GROUND-WATER RESOURCES OF THE UPPER WINOOSKI RIVER BASIN, VERMONT

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 77-120

Prepared in cooperation with the
STATE OF VERMONT, AGENCY OF ENVIRONMENTAL CONSERVATION, DEPARTMENT OF WATER RESOURCES

U.S. DEPARTMENT OF THE INTERIOR
MARCH 3, 1849

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By

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1977

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

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Open-File Report

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GROUND-WATER RESOURCES OF THE

UPPER WINOOSKI RIVER BASIN, VERMONT (WRI 77-120)

E R R A T A

Plates 1 - 4	Errors in registration of overlays with base maps during final printing are responsible for slight mislocations of the information as shown.
Plate 3	The lense shaped map unit surrounding test site MEX-1 in Marshfield should have the pattern of an area underlain chiefly by coarse-grained saturated stratified deposits.

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ILLUSTRATIONS

[Plates are in pocket]

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CONVERSION FACTORS

The following factors may be used to convert the U. S. customary units published herein to the International System of Units (SI):

Multiply U.S. customary units	By	To obtain SI units
	Length	
inches (in)	25.4	millimeters (mm)
	.0254	meters (m)
feet (ft)	.3048	meters (m)
miles (mi)	1.609	kilometers (km)
	Area	
square miles (mi^2)	2.590	square kilometers (km^2)
	Volume	
gallons (gal)	3.785	liters (L)
	3.785×10^{-3}	cubic meters (m^3)
million gallons (10^6 gal)	3785	cubic meters (m^3)
	3.785×10^{-3}	cubic hectometers (hm^3)
	Flow	
gallons per minute (gal/min)	.06309	liters per second (L/s)
	.06309	cubic decimeters per second (dm^3/s)
	6.309×10^{-5}	cubic meters per second (m^3/s)
million gallons per day (Mgal/day)	43.81	cubic decimeters per second (dm^3/s)
	.04381	cubic meters per second (m^3/s)

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ABSTRACT

Ground water in the upper Winooski River basin occurs in bedrock, and in overlying unconsolidated deposits of glacial origin. Bedrock in the area is composed of a series of metamorphic and igneous rocks. Median yield for 126 wells in four different bedrock formations ranges from 5 to 6 gallons per minute (0.32 to 0.38 liters per second), and median depth ranges from 130 to 200 feet (40 to 61 meters). Lineaments, interpreted as fracture or breakage zones in bedrock, were mapped to identify zones where well yields are expected to be higher than average.

Unconsolidated deposits in the upper Winooski River basin include unsorted till, and water-sorted clay, silt, sand, and gravel. Properly constructed wells in saturated deposits of sand or gravel having high permeability can yield large quantities of water. Twenty-six domestic wells in these unconsolidated deposits have a median yield of 18 gallons per minute (1.1 liters per second) and a median depth of 58 feet (17.6 meters).

Chemical analyses of water from six wells in the upper Winooski River basin indicate a median hardness of 120 milligrams per liter (as $CaCO_3$), which is moderately hard. Iron and manganese are common constituents of ground water in the area, and several analyses show concentrations of these elements which exceed recommended National Academy of Sciences and National Academy of Engineering (1973) limits for public drinking water supplies.

INTRODUCTION

Purpose of Investigation

This report describes the ground-water resources and related geologic environment of the upper Winooski River basin and is a part of a continuing program to locate and evaluate ground-water resources in Vermont. The program, begun in 1965, is a cooperative study program carried on by the U.S. Geological Survey and the State of Vermont. Field work for the investigation was started during the summer of 1972 and continued through October 1975.

The purpose of the work was as follows: to determine the thickness and extent of the water-bearing unconsolidated deposits, to evaluate the hydraulic properties of these water-bearing materials and their potential yield, to evaluate the potential yield of bedrock aquifers and to evaluate the variations and concentrations of chemical constituents in the ground water and their effect on its general use.

Location and Extent of Area

The 203 mi^2 (526 km^2) area of investigation includes all or parts of the Towns of Cabot, Calais, Marshfield, Woodbury, and Worcester in the northeast corner of Washington County (fig. 1) and lies adjacent to the Barre-Montpelier area, a major commercial, industrial, and governmental center.

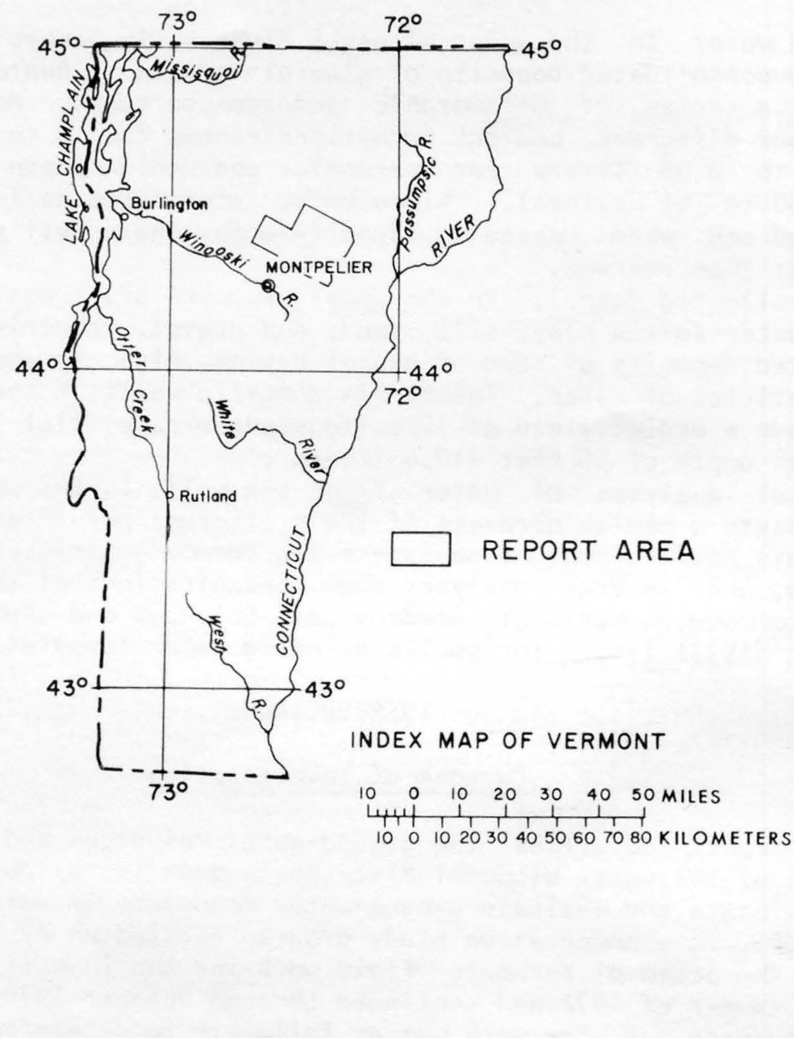


Figure 1.--Location of study area

Previous Investigations

One ground-water study and a number of geologic reports, mostly at the reconnaissance level, have been made covering all or part of the study area. The Department of Water Resources of the State of Vermont in cooperation with the U.S. Geological Survey has published a Ground Water Favorability Map of the Winooski River Basin, Vermont (Hodges, 1967). Geologic studies include bedrock mapping and reports by Cady (1956), Hall (1959), Doll and others (1961), and Konig (1961); and surficial mapping by Doll and others (1970), and Stewart and MacClintock (1969). A more recent report (Stewart, 1971) provides general information on geology for environmental planning.

Methods of Investigation

Field mapping was undertaken to delineate and identify unconsolidated materials, their origin and character, and to map bedrock exposures. Seismic refraction profiling was carried out to determine the thickness of unconsolidated deposits in various areas where water saturated coarse grained materials appeared sufficiently thick to yield large quantities of water to wells. Location maps and seismic refraction profiles for 10 sites tested are shown on plate 4 and in figures 2 and 3.

Based on the results of the seismic investigations, wash borings were made at 23 sites to obtain detailed lithologic descriptions of the underlying unconsolidated deposits. These borings were made during the summers of 1973 and 1974 and involved a total of about 1,200 linear feet (360 m).

Location, construction, and hydrologic data for 186 privately owned water wells were obtained. Most of these wells were drilled into bedrock and provided information on thickness and character of the unconsolidated deposits, and the nature and yield of the bedrock aquifer.

Water-quality analyses of surface water from 23 sampling sites were made by the Vermont Department of Water Resources between 1953 and 1965. Thirteen drilled wells from which water had been chemically analyzed by the Vermont Department of Health were located in the field.

Aerial photographs were examined for geologic information with particular emphasis on the character and location of surficial material, borrow pits or quarries, and lineaments.

The stratigraphic nomenclature used in this report is that used by the Vermont Geological Survey and does not necessarily follow the usage of the U.S. Geological Survey.

Well-Numbering System

Data on wells and borings used in compiling this report are given in tables 6 and 7. Well and boring identification numbers used in this report are composed of a two-letter town code, the letter "W" or "X", and a sequential number. The letter "W" designates a well while "X" represents a test boring. The letter codes for the five towns in the upper Winooski River basin are: Cabot, CA; Calais, CB; Marshfield, ME; Woodbury, X6; and Worcester, X9.

