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow	
cubic foot per second (ft^3/s)	28.32	liter per second (L/s)
gallon per minute (gal/min)	.06309	liter per second (L/s)

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ABSTRACT

In general, yield of water from individual wells in unconsolidated surficial deposits is low (0-10 gallons per minute). Several small, unconsolidated deposits may yield moderate quantities (50-100 gallons per minute) but these have not been adequately tested.

Yields from 160 wells in the crystalline bedrock range from 0.5 gallons per minute to 100 gallons per minute, with a median yield of 10 gallons per minute. Wells in zones of extensive fracturing or faulting generally have higher than average yields. Zones of fracturing may correspond to lineations which have been mapped by interpretation from topographic maps and aerial photographs.

In general, ground water is of suitable chemical quality for public supply. Most ground water is low in dissolved solids and is soft. Iron exceeds 0.3 milligrams per liter and manganese exceeds 0.05 milligrams per liter in water from some wells. Brackish (salty) water is present in only a few wells at the coast or adjacent to saltwater bodies. Elevated concentrations of Radon-222 have been reported from wells in the granite aquifer.

INTRODUCTION

This report presents the results of a preliminary investigation of ground-water availability in Acadia National Park and vicinity by the U.S. Geological Survey, in cooperation with the National Park Service. The investigation provides ground-water information for a water-resources management plan for the park being prepared by the Park Service. This information may also be used in siting water supplies or waste-treatment facilities and for determining land uses.

This report assesses the availability of ground water from various geologic units. The assessment is based on previous geologic mapping (Borns, 1974a, 1974b, 1974c; Chapman, 1962; and Smith and Borns, 1974), well construction, well yield, and water-quality data collected by the Maine Bureau of Geology; field investigations during 1979; and examination of aerial imagery.

GEOLOGIC UNITS, WATER-BEARING CHARACTERISTICS, AND AVAILABILITY OF GROUND WATER

Unconsolidated Deposits

The unconsolidated deposits consist of drift of Pleistocene age and alluvium and swamp deposits of Holocene age. The drift was deposited during the advance and subsequent disappearance of ice during the Wisconsin Glaciation. The drift includes ice-laid deposits (till) and water-laid glaciofluvial deposits (ice-contact, outwash, deltaic, and marine deposits).

Till

Till is an unsorted, or poorly sorted, unstratified mixture of clay, silt, sand, pebbles, and boulders deposited directly by glacial ice. Till is shown as ground moraine on the map of unconsolidated deposits (fig. 1). It forms a discontinuous mantle over bedrock, with the exception of the summit areas, where it is absent. It also underlies marine and end moraine deposits in the lowlands. Deposits generally have low hydraulic conductivity and are less than 10 feet thick. However, till deposits as thick as 50 feet may be found at several locations on Mount Desert Island (Caswell and Lanctot, 1975). Water availability from individual wells is generally small (0-10 gal/min) because of the small saturated thickness and low hydraulic conductivity of till. Properly located dug wells might be adequate for small water supplies.

Glaciofluvial Deposits

Meltwater streams flowing from the glacier washed boulders, gravel, sand, silt, and clay from the ice and deposited them in contact with and beyond the limits of the glacier. These deposits are collectively referred to as glaciofluvial deposits. In New England, these deposits, composed of sand and gravel, have high transmissivity and are the principal source of large ground-water supplies. However, in the study area, only a few very small deposits occur and are not shown separately on the map.

With several exceptions, these deposits in the study area have no ground-water potential. A small delta, composed of fine sand to gravel, about 0.8 mile south-southeast of Jordan Pond (location 1 on surficial map), may have some ground-water potential, but test drilling will be necessary to determine the depth, extent, and lithologic characteristics of the deposit. End moraines are composed, in part, of glaciofluvial material.

