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Hydrogeology and Development Pressures

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HYDROGEOLOGY AND DEVELOPMENT PRESSURES BRUNSWICK, MAINE

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INTRODUCTION

This field trip is intended to focus upon the hydrogeologic aspects of a sand and gravel aquifer in Brunswick, Maine. It is developed from, and based upon, the results of a five-months long study done for the Town of Brunswick during the period October 1988 to March 1989. Conceptually structured by the Town's Planning Board and Conservation Commission, the study was intended to satisfy the conditions of a moratorium on residential development in a part of Brunswick referred to as the "Old Bath Road Area" (see Figure 1). It was enacted in Spring, 1988 by the Brunswick Town Council.

PREVIOUS WORK

Wisconsin glaciation of the State of Maine and the subsequent geologic history of the area has resulted in the deposition of large volumes of sand and gravel. Many of these are aquifers. A significant aquifer, as defined by the Maine State Legislature (38 M.R.S.A., Chapter 3, Section 482 4-D), is a porous formation of sand and gravel that contains significant quantities of water that are likely to provide drinking water supplies.

Maine has a number of laws which restrict land use in various ways where such uses may have negative impacts on sand and gravel aquifers (see for example Site Location of Development Act, 38 M.R.S.A., Sections 481-490). In order to inform the State and local governments as they continue to develop laws and ordinances, the Maine Geological Survey and the United States Geological Survey began a joint mapping program in 1978 to identify, locate, and describe the existing sand and gravel aquifers in the State. This program, continuing until 1980, resulted in the publication of 59 maps summarizing the results of the investigation. These maps show approximate aquifer boundaries, estimates of potential well yields, and locations of some possible point sources of contamination of the aquifers. Subsequently, the State Legislature directed the Department of Environmental Protection and the Maine Geological Survey to update these maps, providing more information (38