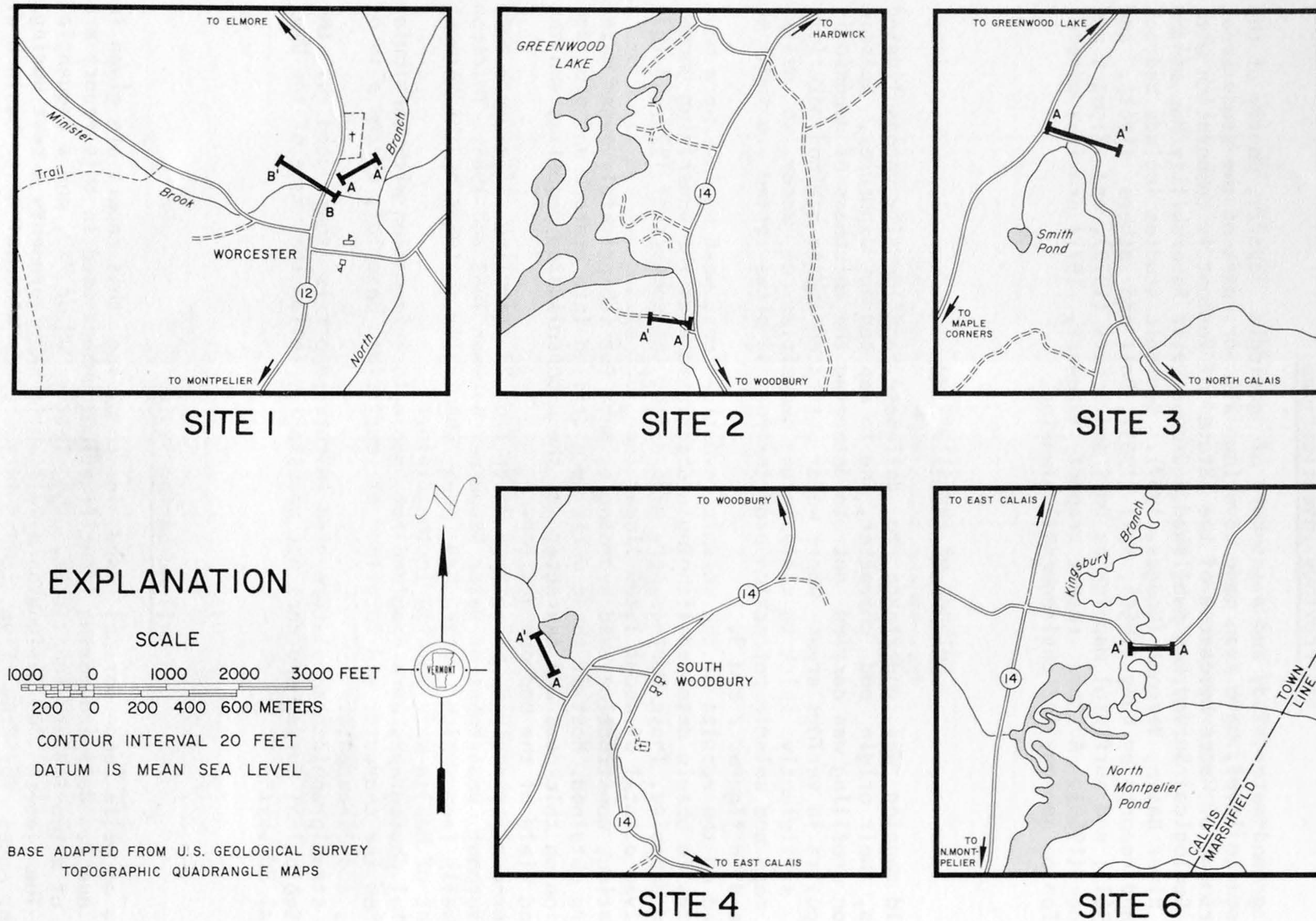


Figure 2.-- Detailed location maps of seismic surveys

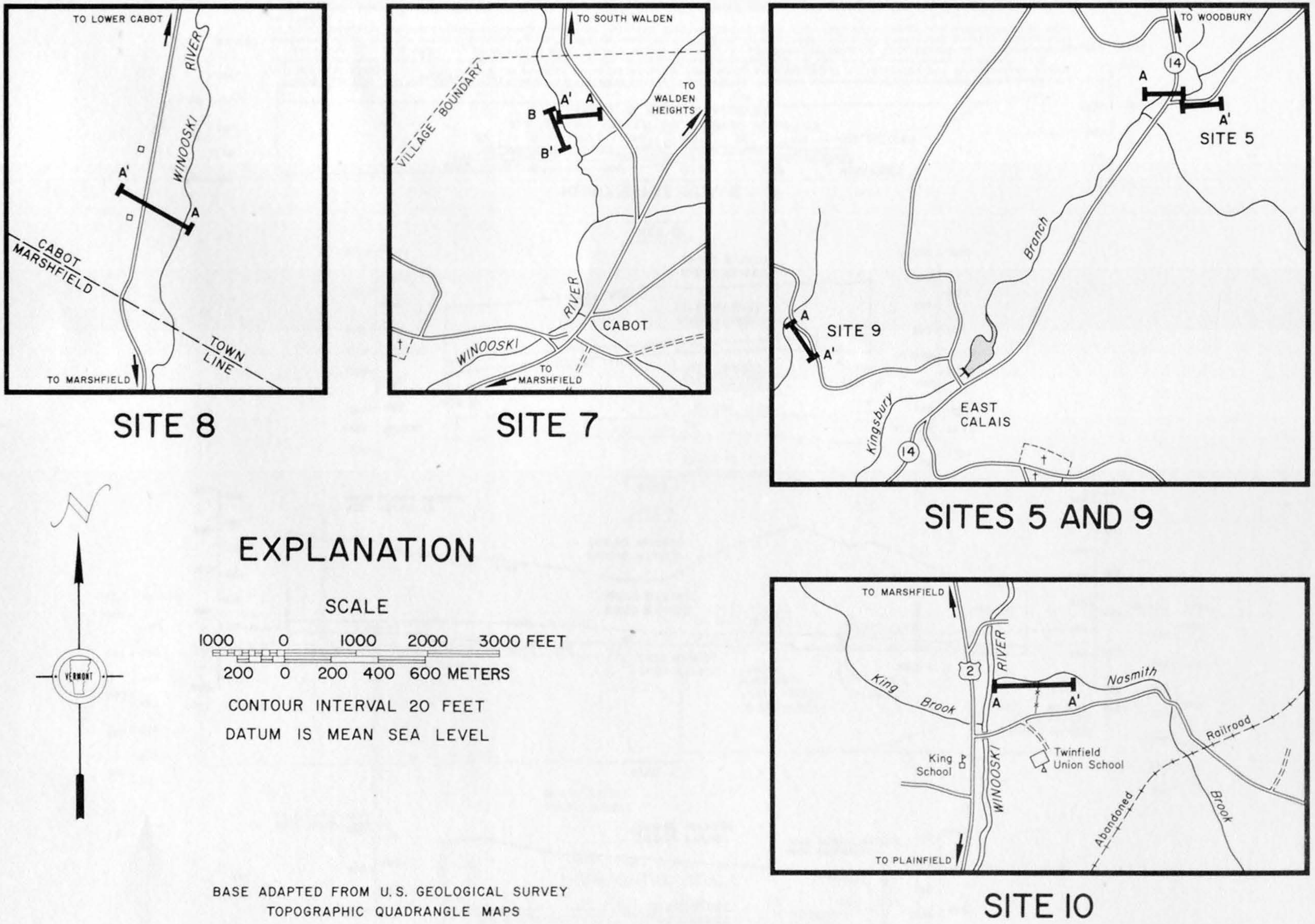
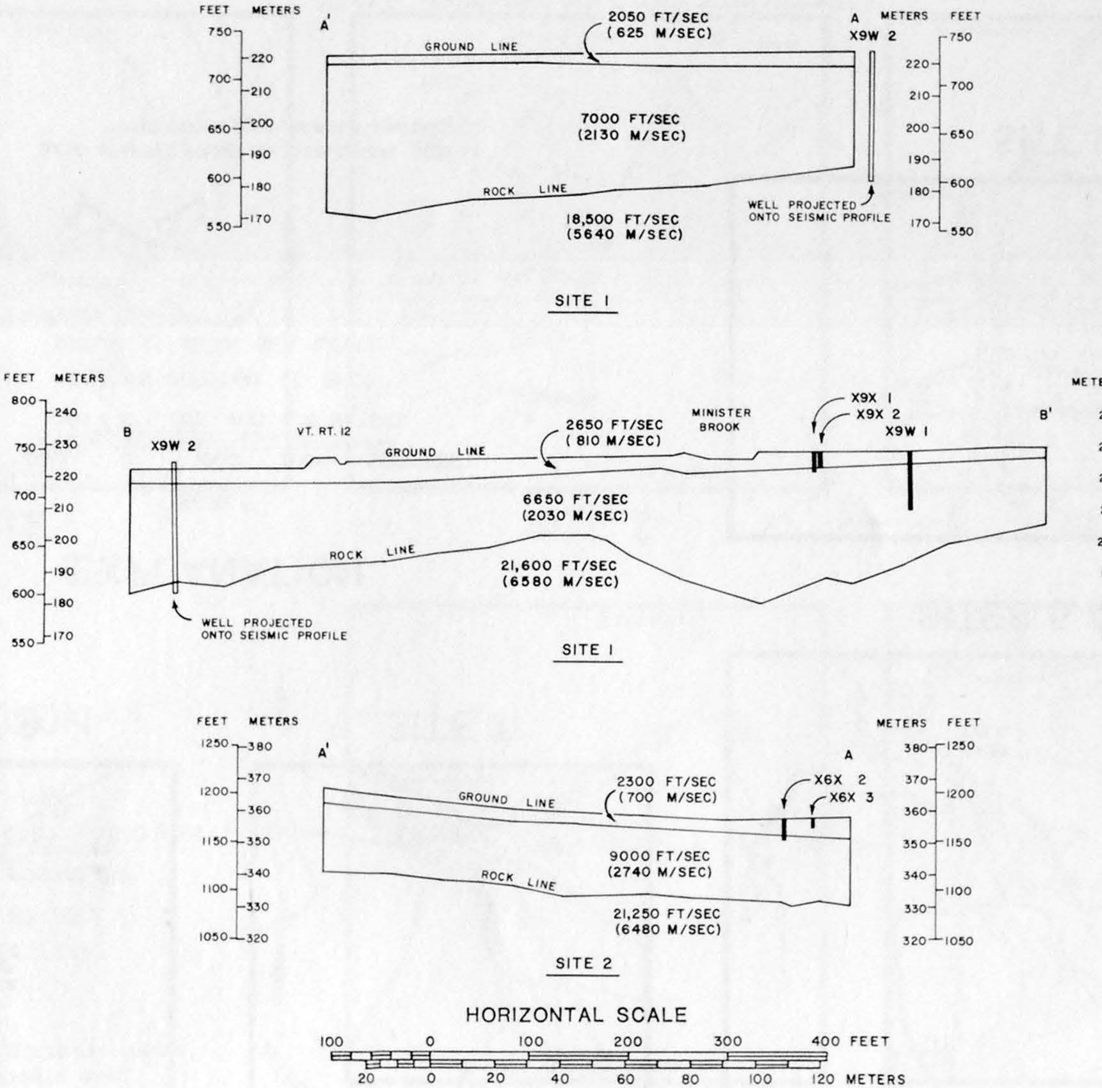


Figure 2.-- Detailed location maps of seismic surveys (continued)



ALL SEISMIC VALUES ARE AVERAGE VELOCITIES
DATUM IS MEAN SEA LEVEL

These profiles are the result of a seismic survey made during June 1973 for Vermont Department of Water Resources by Lockwood, Kessler & Bartlett, Inc. The survey was made at selected areas in the upper Winooski Basin to determine the thickness of unconsolidated sediments overlying bedrock. Locations of the seismic lines corresponding to the profiles are shown on figure 2.