End Moraines

End moraines are ridges of unconsolidated drift, which were formed at the margin of ice lobes when the recessional margin of the ice temporarily halted and remained stable. They include varying amounts of material that sloughed from the ice surface (till) and material that was washed out from the ice by meltwater (glaciofluvial deposits). The materials are poorly sorted till, which has low hydraulic conductivity and glaciofluvial sand and gravel, which are poorly to well sorted and low to high hydraulic conductivity. The glaciofluvial fraction in these moraines accounts for any ground-water potential that they might have. The moraines are as thick as 40 feet, but generally saturated thicknesses are considerably less. End moraines, therefore, are generally not sources of large quantities of water. One exception may be the moraine at the south end of Long Pond (location 2 on surficial map), where the saturated thickness, percentage of glaciofluvial material, and source of induced infiltration may be sufficient for a public ground-water supply. Thickness and lithology of the material in this moraine can be determined by test drilling.

Marine Deposits

As the ice sheet melted in Maine, sea level rose in relation to land surface; consequently, the lowlands of the island were covered by the sea, in which sand, silt, and clay were deposited. Since then, the land has risen and the sea retreated to the present shoreline. Marine deposits, commonly described as "blue" or "gray" clay are found in valleys and lowlands and discontinuously overlie till and moraine deposits. The thickness of the marine deposits ranges from less than a foot to more than 20 feet. Because these marine deposits are generally fine grained with low permeability, they have small water-yielding capability and are not considered sources of water.

Alluvium

Alluvium is material deposited by streams since glacial time and occurs in discontinuous patches along present day streams. It consists of stratified sand, silt, and gravel and is ordinarily less than 10 feet thick. It has not been mapped separately except on Isle Au Haut. There, these deposits may yield water to shallow wells or infiltration galleries, but they are located in areas subject to flooding by streams.

Swamp Deposits

Swamp deposits, consisting of peat and other organic matter mixed with silt and sand, are found in many poorly drained areas. Swamp deposits are commonly underlain by marine deposits but may overlie depressions in ground moraine or bedrock. These deposits have not been mapped separately, but most coincide with swamp areas shown on the topographic map. Swamp deposits have no ground water potential in Acadia National Park and vicinity.

Bedrock

Types and Water-Bearing Characteristics

The bedrock is predominantly fine- to coarse-grained granite and diorite. Smaller areas of metasedimentary and metavolcanic rock are present mainly on the perimeter of the island (fig. 2).

The several bedrock units seem to have no significant differences in their water yielding properties and are treated as a unit in this report.

Bedrock contains water chiefly in secondary openings, which include joints, faults, cracks, and other types of fractures. Most joints are planar and steeply including or vertical. However, some (sheeting) are curved, conform roughly to the topography, and are more numerous in granite than in other rock types. Fractures are generally interconnected and make up a network capable of transmitting water. For a given hydraulic gradient, the rate at which water moves through bedrock is determined by the size, distribution, orientation, and degree of interconnection of the secondary openings. Fracture openings commonly decrease in size and number with depth below the bedrock surface. These characteristics are, in turn, influenced by geologic history, topography, and other factors.

Yields of 160 domestic supply wells, for which records were available, range from 0.5 to 100 gal/min, with a median yield of 10 gal/min. Wells are as deep as 545 feet, but 78 percent of the 160 wells are less than 200 feet deep. The wells 200 feet or deeper had a median yield of 5 gal/min. The deeper wells were probably drilled in an attempt to obtain greater yields or to provide storage to compensate for low or inadequate yields obtained at shallower depths. In general, data from this area and other geologicaly similar areas of New England indicate that the yield per foot of rock penetrated decreases with depth. Stated more practically, if sufficient yield has not been obtained in the first 200 to 300 feet of bedrock, the chances of significant increases in yield at greater depths are small.

Fracture Trace Mapping

Reliable estimates of well yields at a particular site in rock that yields water only from fractures are seldom available. However, it may be possible to identify some zones that have higher than average yields. There are zones of varying length and width where fracture concentration and (or) size are greater than in other areas. Wells drilled in these zones may have yields greater than average. Wells drilled at the intersections of these zones should have even higher yields.