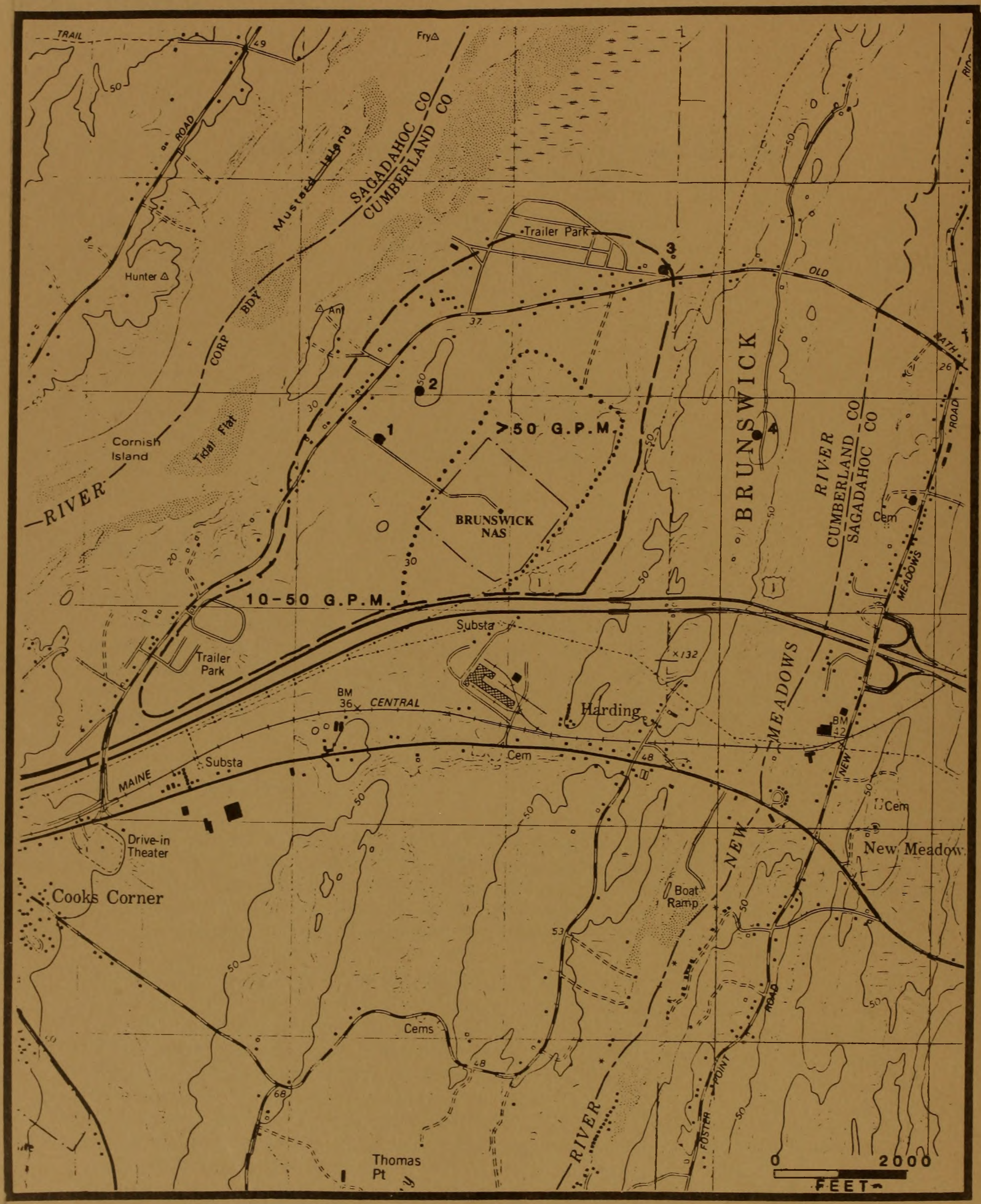


FIGURE 1 - LOCATION OF FIELD TRIP STOPS; PROJECTED WELL YIELDS

M.R.S.A., Chapter 3, Section 403). The additional work resulted in the publication of a new series of maps, referred to as Significant Sand and Gravel Aquifer Maps. Map #10 in that series, shows the aquifer in which the present study is located (See Figure 2).

Additional studies in the Brunswick area have been done by the E.C. Jordan Company for the Topsham/Brunswick Water District. These studies, focusing on the well fields which supply water to the District, include information relative to the relationship between the Androscoggin River and the sand and gravel aquifer.

GEOLOGY OF THE STUDY AREA

Bedrock Geology

As shown on the 1987 Bedrock Geologic Map of Maine and unpublished information of A.M. Hussey, II, the study area is underlain by various lithologies mapped as part of the Cape Elizabeth Formation. Few outcrops exist exposing these geologically old, and highly deformed, metamorphosed sedimentary rocks. The Cape Elizabeth Formation includes amphibolite, rusty weathering granofels, biotite schist, and quartzite. Some of these lithologies may be correlated with, and be the cause of, poor quality groundwater.

Mapping done to date has also confirmed the existence of geologically young, brittle fractures. These fractures, or fracture systems, have been named and in the area of the present study are represented by the Flying Point Fault and the Cape Elizabeth Fault (see Figure 2). Although, evidence of the existence of these structures is not directly observed, from relationships seen elsewhere the faults are inferred to be present beneath the surficial materials of the Old Bath Road area.

Prior to 2.5 million years ago, the metamorphosed rocks of the Cape Elizabeth Formation had been exposed and eroded to a gently rolling surface. An extensive mantle of soil existed, which had developed from the weathering of these metamorphic rocks. The topography then was presumably similar to present-day topography. It was characterized by northeast trending hills separated by long, narrow valleys. This is an expression of the "structural grain," which not only characterizes this part of Maine, but is also characteristic of much of the Appalachian Mountains of which this area is a part. The metamorphic rocks have been deformed into a series of folds which trend northeast-southwest and the folds in the bedrock control the topography which has evolved as the surface has been molded by the prolonged weathering and erosion of the rocks.

Surficial Geology

The bedrock surface was traversed by great thicknesses of ice, beginning approximately 2.5 million years before present. Ice moved very slowly across the landscape. During alternating, advance and retreat, sediment entrained within it was deposited. Material deposited directly from ice, which is referred to as "till," contained a wide variety of particle sizes and showed no evidence of layering (stratification). Material which was deposited by meltwater streams, derived from the back-wasting of the ice sheet, was stratified due to aqueous transport and is referred to as "outwash."