Low velocity (1500-4000 ft/s or 457-1219 m/s) layers at the top of the profiles are usually interpreted as unconsolidated sediments which may lie above the water table. Medium velocity (4700-5300 ft/s or 1432-1615 m/s) layers are usually interpreted as water-saturated unconsolidated sediments, and high velocity (7400-25,200 ft/s or 2255-7680 m/s) layers are interpreted as till or bedrock.

The ground line (assumed) designates the profiles which were not surveyed prior to the set-up of the seismic instrument.

FIGURE 3.--PROFILE SECTIONS OF SEISMIC SURVEYS

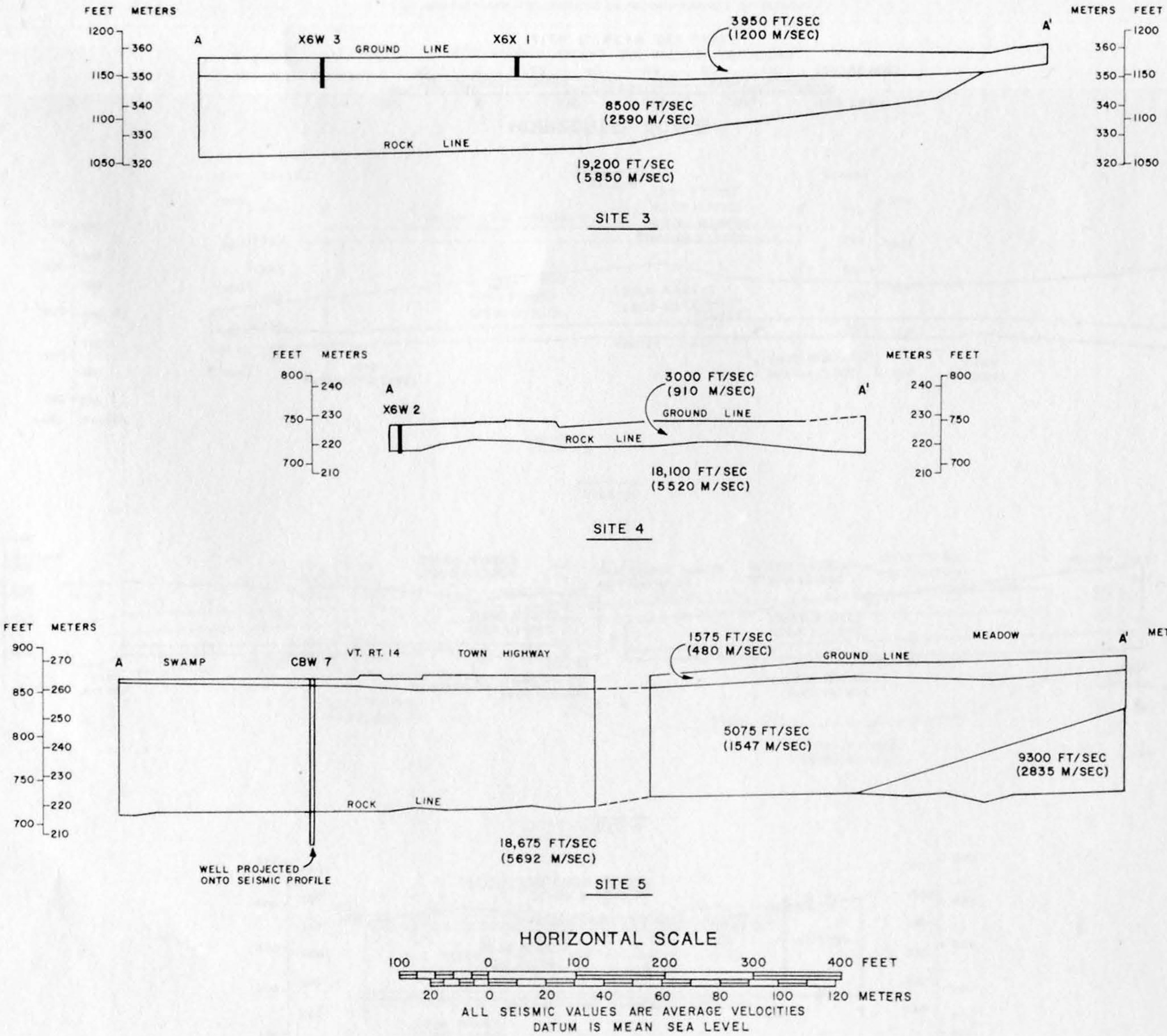


FIGURE 3.--PROFILE SECTIONS OF SEISMIC SURVEYS (CONTINUED)

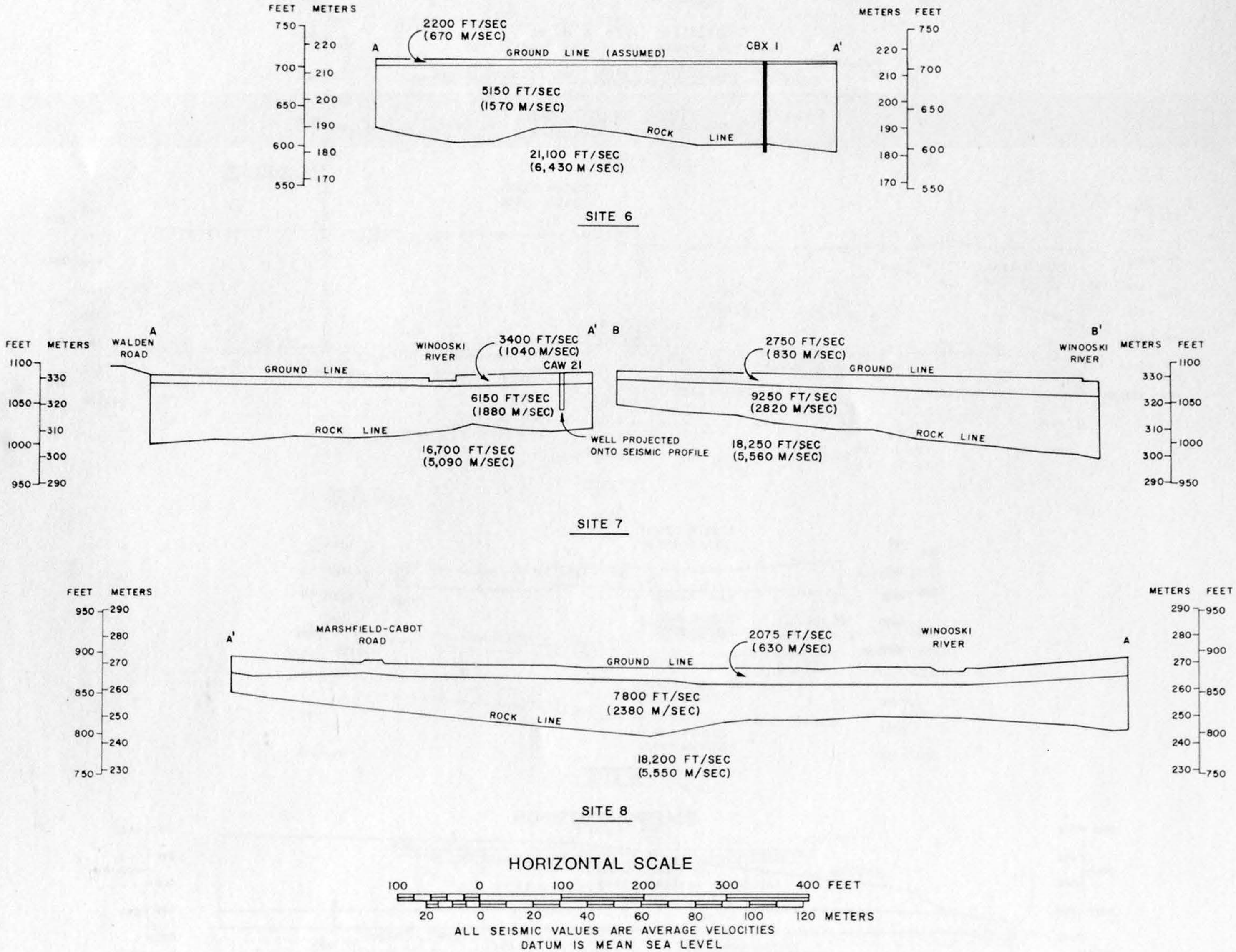


FIGURE 3.--PROFILE SECTIONS OF SEISMIC SURVEYS (CONTINUED)