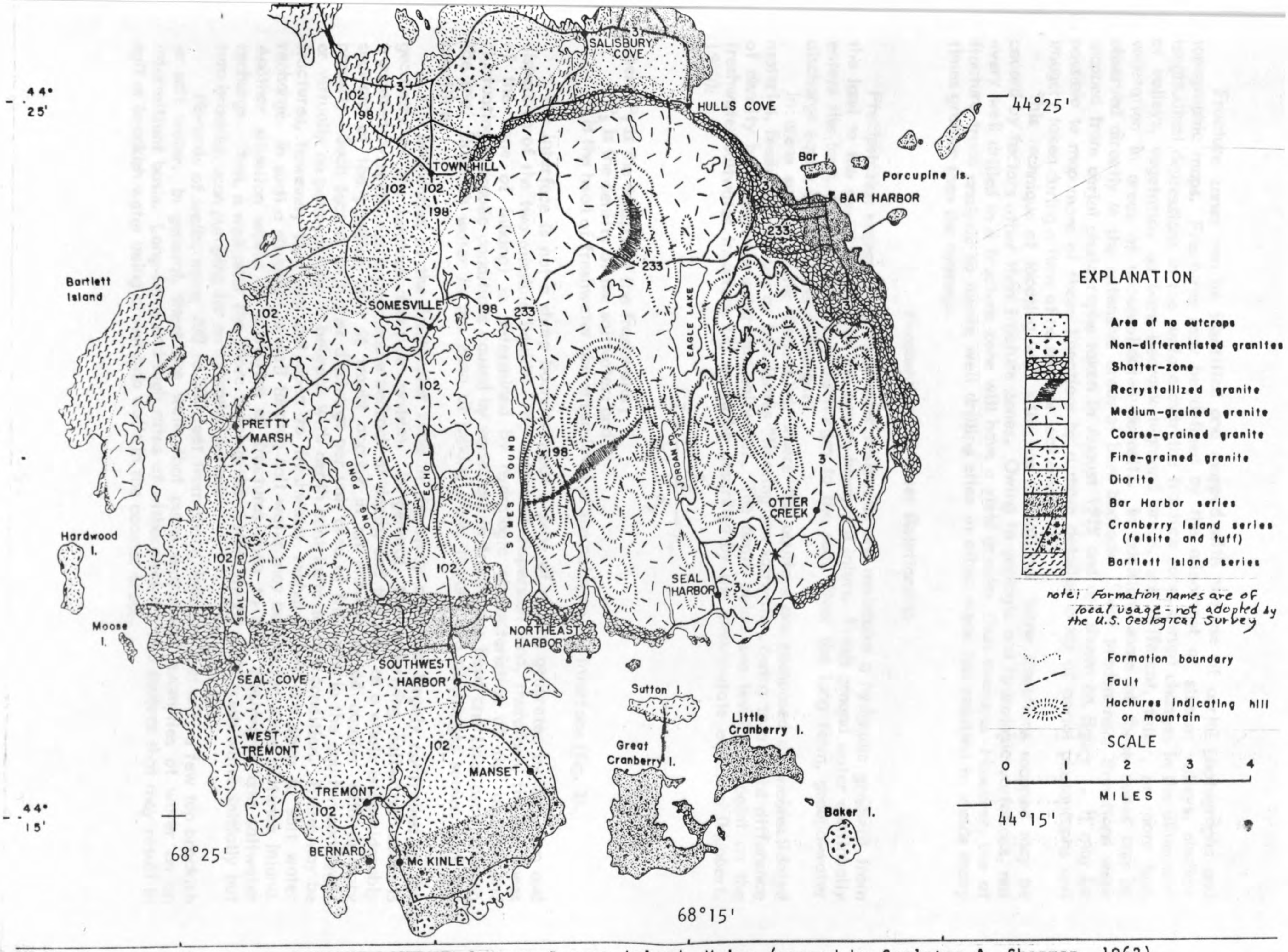


Figure 2.--Bedrock geology of Mount Desert Island, Maine (mapped by Carleton A. Chapman, 1962)