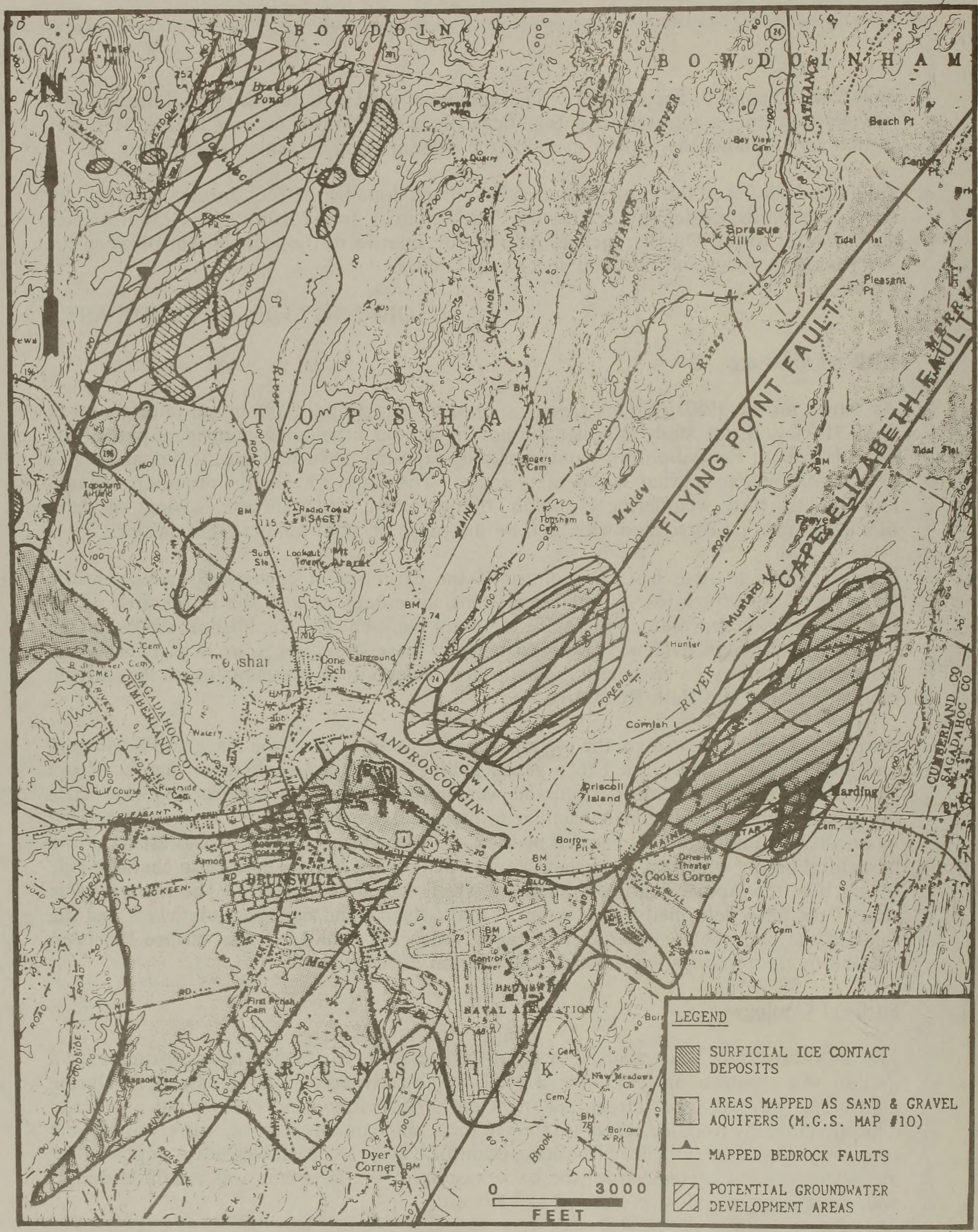


FIGURE 2 - POTENTIAL GROUNDWATER SUPPLY LOCATIONS
(MODIFIED FROM E.C. JORDAN CO., 1986)

The study area is a large outwash plain characterized by fine to coarse sands and fine gravel. It represents slightly more seaward deposition of sediment than the nearer-shore deposits of deltaic coarse sand and gravel. Examples of the latter exist to the north across the river in Topsham.

Outwash deposits, consisting of deltaic sands and gravels and more distal sandy deposits, were deposited contemporaneously with, and succeeded by, younger accumulations of marine silt and clay as sea level rose and transgressed the land surface. The deltaic and outwash deposits were, in part, eroded by near-shore currents during the deposition of these younger and finer marine sediments.