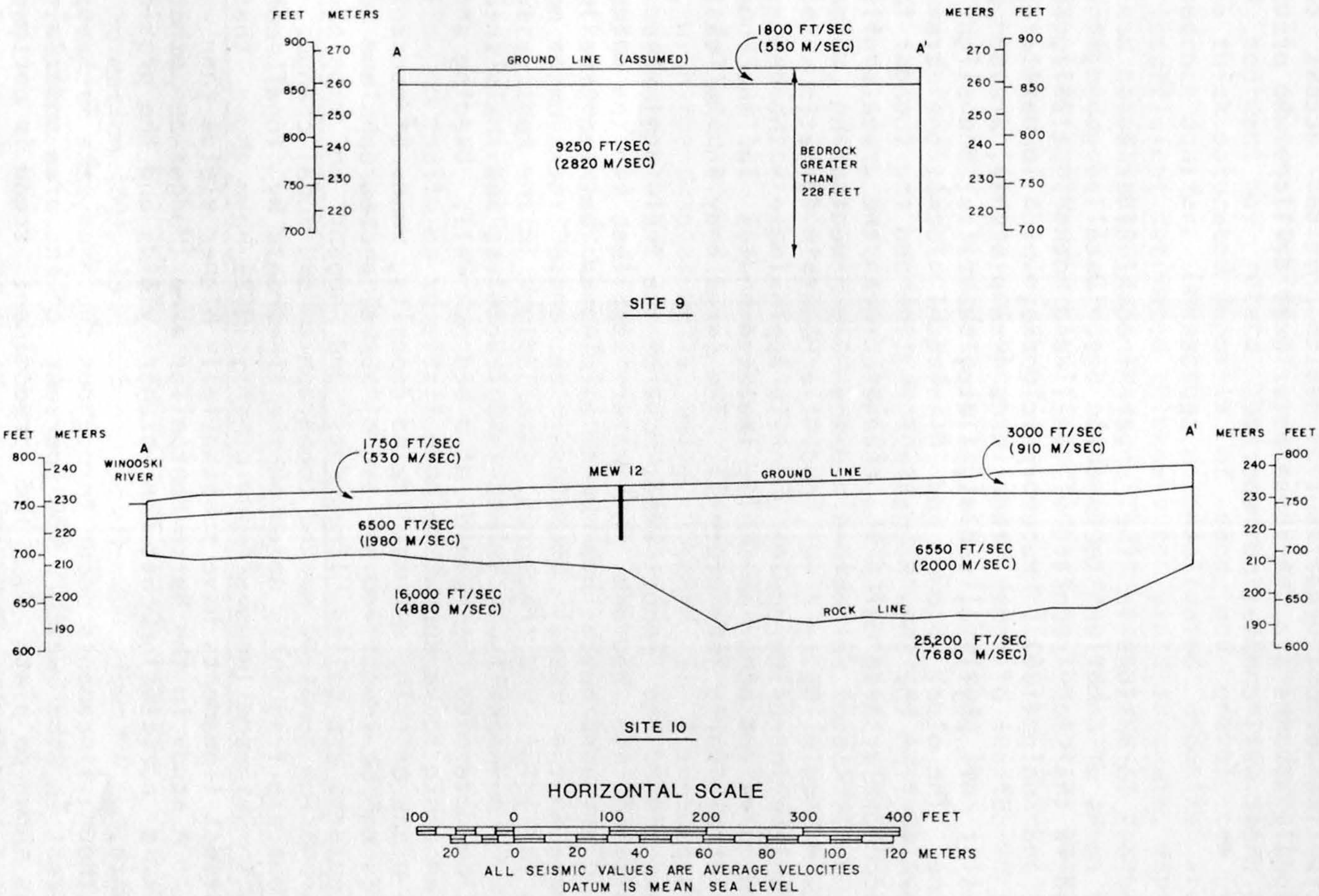


FIGURE 3.--PROFILE SECTIONS OF SEISMIC SURVEYS (CONTINUED)

Acknowledgments

The assistance of many individuals and agencies has greatly facilitated the progress of this investigation. The authors wish to express their thanks to the many landowners who granted permission for various tests on their property. The Vermont Department of Health provided access to water-quality data. Special thanks are due those water well drillers who provided information through their well completion reports.

BEDROCK

Bedrock formations in the upper Winooski River basin are primarily metamorphic rocks of Cambrian to Devonian age. Detailed geologic descriptions are provided in the map reports of Doll and others (1961), Cady (1956), Hall (1959), and Konig (1961). Metamorphic rocks, which underlie approximately the western 80 percent of the study area (see plate 1), are compact and altered, and consist of phyllite, schist, slate, quartzite, and slightly metamorphosed limestone. The older Stowe and Missisquoi Formations are separated by an unconformity from the Shaw Mountain Formation and the younger formations above. This unconformity also marks the change between the green argillaceous rocks of Stowe and Missisquoi Formations and the brown-weathering calcareous rocks of the Shaw Mountain, Waits River, and Gile Mountain Formations above.

Granitic intrusive bodies underlie approximately the eastern 20 percent of the study area and occur as small, isolated bodies in the north-central and south-central parts (see plate 1). The large body in the east is the Knox Mountain pluton.

Throughout the report area, most of the individual water users depend on wells drilled into bedrock for water supplies. In the metamorphosed rocks, virtually all pore space has been eliminated between the individual grains which make up the rock. Therefore, in these rocks water moves principally through the joints and fractures. Similarly, in the massive igneous intrusive rocks water movement is in joints and fractures; and their interconnection and saturation determine the yield of a bedrock well. Bedding and schistosity of the metamorphic rocks appear to have little or no effect on well yield.

In areas of thin, unconsolidated deposits, zones of concentrated joints or fractures can be identified by use of aerial photographs and topographic maps. These features are called "lineaments" and appear on maps and photographs as lines or narrow zones of marked topographic or tonal change. Wetter or dryer conditions are frequently noted on the lineaments by tonal contrast. Recent studies in Delaware (Woodruff and others, 1972) have shown that wells drilled to intersect lineaments have substantially higher yields than wells located at random. A study in the Barre-Montpelier area (Hodges and others, 1976a) also suggests a correlation between higher yields and the proximity of wells to lineaments.

Although lineaments occur throughout the area, the frequency of occurrence is greatest in the western 80 percent of the area underlain by metamorphic rocks as shown on plate 1. The predominant trend is northwest--striking at right angles to the trend of the regional structure.

Median yields (table 1) of 5 to 6 gal/min (0.32 to 0.38 L/s) for wells in bedrock in the upper Winooski River basin are generally lower than yields for similar rock types in the Barre-Montpelier area (Hodges and others, 1976a) or the White River Junction area (Hodges and others, 1976b). These lower median yields may be substantially influenced by the very small number of high volume commercial-industrial water users in the report area. However, a well yield of 5 to 6 gal/min (0.32 to 0.38 L/s) is generally adequate for domestic needs.

The total thickness of unconsolidated deposits which, in the upper Winooski River basin, varies from zero at bedrock outcrops to more than 275 ft (84 m) in Calais (well CBW52), can directly affect both the availability of water and the cost of construction of a water system. Thick deposits of till or fine-grained sediment may retard the movement of water into bedrock fractures, while thick saturated deposits of sand and gravel can readily recharge the bedrock aquifer. Where the unconsolidated deposits are fine grained or have insufficient saturated thickness to yield adequate, dependable quantities of water to fit the user's needs, it is necessary to case through them and drill into bedrock. The length of casing required to case off the unconsolidated deposits can have a significant impact on the total cost of the water system. Estimates of the length of casing needed can be determined from the map showing the thickness of unconsolidated deposits (plate 2) prepared from analysis of well-construction data in table 6, lithologic logs in table 7, and seismic-survey data in figures 2 and 3.

The data in table 1 on median depth of wells drilled in each formation suggest that where massive, generally brittle rock types are present, such as quartzite or granite, adequate yields may be obtained with shallower wells than in areas underlain by incompetent phyllite and schist. Wells were shallowest in the Moretown Member of the Missisquoi Formation, with a median depth of 130 ft (40 m) for 35 wells. The next deeper wells were located in the granitic intrusive areas, followed by wells in the Barton River Member of the Waits River Formation, with the deepest wells being located in the Gile Mountain Formation. The median depth for 19 wells in this last formation is 200 ft (61 m). There appears to be a direct relationship between the massiveness or competence of rock type, the degree of jointing and fracturing, and the extent to which these breaks in the rock remain open to transmit water. It is expected, however, that with depth there is a diminishing probability of increasing well yield because the weight of overlying rock closes the joints and fractures.

Table 1.--Range, median yield, and depth of selected wells by type of material

Type of well	Number of wells	Yield (gal/min) median	Yield (gal/min) range	Depth (ft) median	Depth (ft) range	Median* yield/foot [(gal/min)/ft]
Wells finished in bedrock:						
Granite (nhu)	10	5	1-35	150	63-225	0.032
Gile Mountain Formation (Dg)	19	6	.5-300	200	100-320	.030
Waits River Formation (Dwb)						
Barton River Member	62	6	1-100	174	21-340	.034
Missisquoi Formation						
Moretown Member (Omm)	35	6	0-50	130	35-500	.038
Domestic wells finished in unconsolidated material	26	18	1-90	58	6-155	.310

*Median yield per foot drilled (total depth).

UNCONSOLIDATED DEPOSITS

The unconsolidated deposits found in the upper Winooski River basin are a result of several periods of glaciation during Pleistocene time. Moving ice removed soil and rounded and shaped the bedrock surface as the ice flowed over the study area. The ice also deposited a mantle of till over bedrock. Till is an unsorted mixture of rock fragments which range in size from clay to boulders.

Most areas throughout the upper Winooski River basin are covered with till, with moderately to very thick deposits (as much as 275 ft, 84 m) being located near South Cabot, the southeastern section of Marshfield, and substantially filling Carr Brook valley located west of the village of East Calais.

Two types of till have been described in the upper Winooski River basin area by Stewart and MacClintock (1969). Basal till is compact, gray, and commonly fissile, suggesting a subglacial origin. Ablation till is a loose mixture of brown sand, cobbles, and boulders containing minor amounts of silt and clay. Stewart and MacClintock (1969) ascribe the formation of this material to slow settling of supraglacial debris during ice wasting. Water velocities were assumed to be only fast enough to remove clay and silt while leaving the larger particles behind.

Glacial meltwaters also carried, sorted, and deposited rock and soil debris. Streams in channels in and under the melting glacial ice formed long, sinuous deposits of sand and gravel. Deposits of this type are potential aquifers and are found throughout the length of the valley of the Kingsbury Branch and Cooper Brook from Hardwick to Plainfield. Streams also deposited layers of silt, sand, and gravel in some valley areas along the margins of melting ice. Deposits of these types are potential aquifers and are found throughout the upper Winooski River basin (plate 3). The largest is located around Nichols Pond on the Woodbury-Hardwick Town boundary. Large, temporary lakes were formed in most river valleys. Silt- and clay-laden waters entering these lakes deposited fine-grained sediment over the lake bottoms which remain as large flats and terraces in valleys today. The most prominent terraces are located along the lower Kingsbury Branch, Cooper Brook, and the Winooski River from Marshfield to Plainfield. Some terraces are also found along the Middle Branch in the Town of Worcester.