Fracture zones can be identified and mapped with the use of aerial photographs and topographic maps. Fractures may be defined by the alinement of stream valleys, shallow longitudinal depressions in the surface over the fracture zone, abrupt changes in the alinement of valleys, vegetation on bare bedrock highland areas, and different, taller, or more lush vegetation in areas of unconsolidated deposits. In addition, some of these zones can be observed directly in the extensive areas of bare bedrock. Some predominant lineations were mapped from aerial photographs taken in August 1979 and are shown on figure 1. It may be possible to map more of these lineations by a more detailed study of aerial photographs and imagery taken during a time of no snow or leaf cover.

This technique of locating well sites has limitations. Some lineations mapped may be caused by factors other than fracture zones. Owing to geologic and hydrologic variations, not every well drilled in a fracture zone will have a yield greater than average. However, use of fracture-trace analysis to locate well drilling sites in other areas has resulted in yields many times greater than the average.

Freshwater/Saltwater Relationship

Precipitation recharges ground-water reservoirs and maintains a hydraulic gradient from the land to the sea in areas near the ocean, bays, and inlets. Fresh ground water continually enters the land, flows toward, and discharges to the sea. Over the long term, ground-water discharge equals ground-water recharge.

In areas such as outer Cape Cod, where the aquifers are composed of unconsolidated material, freshwater occurs as thin lenses "floating" on saltwater, owing to a slight difference of density between freshwater and saltwater. The depth below sea level to a point on the freshwater/saltwater interface (Z) would be described by the steady-state equation (Hubbert, 1940):

$$Z = \frac{P_f}{P_s - P_f} h,$$

where P_f is the density of the freshwater;

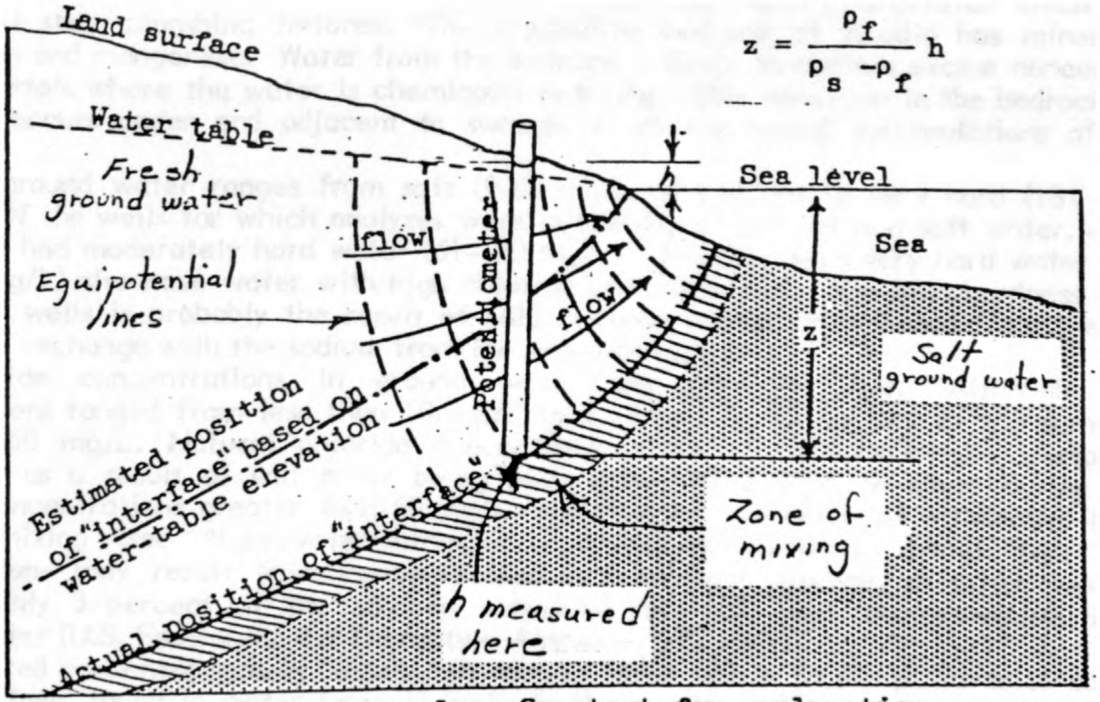
P_s is the density of the saltwater; and