The crust of the earth, free of the weight of the ice sheet, rebounded. Sea level (relative to the land) began to fall. As the shoreline retreated seaward, much of the previously deposited outwash and marine sediments were reworked by the streams which drained the land. As a result, stratified sediments have been deposited in places above the fine-grained marine silts and clays. In the study area, these near-surface coarse sands and fine gravels are typically very poorly stratified. They imply braided streams which had constantly changing channels as they eroded and re-worked the previously deposited sediments. Although subtle, it can be seen that some of the surface topography is due to stream erosion as the "ancestral" Androscoggin River shifted its channel throughout this area.

To obtain more information about the subsurface stratigraphy, the logs of 5 previous borings and samples from 5 new borings were examined. The borings totaled 147.5 feet. Most borings intersected very poorly sorted, and hence only weakly stratified, medium sand to sandy gravel at shallower depths. At greater depths, the sediments became finer and distinctly stratified. Some of the holes, but not all, encountered blue-gray marine clay and clayey silt.

The stratigraphy shows significant variation. Borings to the east all intersect sands which are fine to coarse, as well as some gravel. Four MDOT test borings along U.S. Route 1, although they are separated by only 100 feet, appear to reflect a transition between stratigraphy with significant clay layers to the west, and stratigraphy devoid of such fine-grained material to the east.

The reasons for the differing stratigraphy in the eastern and western parts of the study area is not clear. The two areas are separated by a till mantled bedrock ridge, which extends from the benchmark located on the north side of U.S. Route 1 northeast to the south side of the Old Bath Road. This bedrock ridge may have controlled currents in the near-shore area which existed during the time of sediment deposition. Such currents could have removed the fine fraction of deposited sediment to the east while the absence of such currents west of the bedrock high may be the reason why a much larger percentage of fine material has accumulated there.

Measurement of Water Levels

Because the depth to unsaturated material is nowhere greater than 15 feet, and in many places is less than 3 feet, residents of the Old Bath Road area rely on dug wells, or driven points, for domestic water. Thus, at numerous locations the ability to monitor groundwater level, measure hydraulic conductivity of the aquifer, and retrieve samples for chemical analysis already existed. Monitoring wells, constructed of 2" diameter PVC, installed in 6" hollow-stem auger borings, and 1 1/4" diameter stainless steel well points were established to supplement these existing observation points. In summary, the data points were as follows:

1. 2" observation wells (5)
2. 1 1/4" diameter stainless steel well points (5)
3. large diameter concrete-lined or stone-lined dug wells (5)
4. pre-existing observation wells (6)
5. ponds (2)

Estimates of Permeability

Permeability was calculated or estimated by three methods. Falling-head and constant-head field test data were used to calculate permeability in a manner suggested by Hvorslev (1951). Permeability was also estimated from the lithological descriptions of sediment encountered by borings in the study area. This was done using data presented in Weiss et al (1982). The values determined using the latter approach were confirmed by reference to Masch and Denny (1966).

Estimates of Yield

Yields to domestic wells in the aquifer, as well as to the five 2" monitoring wells installed in the course of the study, were estimated using a method proposed by Mazzaferro (1980). The yield in gallons per minute was determined by multiplying the transmissivity by the aquifer thickness and dividing by 750. This method has been used by the Maine Geological Survey in the evaluation of sand and gravel aquifers.

These estimates, coupled with field observations on the distribution of sediments, identified an approximate area which would yield in excess of 50 gallons per minute to properly installed wells. It lies within the larger area of the sand and gravel aquifer, where it is estimated that 10 gallons per minute is an expectable yield (see Figure 1).

Two features of the outwash aquifer are especially noteworthy. The first is that the sand aquifer is not very thick (though silty sands are in places up to 60 feet thick). Thus, though permeabilities in sandy portions of the aquifer are high, transmissivities (permeability multiplied by aquifer thickness) are not. Consequently, few locations within the study area offer the potential for high volume wells necessary for municipal water supply. Secondly, many parts of the outwash aquifer are laminated sand and silt. In such portions of the aquifer, horizontal permeability greatly exceeds vertical permeability.

GROUNDWATER QUALITY

The large number of dug wells and driven points attest to the fact that groundwater quality at present in the Old Bath Road area is very high. However, continued growth and development in the Town of Brunswick threatens to impact water quality. The following are either existing or potential sources of contaminants, which in the future could significantly change water quality. Each is briefly discussed.