Water Availability in Unconsolidated Deposits

Water fills the pores between grains of unconsolidated deposits below the water table, but not all of it may be available for use. The rate at which water will flow through a deposit (hydraulic conductivity) is a major aquifer characteristic which controls well yield. Generally, coarse-grained and well-sorted deposits have the highest hydraulic conductivities and will provide the highest yields to wells. Silt, clay, and till with low hydraulic conductivities yield little water to wells.

The sustained yield of an aquifer is governed by its rate of recharge and the amount of water held in storage. The amount of water held in storage is related to the type of material within the aquifer, the areal extent of the aquifer, and its saturated thickness. Delineation of aquifers by predominant material type and approximate minimum saturated thickness (plate 3) was obtained from a study of the surficial geology, drillers' records of water wells, U.S. Geological Survey test borings, and seismic information. Estimates of the total thickness of unconsolidated deposits are presented in plate 2, but insufficient data exist to construct a saturated thickness map of the study area. Because aquifers in Vermont are commonly small, the availability of water from this is ultimately dependent on the rate of recharge. This is discussed more fully under the Recharge and Discharge section of this report.

Till

Shallow, large-diameter dug wells are used to obtain water from till. Wells in ablation till usually yield more water than wells in basal till because ablation till has a loose, sandy texture and, therefore, has a higher hydraulic conductivity. Because wells in till are usually shallow and located on hillsides where water-table fluctuations are greatest, they are more susceptible to failure or to a reduction in yield during drought than wells in other aquifers.

Fine-grained Deposits

Unconsolidated deposits over much of the valley areas along the main stem of the Winooski River in Marshfield and Cabot and the lower Kingsbury Branch consist of lake bottom deposits composed of fine sand, silt, and clay. These and similar deposits throughout the area are mapped as fine-grained deposits (plate 3). Some are covered with an unsaturated veneer of sand and gravel. The fine-grained deposits have a low potential for ground-water yield because of their low hydraulic conductivity. However, lenses of coarse-grained, intercalated material occur in them at some locations and may yield moderate quantities of water suitable for domestic and some commercial supplies. Although these fine-grained deposits may not readily yield water to wells, they do hold large quantities of water which are available for slow release to supply adjacent streams and unconsolidated aquifers, or underlying bedrock aquifers.

Sand and Gravel

Sand and gravel deposits, where they have sufficient saturated thickness and are readily recharged, offer the greatest ground-water potential in the study area. The most extensive sand and gravel aquifer is located along the Kingsbury Branch between South Woodbury and East Calais (plate 3). This location and other similar areas underlain chiefly by saturated medium sand to gravel deposits with a total thickness of more than 20 ft (6 m) are capable of yielding more than 200 gal/min (13 L/s), sufficient to meet some commercial-industrial or municipal needs. Areas underlain mainly by saturated fine sand to gravel deposits having a total thickness of more than 20 ft (6 m) should yield 50 gal/min (3 L/s) to 200 gal/min (13 L/s), sufficient to meet light industrial and small public supply requirements as at Woodbury well X6W2 (plate 3 and table 3). Recharge from precipitation alone is commonly inadequate to sustain high yield wells in aquifers with small recharge areas. However, induced infiltration from adjacent surface waters can provide additional recharge for such aquifers to sustain high yield wells.

Estimated Yield of Stratified Deposits

Twenty-three test wells were drilled in stratified drift deposits at selected locations to provide data for estimating potential ground-water yields. Seven test wells penetrated water-saturated granular materials of sufficient thickness (at least 17 ft) to have some potential for ground-water development. Because aquifer tests were not made, estimates of ground-water yield at the seven test sites are based on an indirect method (Lohman, 1972, p. 53) using the lithologic description of materials sampled. Estimated values for hydraulic conductivity (table 2) were assigned to each lithologic unit described in table 7. The assigned hydraulic conductivity was multiplied by the saturated thickness of each unit and the products were summed to provide an estimated transmissivity value for each test well site in table 3.

Table 2.--Estimated hydraulic conductivity for various materials

[Modified from tables by Lohman (1972, p. 53), and Ryder and others (1970, p. 21).]

Material	Estimated hydraulic conductivity (feet per day)
Clay	1
Till	1
Silt	1
Silt and very fine sand	1
Silt and clay	1
Silt and gravel	2
Fine sand, very fine sand and silt	2
Clayey fine sand to fine gravel	5
Fine sand with clay layers	5
Fine sand, some clay and gravel	10
Fine sand	15
Fine and medium sand with clay layers	20
Fine sand and medium sand	25
Sandy till	25
Fine sand to fine gravel	30
Medium and coarse sand, clay layers	40
Alluvium	50
Sand and gravel, some clay	60
Medium sand	100
Medium sand and coarse sand	125
Medium sand, some fine sand to fine gravel	300
Sand and gravel	500
Fine gravel and sand	600
Medium and coarse sand, some gravel and silt	700
Fine gravel	800
Medium and coarse sand and gravel	900
Coarse sand to gravel, some fine to medium sand	900
Coarse sand and cobbles	1000
Gravel	1000
Cobbles and gravel	1000

Well yields were computed from the estimated transmissivity values and the maximum allowable drawdown, selected as the difference between the static water level and 1 ft (0.30 m) above the top of the screen, using the Theis non-equilibrium equation (Lohman, 1972, p. 8). The drawdowns were then adjusted for thinning of the aquifer due to dewatering and the effects of partial penetration of the aquifer by the well screen (Cervione and others, 1972, p. 50-55). If the adjusted drawdown exceeded the maximum allowable drawdown, the calculations were repeated until a well yield was obtained where the resultant drawdown did not exceed the specified limit (table 3).

The estimated yield for each site applies strictly to a well 24 in (610 mm) in diameter, 100 percent efficient, that has been pumped continuously for 200 days. It is also assumed that the horizontal hydraulic conductivity is 10 times greater than the vertical hydraulic conductivity and the average storage coefficient is 20 percent.

Hydrogeologic boundaries, although not considered in these calculations, can also affect well yields and resultant drawdowns. The effects of impermeable boundaries (bedrock, till, clay) decrease well yield by increasing drawdown; recharge boundaries, as a result of induced infiltration from surface-water bodies, increase well yield by decreasing drawdown.

The foregoing methods give qualitative estimates for the potential yield of wells in stratified-drift deposits, but systematic exploratory drilling and aquifer testing are necessary for locating large capacity wells.

Table 3.--Estimated transmissivity and yield at selected test-well sites

[Estimated yields apply strictly to a 100 percent efficient, 24-in (610 mm) well that has been pumped continuously for 200 days with the pumping level maintained at 1 foot (0.30 m) or more above the top of the screen. For a full discussion of the methods used and conditions assumed, see the text.]

Well or boring number	CAW21	CBW7	MEX1	X6W2	X6W3	X6W4	X9W1
Total depth (ft)	36	84	23	30	20	35	63
Saturated thickness (ft)	34	67	17	27	17	31	63
Length of screen, estimated (ft)	10	19	5	5	5	10	10
Maximum allowable drawdown (ft)	23	42	11	21	11	21	52
Transmissivity, estimated (ft^2/day)	23,000	20,000	10,500	5500	8500	24,000	5000
Well yield, estimated (gal/min) under conditions described in this report	875	1275	225	150	200	875	275

RECHARGE AND DISCHARGE

Water movement into and out of the project area can be expressed by the following equation:

$$P = R + ET + \Delta S$$

Where P = precipitation, R = runoff, ET = evapotranspiration, and ΔS = change in storage. At the Edward F. Knapp Airport, Berlin, near the study area, precipitation averages 34 in (864 mm) per year, with somewhat more during summer than winter.

Of the precipitation each year, evapotranspiration returns an average equivalent of 14 in (360 mm) of water to the atmosphere (Hodges, Butterfield, and Ashley, 1976a). Evapotranspiration is the sum of direct evaporation of surface water, the sublimation of snow, and the transpiration of living organisms. Most evapotranspiration occurs during the spring and summer growing season with the result that ground-water levels decline during this period as trees and plants remove water from the ground and release it to the atmosphere as water vapor. Killing frosts in September or October end the yearly growth cycle, cause transpiration rates to decline, and result in the rise of ground-water levels.

An average of 20 in (508 mm) of water per year leaves the area as runoff. This includes water that runs directly over the land to the streams, and that which seeps into the ground, recharges ground-water bodies, and then discharges to the streams. Ground-water discharge to streams forms a significant proportion of the total streamflow and sustains flow during periods of little or no rainfall or below-freezing temperatures.

Normally, ground-water levels at central Vermont (Hodges, Butterfield, and Ashley, 1976a) have a seasonal high in March or April, coinciding with melting of the snowpack and break-up of ice in the rivers and a seasonal low in September or October at the end of the growing season. This sequence, however, can be modified by excessive rainfall or drought. The change in ground-water storage over the years is probably negligible because decreases in storage during dry years are offset by increases in storage during wet years.

CHEMICAL QUALITY OF WATER

Chemical analyses of 13 ground-water samples (table 4) and 38 surface-water samples (table 5) were obtained from several governmental agencies for comparison in this study.

Eight of the analyses of water from wells contained one or more constituents that equaled or exceeded the recommended or maximum allowable limits of concentration adopted by the National Academy of Sciences and National Academy of Engineering (1973) for drinking water supplies. Of the eight samples in which the limits were equaled or exceeded, the recommended limit for manganese was exceeded in four samples, the recommended limit for iron was exceeded in two samples, and the maximum allowable limit for nitrate was exceeded in three samples.

Surface water in the upper Winooski River basin was sampled at 23 locations (plate 4) to determine chemical composition. Analyses of these samples are shown on table 5. Surface waters showed a median pH of 7.7 and a median

Table 4.--Chemical analyses of ground water

(Analyses in milligrams per liter except as indicated.)