h is the head of freshwater above sea level at the point on the interface (fig. 3).

The interface is not a sharp boundary, but a zone of mixing generated by diffusion and dispersion of the two missible liquids. The extent of dispersion (and, therefore, the thickness of the zone of mixing) is determined by hydrologic characteristics of the aquifer and fluctuating hydraulic conditions caused by variations in freshwater head and tidal oscillation in the sea. Brackish water in the zone of mixing flows toward and discharges seaward of the coastline.

The boundaries of the freshwater zone in the study area are largely controlled by the geometry of the bedrock fracture system. In general, the underlying saltwater zone is truncated by relatively impermeable bedrock at depth, and the zone as a whole is considerably seaward of the position that it would occupy in an unconsolidated aquifer with primary porosity. Such factors as higher discharge per unit area of fractures in the aquifer and lower or virtually no permeability of bedrock with depth contribute to this condition. There may be fractures, however, that are not open to freshwater recharge but are open to salt water recharge. In such a situation, a well tapping salt water may be located some distance inland. Another situation would be a system of fractures open to both freshwater and saltwater recharge. Then, a well near the shore tapping the system might yield fresh water initially but turn brackish upon pumping for an extended period.

Records of wells, many 200 to 500 feet from shore, indicate that only a few tap brackish or salt water. In general, these are wells that pump only small quantities of water on an intermittent basis. Long-term and high rates of withdrawal are two factors that may result in salt or brackish water being drawn into wells in the coastal areas.



Not drawn to scale. See text for explanation.

Figure 3.--Relationship between fresh and salt ground water for steady-state outflow to the sea

GROUND-WATER QUALITY

Most of the ground water in Acadia National Park and vicinity is of good quality and is satisfactory for domestic use.

Water from the crystalline bedrock aquifer contains low concentrations of dissolved solids (50-100 mg/L, milligrams per liter), due mainly to the fact that the bedrock is composed of silicate minerals that are only slightly soluble. Also, water moves through the aquifer along fractures, so only a relatively small amount of bedrock surface is exposed to chemical reaction. These factors account for the low dissolved-solids concentrations in water from the bedrock.

Iron and manganese concentrations are generally low. However, some wells do yield water that exceeds 0.3 mg/L of iron and 0.05 mg/L of manganese and is, therefore, objectionable for domestic use (U.S. Environmental Protection Agency, 1975, 1977). On exposure to air, dissolved iron and manganese oxidize and form precipitates which discolor fabrics and stain plumbing fixtures. The crystalline bedrock of Acadia has minerals that contain iron and manganese. Water from the bedrock is likely to contain excess concentrations of these metals where the water is chemically reducing. This condition in the bedrock aquifer commonly occurs under and adjacent to swampy areas containing accumulations of organic material.

The ground water ranges from soft (0-60 mg/L as $CaCO_3$) to very hard (181 mg/L or greater). Of the wells for which analyses were available, 68 percent had soft water, and most of the rest had moderately hard water (61-120 mg/L). The few with very hard water (greater than 181 mg/L) also have water with high chloride concentrations. The high hardness in water from these wells is probably the result of calcium and magnesium released from the aquifer material by exchange with the sodium from the brackish water.