Septic Systems

Septic systems have been in use in rural areas in the United States and elsewhere for many years. Despite the fact that design requirements have been changed from time to time and the systems presumably improved, many studies indicate unacceptable impact on groundwater quality from contaminants introduced with wastewater. All single-family homes in the Old Bath Road area presently dispose of their wastewater through individual septic systems.

Figure 3 illustrates the behavior of septic system contamination plumes in sand and gravel aquifers. The threat to shallow water supply wells is clear.

Underground Storage of Petroleum Products

Underground storage of petroleum products is a serious form of groundwater contamination in Maine (Garrett, 1986). But in the study area, there are only two registered underground tanks, both used for heating oil in the vicinity of the offices of H.C. Crooker & Sons, Inc.

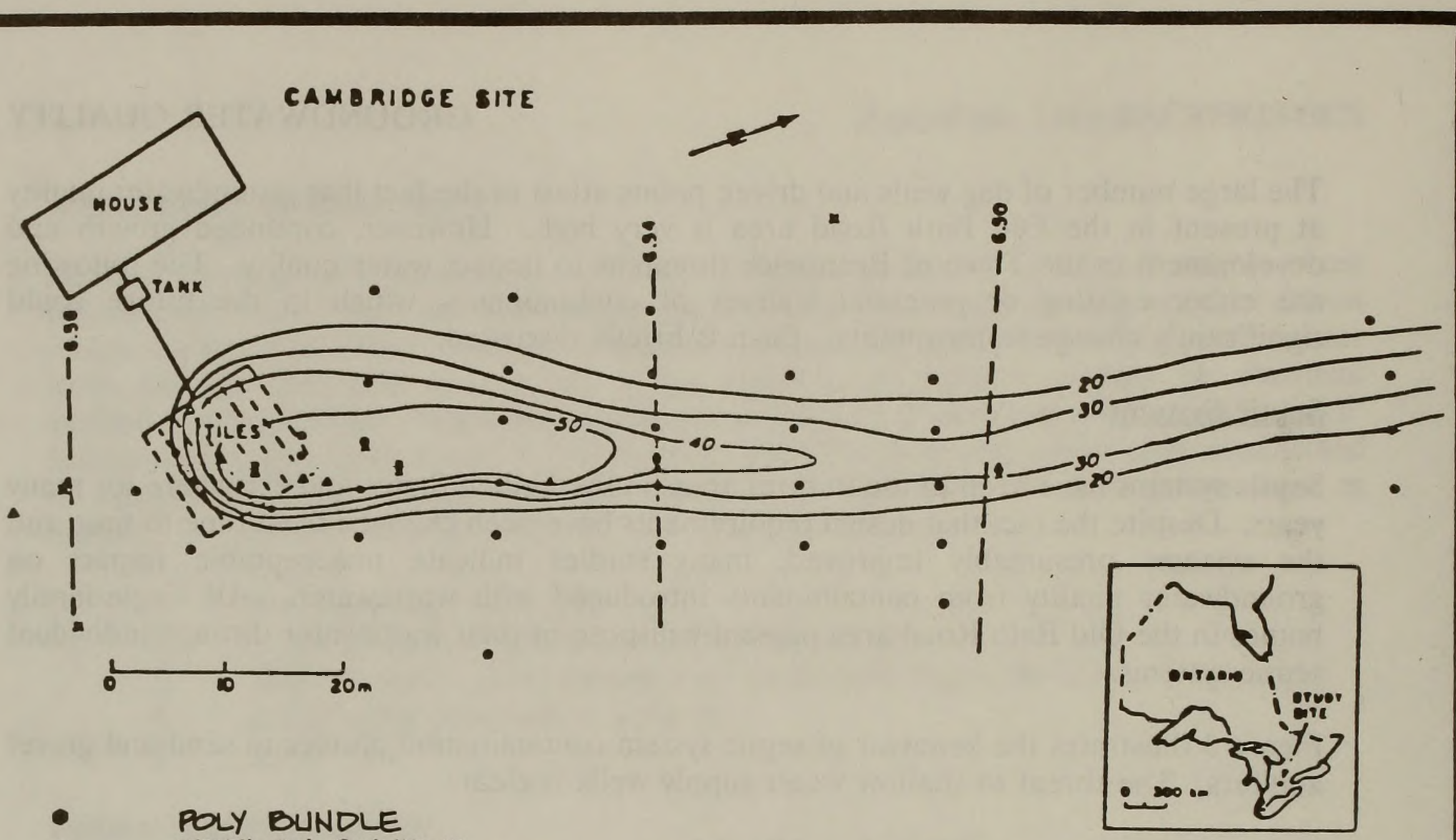
Agriculture

There is currently limited agricultural activity in the area of the aquifer. It includes:

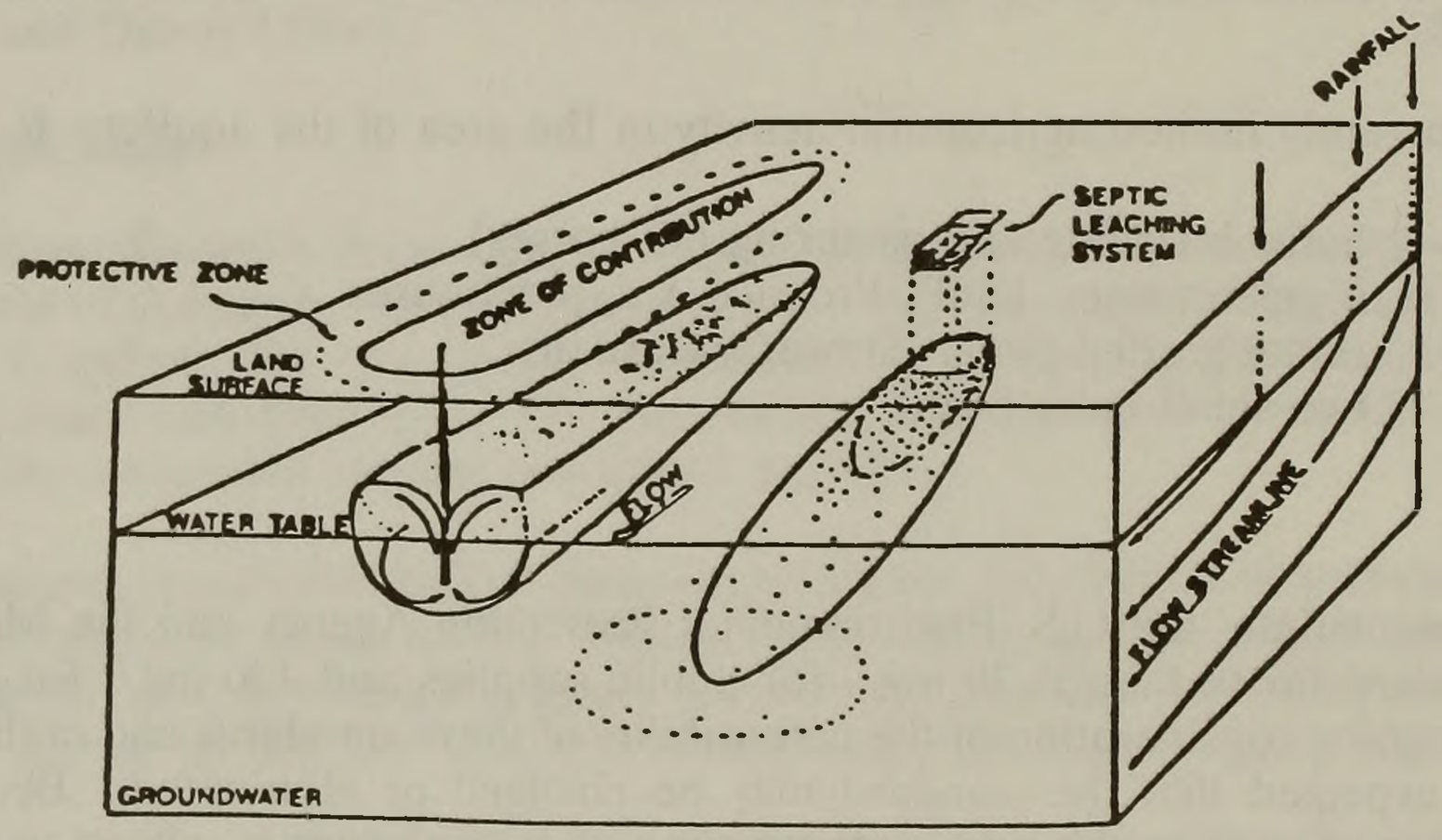
1. horse boarding and pasturing (17 horses)
2. a greenhouse: Paul's Produce & Greenhouses
3. rental garden plots: Stewarts Gardens
4. two small dairy farms