Local well number	Date	Dissolved iron (Fe)	Dissolved manganese (Mn)	Dissolved sodium (Na)	Alkalinity as $CaCO_3$	Dissolved chloride (Cl)	Dissolved nitrate (N)	Dissolved nitrite (N)	Hardness (Ca,Mg)	pH (units)	Color (Platinum-cobalt units)	Turbidity (Jtu)	Total copper (Cu)	Total lead (Pb)	Total zinc (Zn)	Source of data[1]	Type of aquifer[2]
Standards[3]		0.3*	0.05*	--	--	250*	10.0*	--	--	--	15*	5*	1.0*	0.05**	5.0	--	--
								CABOT									
W-21	7-26-73	0.02	0.09	--	120	34	18	0.01	--	7.3	5	--	--	--	--	WR	U
W-23	6-12-75	.00	.00	4	97	13	.0	.00	120	7.8	--	--	0.1	0.00	0.0	H	R(Dg)
								CALAIS									
W-30	7-14-71	.03	.00	2	100	6	1.8	.00	240	7.2	0	0	.0	--	--	H	R(Dw)
								MARSHFIELD									
W-45	5-14-72	.00	.00	1	60	3	1	.00	66	7.1	0	0	.0	.00	.2	H	R(Dw)
W-48	1-15-74	.21	.03	8	140	3	.2	.0	140	7.2	0	0	.0	.0	.0	H	R(Dg)
								WOODBURY									
W-2	7- 2-73	.00	1.10	--	110	1.4	.1	--	--	6.6	5	--	--	--	--	WR	U
W-3	7-31-73	.00	.00	--	120	39	22	.00	--	7.7	10	--	--	--	--	WR	U
								WORCESTER									
W-1	8- 3-73	.16	.00	--	65	44	13	.10	--	7.5	50	--	--	--	--	WR	U
W-3	1-26-73	.00	1.60	--	--	--	--	--	--	--	--	--	.2	.00	.5	H	R(Omm)
W-9	11- 7-71	.05	.00	2	50	0	.0	.0	140	6.7	0	0	.0	.0	.0	H	R(Omm)
W-37	12-29-71	.66	.04	4	42	25	.2	.01	54	6.9	0	4	.0	.05	.4	H	--
W-49	8-19-69	.07	.18	1	--	--	--	--	--	7.9	5	0	.06	.00	.018	US	U
W-50	7-11-74	.66	.03	96	68	150	1.8	.0	92	6.4	0	0	.0	.0	.0	H	R(Omm)

[1]Source of data: H, Vermont Department of Health; WR, Vermont Department of Water Resources; and US, U.S. Public Health Service.

[2]Type of aquifer: R, bedrock (letters in parentheses refer to bedrock formations, see Plate 1); U, unconsolidated materials.

[3]National Academy of Sciences and National Academy of Engineering (1973) drinking water standards limits of concentration: *recommended limit, **maximum allowable.

Table 5.--Chemical analyses of surface water

(Analyses by Vermont Department of Water Resources.
Analyses in milligrams per liter except as indicated.)

Map no.	Location and station number[1]	Date	Dissolved calcium (Ca)	Dissolved magnesium (Mg)	Alkalinity as $CaCO_3$	Dissolved chloride (Cl)	Hardness (Ca,Mg)	pH (Units)	Temperature (°C)	Color (Platinum-cobalt units)	Turbidity (Jtu)	Dissolved oxygen	Total coliform (Most probable number colonies per 100 milliliter)
1	Winooski River (29)	8-31-53	80	12	88	5.5	92	7.8	23.0	10	0	7.8	1,500
		8-24-65	--	--	--	4.7	--	8.3	18.0	20	5	9.0	--
2	Nasmith Brook (30)	9-03-53	74	14	84	3.0	88	8.3	18.5	5	1	9.5	450
3	Nasmith Brook (31)	9-03-53	74	24	86	2.4	98	8.2	18.0	0	0	9.3	250
4	Winooski River (32)	8-31-53	38	22	40	3.6	60	7.7	20.0	25	1	8.4	9,500
		7-15-55	38	2	42	1.4	40	7.6	19.0	30	14	8.3	450,000
		6-06-57	54	10	44	6.0	64	7.7	15.0	20	4	9.2	--
5	Marshfield Pond Brook (33)	9-03-53	18	44	24	2.4	62	8.0	21.0	25	0	8.7	4,500
6	Winooski River (34)	8-31-53	38	26	40	4.2	64	7.3	19.7	25	5	6.5	9,500
		6-06-57	48	22	44	6.0	70	7.7	14.5	20	4	8.4	--
		8-24-65	--	--	--	5.5	--	8.0	18.0	35	4	8.0	--
7	Molly's Falls Brook (35)	9-03-53	88	8	94	5.4	96	8.1	19.0	10	0	8.4	250
8	Winooski River (36)	7-15-55	118	22	142	3.4	140	7.7	20.5	35	38	5.2	1,100,000
		6-06-57	98	88	40	5.0	186	7.3	14.0	30	6	3.4	--
		6-21-62	--	--	--	5.0	--	7.6	16.5	15	3	7.4	34,000
9	Winooski River (37A)	6-21-62	--	--	--	2.0	--	7.5	16.0	20	3	6.2	80,000
10	Winooski River (37)	8-31-53	106	22	114	6.1	128	6.9	23.0	20	20	.3	950,000
		6-06-57	100	26	98	6.0	126	7.5	13.5	20	5	5.8	--
11	West Hill Pond Brook (38)	9-03-53	88	20	94	3.0	108	8.0	19.0	10	0	8.4	1,500
12	West Hill Pond Brook (39)	9-03-53	78	12	72	3.0	90	7.4	24.0	15	1	7.1	7,500
13	Winooski River (40)	8-31-53	144	32	184	18	176	6.7	24.0	15	47	0	2,500,000
		7-15-55	208	44	58	20	252	5.2	21.0	15	60	0	1,100,000
		6-06-57	100	16	100	6.0	116	7.5	12.5	30	6	6.6	--
		3-13-63	--	--	--	4.4	--	6.8	1.2	10	6	10.9	--
		8-24-65	--	--	--	8.3	--	7.9	17.0	20	14	7.0	--
14	Winooski River (41)	8-31-53	140	16	145	3.6	156	7.8	19.5	5	0	7.5	950
		7-15-55	84	22	130	.7	106	8.0	19.0	10	6	8.7	2,500
		6-21-62	--	--	--	.8	--	8.1	14.0	10	1	10.2	2,400
		3-13-63	--	--	--	2.8	--	8.1	.5	10	6	13.0	--
15	Kingsbury Branch (7-4)	9-04-53	98	24	108	7.3	122	7.9	20.5	15	0	6.8	2,500
16	Kingsbury Branch (7-5)	9-04-53	92	22	100	7.3	114	8.2	21.0	10	0	7.9	9,500
17	Kingsbury Branch (7-6)	9-04-53	96	16	96	6.7	112	7.9	16.0	0	0	8.0	9,500
18	Pekin Brook (7A-1)	9-04-53	102	22	118	2.4	124	7.8	22.0	15	5	6.7	2,500
19	Curtis Pond Brook (7A-2)	9-04-53	80	24	86	3.0	104	7.8	22.0	25	0	6.7	750
20	Sugar Brook (7A-3)	9-04-53	106	14	116	3.0	120	7.6	18.5	0	0	6.6	9,500
21	Pekin Brook (7A-4)	9-04-53	72	10	70	3.0	82	8.1	21.0	0	0	8.3	9,500
22	North Branch (5-8)	7-11-55	16	8	18	1.0	24	7.0	22.0	20	4	6.8	4,000
23	North Branch (5-9)	7-11-55	16	2	18	.7	18	7.0	25.5	35	11	8.4	75,000

[1]Station numbers are site designations used by the Vermont Department of Water Resources.

hardness of 105 mg/L (milligrams per liter) as $CaCO_3$. This compares with a median pH of 7.2 and hardness of 120 mg/L for ground-water samples. Surface water is generally more alkaline than ground water. The most alkaline of the surface-water samples came from three streams originating principally from the area of the Knox Mountain pluton in the southeast corner of the study area.

Hardness

Hardness is a term applied to the soap-neutralizing power of water. Hardness is largely determined by the concentration of calcium and magnesium, and is expressed as calcium carbonate ($CaCO_3$). The following ranges have been used in various U.S. Geological Survey reports to classify hardness:

Hardness as $CaCO_3$ (mg/L)	Descriptive rating
0 - 60	Soft
61 - 120	Moderately hard
121 - 180	Hard
181 or more	Very hard

While soft and moderately hard water can generally be used without treatment except for some industrial purposes, hard water frequently requires treatment (softening) for use in laundries, some industrial and most domestic uses. Very hard water requires softening for most purposes to make the water usable and to prevent damage to water-supply and water-using equipment.

Median hardness of the six ground-water analyses in the upper Winooski River basin was 120 mg/L, ranking the water as moderately hard to hard. Therefore, treatment of some water may be required.

The degree of hardness shown by these ground-water samples generally reflects the regional trends found in surface-water samples, wherein surface waters originating from calcareous rocks (Gile Mountain and Waits River Formations) show the highest levels of hardness (106 to 252 mg/L). Surface waters flowing from the area of the Knox Mountain granite show lower levels of hardness (88 to 96 mg/L) and streams underlain by quartzite and slate (Moretown Member of the Missisquoi Formation and Stowe Formation) show the lowest levels of hardness (18 to 24 mg/L).

Iron and Manganese

Iron and manganese are minor constituents of water, but excessive concentrations, particularly of manganese, may have harmful effects on health (Yase, 1972). The National Academy of Science and National Academy of Engineering (1973) recommended a maximum limit of 0.3 mg/L of iron and 0.05 mg/L of manganese in drinking water supplies. The median iron content for all wells sampled (table 4) was 0.03 mg/L, although samples from two rock wells were more than double the recommended limit. Iron found in the water may be from many sources in the upper Winooski River basin. Most bedrock formations in the report area contain iron-bearing minerals. Magnetite is listed as a common accessory mineral by Cady (1956) and Konig (1961), and was commercially extracted from sand deposits near East Calais during the 1800's (Konig, 1961). Iron in ground water may increase as a result of reducing conditions produced by decaying organic matter in aquifers or derived from industrial waste and dumps (landfills).