Chloride concentrations in ground water are generally low. Although chloride concentrations ranged from less than 10 mg/L to 1,790 mg/L, 85 percent of the samples had less than 50 mg/L. Natural chloride concentrations are slightly higher in coastal areas, presumably as a result of salt spray being picked up and carried on shore during storms. Chloride concentrations greater than 50 mg/L, are probably the result of withdrawal from the zone of mixing (see "freshwater/saltwater relationship" section). Some high chloride concentrations may result from contamination by road salt, sewage, or other man-caused sources. Only 3 percent of the samples exceeded the 250 mg/L recommended limit for drinking water (U.S. Environmental Protection Agency, 1975, 1977).

Elevated concentrations of Radon-222, ranging from 692 to 34,866 pCi/L (pico curies per liter) have been found in water from 15 wells in the granite aquifer underlying Mount Desert Island (Hess and others, 1979). Radon-222 is a radioactive gas produced by the decay of uranium. It is reported that the mean concentration from the "Mount Desert East granite" was 3,000 pCi/L and 15,000 pCi/L for the "Mount Desert West granite." The "East granite" probably corresponds to the coarse-grained granite and the "West granite" to the younger, medium-grained granite shown on the bedrock map (fig. 2).

CONCLUSIONS

Water availability from individual wells in unconsolidated deposits is generally low. Several small unconsolidated deposits, which may have a greater than average potential yield, must be tested in order to be evaluated.

Yields from 160 wells in the crystalline bedrock range from 0.5 gal/min to 100 gal/min, with a median yield of 10 gal/min. Wells in zones of extensive fracturing may have higher yields than average. These zones may correspond to lineations, which can be observed and subsequently mapped utilizing topographic maps and aerial photographs.

The available information indicates that the ground water has good overall chemical quality, is low in dissolved solids, and is soft. The levels of iron and manganese are elevated in water from some wells. Brackish water is present in only a few wells adjacent to saltwater bodies. Elevated concentrations of Radon-222 have been reported from wells in granite.

REFERENCES

Borns, H. W., Jr., 1974a, Reconnaissance surficial geology map of Bar Harbor, Maine: Maine Department of Conservation, Bureau of Geology, open-file report.

_____1974b, Reconnaissance surficial geology map of Mount Desert, Maine: Maine Department of Conservation, Bureau of Geology, open-file report.

_____1974c, Reconnaissance surficial geology map of Swans Island Maine: Maine Department of Conservation, Bureau of Geology, open-file report.

Caswell, W. B., Jr., 1974, Physical resources of Knox County, Maine: Maine Department of Conservation, Maine Geological Survey, PR-1.

Caswell, W. B., and Lanctot, E. M., 1975, Ground water resource maps of southern Hancock Co.: Maine Department of Conservation, Maine Geological Survey.

_____1977, revised 1978, Ground water resource maps of southern Knox Co.: Maine Department of Conservation, Maine Geological Survey.

Chapman, C. A., 1962, The geology of Mount Desert Island, Maine: Ann Arbor, Mich., Edward Brothers, Inc., 52 p.

Hess, C. T., and others, 1979, Radon-222 in potable water supplies in Maine: The geology, hydrology, physics and health effects: Land and Water Resources Center, University of Maine, Orono Maine.

Hubbert, M. K., 1940, The theory of ground-water motion: Journal of Geology, v. 48, no. 8, part 1, p. 785-944.

Smith G. W., and Borns, H. W., Jr., 1974, Reconnaissance surficial geology map of Deer Isle, Maine: Maine Department of Conservation, Bureau of Geology, open-file report.

U.S. Environmental Protection Agency, 1975, Water programs, national interim primary drinking water regulations: Federal Register, v.40, no. 248, Wednesday, December 24, 1975, part IV, p. 59566-59587.

_____1977, National secondary drinking water regulations: Federal Register, v.42, no. 62, Thursday, March 31, 1977, part I, p. 17143-17147.