Road Salt

At the present time, the U.S. Environmental Protection Agency and the Maine drinking water standard for sodium is 20 mg/l for public supplies and 100 mg/l for private wells. There is ongoing consideration of the defensibility of these standards and in the near future it can be expected that the standard may be changed or eliminated. Because of this, consideration of sodium chloride contamination of groundwater is subject to some debate. However, the Maine Department of Transportation uses approximately 3.75 tons of salt per lane mile per year on State-maintained roads. Therefore, the 2.3 miles of Route 1, which traverse the boundary of the aquifer study area, represents a significant source of salt introduction (34.1 tons). Records from the Town of Brunswick suggest an effort to reduce the amount of salt which is spread on the roads maintained by the Town. The Town used 11.4 tons per mile in the winter of 1986-87. Direct observation of the Old Bath Road indicates use of significantly less salt than is used on the average throughout the Town.



(AFTER ROBERTSON ET AL, 1987)



(AFTER KERFOOT, 1987)

FIGURE 3 - CONTAMINANT PLUMES IN SAND & GRAVEL AQUIFERS

Therefore, it is very difficult to estimate the input of sodium chloride to groundwater as a consequence of road maintenance.

Sea Water

The contamination of domestic wells by salt water intrusion, as well as by "fossil sea water," in the State of Maine have both been documented. Some bedrock wells that have been drilled through surficial materials and into the underlying bedrock have elevated concentrations of sodium chloride. The reason for these high concentrations is not known. However, the presence of "fossil sea water" in the fractures in bedrock is a suspected source.

Where water is obtained from the bedrock, used and disposed of in a septic system, the effluent sodium and chloride concentrations can be expected to be augmented by the fact that the source water was also higher than usual in concentrations of these two elements. The real threat to sand and gravel aquifer water quality posed by the discharge to it of water from bedrock wells is obviously highly speculative.

SUMMARY

The information presented above, in addition to the brief field trip which follows, are both intended to provide sufficient information for discussions of the impact of development upon the resources of the study area. For the information of trip participants, page 66 of the Town of Brunswick Zoning Ordinance is reproduced here...

404 Aquifer Protection Zone

404.1 Definition of Zone. The Aquifer Protection Zone consists of sand and gravel aquifers and primary and secondary aquifer recharge areas, as identified in the report "Hydrologic Evaluations for Designation of Aquifer Protection Zones, E.C. Jordan Co., January 1986".

404.2 Special Use Provisions for Sand and Gravel Aquifers and Aquifer Recharge Areas. The following special use provisions are applicable to:

A. Prohibited Uses. The following uses are prohibited.
   (1) The disposal of solid waste other than brush or stumps;
   (2) The disposal or storage of hazardous matter, as defined in Section 201.32;
   (3) The disposal of leachable materials, except these from Dwellings, Single and Two-family;
   (4) The storage of road salt or other de-icing agents.

B. Special Exception Uses. The following uses may be permitted by special exception:
   (1) All uses permitted in primary districts except those noted above;
   (2) Animal feed lots;
   (3) Manure piles and storage pits;
   (4) The spreading of chemical fertilizers;
   (5) The storage of petroleum or other refined protroleum

products, except petroleum stored on residential property, to be used for residential purposes;

(6) Aerial spraying of pesticides;

(7) Piling or storing bark.

C. Special Exception Conditions. In addition to the requirements in Section 705, the uses permitted by special exception are also subject to the following:

(1) The use must not deplete ground water supplies;

(2) It must not interfere with aquifer recharge;

(3) It must not lower the quality of potable ground water;

(4) The following information must be provided to the Zoning Board of Appeals to assist it in making a decision:

(i) The immediate and long-range impact on the ground water;

(ii) The amount and types of waste to be granted by the proposed activity, and the adequacy of the disposal system;

(iii) The topography and drainage of the site and its susceptibility to flooding.

REFERENCES

E.C. Jordan Co., 1986a, Hydrogeologic evaluations for designation of aquifer protection zones: a report prepared for the Brunswick and Topsham Water District, 20 p. with Appendices.