Median manganese content for wells sampled was 0.03 mg/L, which approaches the limit of 0.05 mg/L recommended by the National Academy of Science and National Academy of Engineering. However, three domestic wells and one public water-supply well sampled showed excessive manganese. Manganese is not a major part of the mineral composition of any rock types identified by Cady (1956) or Konig (1961) in the upper Winooski River basin. It may be derived from minerals in which it is a minor constituent, or from industrial wastes and dumps. The lack of an obvious source of the manganese suggests that only an in-depth study could determine the factors contributing to excessive levels shown in table 4.

SUMMARY

Ground water can be obtained in quantities suitable to sustain single-family domestic and farm supplies from wells drilled in bedrock nearly everywhere in the upper Winooski River basin. The median yield for 126 domestic supply wells in four different bedrock formations is between 5 and 6 gal/min (0.32 to 0.38 L/s). The median depths for wells in the four different formations range from 130 to 200 ft (40 to 61 m). In the area studied, bedrock well yields are more dependent on rock fracture than rock type; generally, wells located in fracture zones have the greatest yields. Some fracture zones appear as linear features (lineaments) on aerial photographs or topographic maps (plate 1). Lineaments may be used for well-site selection to enhance the probability of obtaining higher-than-average well yields.

Water-saturated sand and gravel aquifers capable of yielding up to 1,000 gal/min (63 L/s) to individual wells, sufficient to sustain commercial, industrial, or municipal supplies, are found in valley areas of all five towns in the study area. These potential sources of large supplies are found throughout the length of the valley of the Kingsbury Branch and Cooper Brook from Hardwick to Plainfield. Water availability and location of sand and gravel aquifers in the valley areas are described on plate 3.

Of the 23 test wells drilled for this study, 7 penetrated water-saturated sand and gravel of sufficient thickness to have potential for ground-water development. Well yields for these seven sites, calculated from geohydrologic data from the test wells, ranged from 150 to 1,275 gal/min (9.5 to 80 L/s).

Chemical analyses of 13 ground-water samples and 38 surface-water samples were used to evaluate water-quality conditions in the basin. Eight of the 13 analyses of ground water revealed one or more constituents that equaled or exceeded the maximum allowable limits for iron, manganese, and nitrate as nitrogen in drinking water. Iron and manganese occur naturally, but nitrate is an indication of pollution from human or animal wastes or from fertilizer. Surface water and ground water were found to be moderately hard to hard. Hardness is derived from carbonate minerals in the bedrock and overlying unconsolidated deposits, and can be reduced through treatment.

Ground-water resources in the basin are of adequate quantity and quality to meet foreseeable needs. Although resources capable of sustaining municipal supplies occur in the basin, they are located only in some valley areas. Test drilling and exploration within these aquifers would be a necessary forerunner of any development. Except for localized water-pollution problems and some instances of excessive levels of iron, manganese, or hardness, which can be controlled with treatment, the chemical quality of ground water is suitable for drinking.

TABLE 6.--DESCRIPTION OF SELECTED WELLS, TEST WELLS AND BORINGS

LOCAL WELL NUMBER: LETTER PREFIX INDICATES--A, U.S. GEOLOGICAL SURVEY AUGER BORING; B, BRIDGE BORING; R, ROADWAY BORING; W, WELL OR TEST WELL; X, MISCELLANEOUS TEST BORING.

LATITUDE-LONGITUDE: NUMBER FOLLOWING DECIMAL POINT IS A SEQUENTIAL NUMBER FOR WELLS OR BORINGS IN A 1-SECOND GRID.

ALTITUDE OF LAND-SURFACE DATUM: ALTITUDES ARE EXPRESSED IN FEET ABOVE MEAN SEA LEVEL.

METHOD DRILLED: A, AIR-ROTARY; B, BORED OR AUGERED; C, CABLE TOOL; D, DUG; H, HYDRAULIC-ROTARY; J, JETTED; P, AIR-PERCUSSION; R, REVERSE-ROTARY; T, TRENCHED; V, DRIVEN; W, DRIVE-WASH.

WELL FINISH: C, POROUS CONCRETE; F, GRAVEL WALL WITH PERFORATED OR SLOTTED CASING; G, GRAVEL WALL WITH COMMERCIAL SCREEN; H, HORIZONTAL GALLERY OR COLLECTOR; O, OPEN END; P, PERFORATED OR SLOTTED CASING; S, SCREEN; T, SAND POINT; W, WALLED OR SHORED; X, OPEN HOLE IN AQUIFER (GENERALLY CASED TO AQUIFER).

WELL DEPTH: DEPTH OF FINISHED WELL, IN FEET BELOW LAND SURFACE.

WELL USE: A, ANODE; D, DRAINAGE; G, SEISMIC HOLE; H, HEAT RESERVOIR; O, OBSERVATION; P, OIL OR GAS; R, RECHARGE; T, TEST; U, UNUSED; W, WATER WITHDRAWAL; X, WASTE DISPOSAL; Z, DESTROYED.

WATER-BEARING MATERIAL: PRINCIPAL WATER-BEARING ZONE.

ADJECTIVE (FIRST CHARACTER)		LITHOLOGY (SECOND CHARACTER)	
1	VERY FINE GRAINED	A	ALLUVIUM
2	FINE GRAINED	B	SEDIMENTARY ROCK, UNCLASSIFIED
3	MEDIUM GRAINED	C	CONGLOMERATE
4	COARSE GRAINED	D	DOLOMITE
5	VERY COARSE GRAINED	E	GYPSUM OR ANHYDRITE
6	CLAYEY	F	SHALE
7	SILTY	G	GRAVEL
8	SANDY	H	IGNEOUS, GRANULAR (GABBRO, GRANITE, ETC.)
9	GRAVELLY	I	IGNEOUS, APHANITIC OR GLASSY (BASALT, ETC.)
0	CAVERNOUS	J	IGNEOUS, UNCONSOLIDATED (TUFF, VOLCANIC ASH)
A	ARGILLACEOUS	K	SAPROLITE
B	BOULDERY	L	LIMESTONE
C	CALCAREOUS	M	MARL OR SHELL MARL
D	DENSE	N	METAMORPHIC, COARSE GRAINED (GNEISS, MARBLE, QUARTZITE)
E	CONCRETIONARY	O	METAMORPHIC, FINE GRAINED (SCHIST, SLATE)
F	IRON STAINED OR IRON CEMENTED	P	CLAY
G	GRANULAR	Q	SILT OR LOESS
H	HARD	R	SAND AND GRAVEL
I	INTERBEDDED	S	SAND
J	JOINTED OR FRACTURED	T	TILL
K	COLUMNAR	U	UNCONSOLIDATED SEDIMENT
L	LAMINATED OR BANDED	V	SANDSTONE
M	MASSIVE	W	SILTSTONE
N	NONCALCAREOUS	X	SILTY SAND
O	ORGANIC	Y	CLAYEY GRAVEL
P	POORLY SORTED	Z	OTHER
Q	CHERTY OR SILICEOUS		
R	REDBED		
S	SOFT		
T	"SALT AND PEPPER"		
U	UNCONSOLIDATED		
V	SEMICONSOLIDATED		
W	WELL SORTED		
X	CROSS BEDDED		
Y	SHALY OR SLATY		
Z	WEATHERED		

WATER LEVEL: LEVELS ARE GIVEN IN FEET BELOW LAND SURFACE; "+" INDICATES WATER LEVEL ABOVE LAND SURFACE; "F" INDICATES FLOWING WELL.

WATER USE: A, AIR CONDITIONING; B, BOTTLING; C, COMMERCIAL; D, DEWATERING; E, POWER GENERATION; F, FIRE PROTECTION; H, DOMESTIC; I, IRRIGATION; M, MEDICINAL; N, INDUSTRIAL (INCLUDES MINING); P, PUBLIC SUPPLY; R, RECREATION; S, STOCK; T, INSTITUTIONAL; U, UNUSED; V, REPRESSURIZATION; W, RECHARGE; X, DESALINATION--PUBLIC SUPPLIES; Y, DESALINATION--OTHER SUPPLIES.

PUMPAGE/YIELD: IN GALLONS PER MINUTE (GAL/MIN).

PUMPAGE/DRAWDOWN: THE DIFFERENCE BETWEEN STATIC WATER LEVEL AND PUMPING LEVEL.

PUMPAGE/TIME: THE FOLLOWING CODES ARE USED FOR PUMPING PERIODS OF LESS THAN 1 HOUR: A, THROUGH 15 MINUTES; B, 16 TO 30 MINUTES; C, 31 TO 45 MINUTES; D, 46 TO 59 MINUTES.

LOG: D, DRILLER'S LOG; E, ELECTRIC LOG; G, GEOLOGIST'S LOG (LOG AVAILABLE IN TABLE 7).

QW: TYPE OF CHEMICAL ANALYSIS AVAILABLE IN TABLE 4, C, COMPLETE; J, CONDUCTANCE AND CHLORIDE; K, CONDUCTANCE; L, CHLORIDE; M, MULTIPLE (INCLUDES ONE COMPLETE AND ONE OR MORE PARTIAL); P, PARTIAL.