____, 1986b, Water Resource Evaluation: a report prepared for the Brunswick and Topsham Water District, 17 p.

Garrett, P., 1986, Threats to Groundwater in Maine: Maine Department of Environmental Protection (poster).

Hvorslev, M.J., 1951, Time Lag and Soil Permeability in Ground-Water Observations, Bull. No.36, Waterways Exper. Sta., Corps of Engrs, U.S. Army, Vicksburg, Mississippi, 50 p.

Kerfoot, W.B., 1987, Is private well protection adequate when groundwater flow is ignored?: Proceedings of the Focus on Eastern Regional Ground Water Issues Conference, National Water Well Association, p. 291-314.

Masch, F.D., and Denny, K.J., 1966, Grain size distribution and its effect on the permeability of unconsolidated sands: Water Resources Research, v.2, no.4, p. 665-677.

Mazzaferro, D.L., 1980, Groundwater availability and water quality in Farmington, Connecticut: USGS water resource investigation open file 80-751.

Osberg, P.H., Hussey, A.M., II, and Boone, G.M. eds, 1985, Bedrock geologic map of Maine: U.S. Department of Energy and Maine Geological Survey, 1:500,000.

Robertson, W.D., E.A., Sudicky, J.A., Cherry, R.A., Rapaport, and R.J., Shimp, 1989, Impact of a domestic septic system on an unconfined sand aquifer: Proceedings of an International Symposium on Contaminant Transport in Groundwater, Stuttgart, Germany, 9 p.

Tepper, D.H., Williams, J.S., Tolman, A.L., Prescott, G.C. Jr., 1985, Hydrogeology and water quality of significant sand and gravel aquifers in parts of Androscoggin, Cumberland, Franklin, Kennebec, Lincoln, Oxford, Sagadahoc, and Somerset Counties, Maine: Maine Geological Survey Report Open-File No.85-82a, 106 p.

Weiss, L.A., Bingham, J.W., and Thomas, M.P., 1982, Water resources inventory of Connecticut, Part 10: Lower Connecticut River Basin: Connecticut Water Resources Bulletin No.31.

ITINERARY

MEETING PLACE: large parking lot on north side of Zayre Store, located on the south side of Old Route 1, 0.5 miles east of Cook's Corner, Brunswick, Maine.

Mileage

0.00 intersection of Old Bath Road and Old Route 1

0.15 overpass over Route 1...Maplewood Mobile Home Park is served by a sewer extension which passes over this bridge and joins a portion of the collection system of the Brunswick Sewer District.

0.40 four-legged nitrate sources in pasture south of road
0.50 Maplewood Mobile Home Park, located on the south side of the Old Bath Road
0.75 small detention pond designed in accordance with storm water run-off calculations (25 yr./24 hr. storm)...Site Location of Development Law, ch. 375, section 4 B.1.
1.40 turn right on paved access road to the Communications Building, Naval Air Station, Brunswick

STOP 1: We will leave the cars at this location and begin a traverse across the sand and gravel aquifer beginning near Route 1 and walking north across the Old Bath Road to the vicinity of the Androscoggin River. On this traverse, we will observe the upper portion of the sand and gravel deposits as revealed in gravel pits (now ponds). In addition, we will conduct falling head and constant head field permeability tests. The rental garden plots referred to above, can be observed. Finally, we will look at seeps which represent the discharge of groundwater to the Androscoggin River. After the traverse is completed, return to
(1.40) vehicles, turn around and proceed back to the Old Bath Road, turn right

1.60 turn left, turn around, and park

STOP 2: We will leave the vehicles for another short walk. The purpose here is to get an overview of a proposed development, focusing on the very difficult questions of appropriate design of water supply and wastewater systems. Return
(1.60) to cars, turn left, and proceed in an easterly direction.

2.50 entrance to Bay Bridge Estates, turn left.

STOP 3: We will simply drive slowly through the development, allowing observation of the development density and wastewater disposal facilities. The latter will not be examined in detail, but some of the component parts of the system can be
(2.50) observed. Return to Old Bath Road and turn left.

2.65 intersection of power line with Old Bath Road

2.85 Bridge Road intersection, turn right.

3.40 STOP 4: The purpose of this stop will be to look at the western boundary of the sand and gravel aquifer, noting the very different character of the topography

END OF FIELD TRIP