TABLE 6.--DESCRIPTION OF SELECTED WELLS, TEST WELLS, AND BORINGS -- CONTINUED

LOCAL WELL NUMBER	LATITUDE-LONGITUDE	ALTITUDE OF LSD (FT)	OWNER OR USER	YEAR/	METHOD DRILLED	WELL: DIAMETER (IN)	WELL: FINISH	WELL: DEPTH (FT)	WELL: USE	FEET TO BEDROCK	WATER-BEARING MATERIAL	WATER: LEVEL (FT)	WATER: DATE MEASURED	WATER: USE	PUMPAGE: YIELD (GPM)	PUMPAGE: DD (FT)	PUMPAGE: TIME (HR)	LOG	QW
CABOT																			
W 1	442437N0721815.1	1210	CABOT TOWN	1949	C	3	X	225	W	--	--	F	--	P	--	--	--	-	-
W 2	442402N0721850.1	970	CABOT CREAMERY	1938	C	8	X	320	W	15	QL	F	--	N	150	50	--	-	-
W 3	442402N0721850.2	950	CABOT CREAMERY	1960	-	6	X	300	U	5	QL	--	--	U	--	--	--	-	-
W 4	442400N0721851.1	1020	CABOT CREAMERY	1960	-	6	X	200	W	--	QL	--	--	N	15	--	--	-	-
W 5	442337N0721954.1	940	MORSE CECIL	1965	D	36	W	6	W	--	2S	2	11-66	H	5	--	--	D*	-
W 6	442336N0721950.1	930	BRIMBLECOMBE R	1958	C	6	X	124	W	--	QL	12	--	H	3	--	--	-	-
W 7	442214N0722019.1	910	BEAN GERALD	1973	P	6	O	61	W	--	G	21	8-73	H	6	--	--	D	-
W 8	442327N0721955.1	950	BICKFORD A E	1972	P	7	X	255	W	13	--	20	11-72	H	2	--	--	-	-
W 9	442335N0721957.1	940	LAMPHERE HAROLD	1973	P	6	X	122	W	35	--	--	--	H	3	--	--	D*	-
W 10	442330N0721956.1	945	MORSE CECIL	1968	P	6	X	209	W	6	--	8	4-68	C	12	--	--	D	-
W 11	442325N0722003.1	940	CARPENTER HAZEL	1968	P	6	X	169	W	6	--	23	4-68	H	25	--	--	-	-
W 12	442334N0721927.1	1110	PISTONE LEON	1970	P	6	X	262	W	17	--	40	10-70	H	2	--	--	D	-
W 13	442351N0721857.1	1180	CABOT CREAMERY	1970	P	6	X	342	W	20	--	F	8-70	N	33	--	1	D	-
W 14	442401N0721342.1	1620	SVEL GEORGE	1971	P	6	X	245	W	6	--	135	6-71	H	2	--	--	D	-
W 15	442453N0721358.1	1660	INCARNATION D	1972	P	6	X	185	W	31	--	20	1-72	H	6	--	--	D	-
W 16	442638N0721824.1	1460	PIKE PHILLIP	1971	P	6	X	115	W	5	--	15	2-71	H	10	--	--	D	-
W 17	442615N0721810.1	1360	SEARLES ROBERT	1968	P	6	X	164	W	6	--	--	--	H	1	--	--	D	-
W 18	442455N0722055.1	1280	CHATEN E W	1972	P	6	X	202	W	9	--	--	--	H	1	--	1	D	-
W 19	442427N0722004.1	1360	BOTHFIELD T	1972	P	6	X	223	W	8	--	--	--	H	3	--	1	-	-
W 20	442349N0721713.1	1720	BURMINGHAM W E	1972	P	6	X	162	W	9	--	8	10-72	H	12	--	1	D	-
W 21	442435N0721848.1	1080	US GEOL SURVEY	1973	W	1	T	36	T	--	R	2	7-73	U	25	--	2	DG*	P
W 22	442312N0722005.1	920	MIDDLETON DAVID	1972	P	6	X	121	W	55	--	6	10-72	H	7	--	1	D	-
W 23	442420N0721800.1	1280	CABOT TOWN	1968	P	6	X	295	W	8	--	F	6-68	P	300	--	--	D	P
CALAIS																			
W 1	441830N0722630.1	730	BARTLETT OTTO	1949	C	8	S	150	W	--	--	10	-49	H	83	--	--	-	-
W 2	441912N0722650.1	770	COTEY PAUL	1966	P	6	X	150	W	--	--	--	--	H	5	--	--	-	-
W 3	441836N0722648.1	730	EATON ELIZABETH	1950	C	6	X	128	W	--	--	--	--	H	--	--	--	-	-
W 4	441834N0722653.1	750	FARNSWORTH EARL	1964	H	6	O	25	W	25	--	--	--	H	--	--	--	-	-
W 5	441847N0722652.1	780	ABBOTT MILTON	1963	H	6	O	30	W	--	--	10	-63	H	4	--	--	-	-
W 6	442042N0723057.1	1270	LANE BRADFORD	1967	P	6	X	37	W	1	--	18	4-67	S	25	--	2	-	-
W 7	442238N0722514.1	880	US GEOL SURVEY	1973	W	1	T	95	T	--	R	16	7-73	U	12	--	--	DG*	-
W 8	442645N0721904.1	780	CAMPBELL C	1970	P	6	X	140	W	39	--	30	7-70	H	6	--	8	-	-
W 9	441912N0722710.1	860	CALAIS ELEM SCH	1970	P	6	X	190	W	20	--	15	5-70	T	12	--	2	D	-
W 10	441912N0722710.2	860	CALAIS ELEM SCH	1970	P	6	X	205	W	16	--	7	5-70	T	4	--	2	D	-
W 11	442012N0722647.1	780	COAN NILES	1968	P	6	X	182	W	150	--	30	10-68	H	20	--	1	D*	-
W 12	442018N0722647.1	760	COFFRIN JOHN	1972	P	6	X	130	W	100	--	12	5-72	H	20	--	1	D	-
W 13	442044N0722737.1	740	COLE VIRGINIA	1968	P	6	X	250	W	49	--	0	10-68	H	100	--	2	D	-
W 14	442053N0722755.1	800	MURELL FORREST	1970	P	6	X	210	W	65	--	10	6-70	H	4	--	8	D	-
W 15	442243N0722415.1	1360	FRANKLIN DAVID	1970	P	7	X	218	W	50	--	4	7-70	H	1	--	8	D	-
W 16	442244N0722510.1	880	ELDRED OWEN	1970	P	6	O	81	W	--	G	5	10-70	H	60	--	1	D	-
W 17	442328N0722640.1	1060	DAILEY & BRYANT	1970	P	6	X	260	W	30	--	32	7-70	H	1.8	--	1	D	-
W 18	442012N0722914.1	1280	HOLMQUEST	1973	-	6	X	340	W	21	--	12	8-73	H	8	--	8	D	-
W 19	442129N0722837.1	940.	STOWELL JUNE	1971	P	7	X	255	W	6	--	10	11-71	H	2	--	1	D	-
W 20	442155N0722843.1	900	CHESAUX OLIVIER	1969	P	6	X	160	W	70	--	40	11-69	H	2	--	1	D	-
W 21	442144N0722929.1	1190	OHMEN PAUL	1968	P	6	X	220	W	6	--	45	5-68	H	1.5	--	--	D	-
W 22	442058N0722951.1	1260	SCHOFF CHARLES	1973	P	6	X	116	W	10	--	6	6-73	H	6	--	1	D	-
W 23	442100N0722958.1	1240	BUELL HAROLD L	1973	P	7	X	165	W	6	--	20	9-73	H	3	--	1	D	-
W 24	442003N0722900.1	1200	RUDIN ANDREW	1968	P	6	X	21	W	6	--	5	11-68	H	12	--	1	D	-
W 25	442003N0722900.2	1200	COPELAND W	1972	P	6	X	200	W	3	--	--	--	H	1	--	1	D	-
W 26	442003N0722900.3	1200	WINSTON JOHN	1973	-	6	X	123	W	2	--	10	6-73	H	6	--	1	D	-
W 27	442213N0722953.1	1300	PURCHASE R	1973	P	6	X	130	W	4	--	15	11-73	H	8	--	2	D	-
W 28	442230N0722944.1	1200	MAPLE CORNER ST	1973	P	7	X	100	W	6	--	7	7-73	H	7	--	1	D	-
W 29	442245N0722930.1	1290	BETZ EDWARD	1970	P	6	X	160	W	3	--	10	7-70	H	6	--	1	D	-
W 30	442258N0722922.1	1280	MORSE EVA	1969	P	6	X	100	W	4	--	15	11-69	H	5	--	2	D	P
W 31	442310N0722933.1	1280	DICKENSON E	1970	P	6	X	250	W	40	--	2	7-70	H	3	--	1	D	-
W 32	441943N0723001.1	1080	SLAYTON ELGIN	1969	P	6	X	70	W	9	--	9	10-69	H	30	--	A	D	-
W 33	441949N0723013.1	1080	SUCHOMEL FRANK	1973	P	6	X	125	W	4	--	10	6-73	H	8	--	2	D	-
W 34	441948N0723017.1	1080	ADAMENT MUS SCH	1970	P	6	X	62	W	4	--	--	--	T	9	--	1	D	-
W 35	442027N0723037.1	1170	SCOTT ROBERT	1971	P	7	X	160	W	8	--	10	9-71	H	2	--	1	D	-
W 36	442039N0723105.1	1270	LANE CLAIR	1973	P	6	X	90	W	10	--	15	6-73	H	10	--	8	D	-
W 37	442126N0723115.1	1550	CHERRINGTON J	1972	P	6	X	75	W	7	--	12	5-72	H	7	--	1	D	-
W 38	442202N0723047.1	1480	MCBRIDE ALBERT	1974	P	6	X	100	W	6	--	12	3-74	H	8	--	8	D	-
W 39	442242N0723023.1	1390	CHERRINGTON J	1974	P	6	X	55	W	3	--	--	--	H	50	--	8	D	-
W 40	442104N0723017.1	1230	LENO PHILIP	1972	P	6	X	142	W	0	--	--	--	H	8	--	--	D	-
W 41	442104N0723012.1	1220	LAFOUNTAIN C	1968	P	6	X	130	W	6	--	--	--	H	2	--	2	D	-
W 42	442246N0723008.1	1360	BROWNELL J	1968	P	6	X	127	W	4	--	10	2-68	H	8	--	--	D	-
W 43	442231N0723003.1	1220	DEFORGE DONALD	1973	P	7	X	205	W	100	--	8	7-73	H	15	--	1	D	-
W 44	442113N0723123.1	1620	LEVIN HERBERT	1971	P	7	X	230	W	9	--	10	7-71	H	5	--	8	D	-
W 45	442310N0722513.1	940	CALAIS TOWN	1975	P	6	O	76	W	--	R	--	--	H	12	--	1	D*	-
W 46	442151N0722428.1	1300	STUKE HERBERT L	1968	P	6	X	192	W	6	--	--	--	H	60	--	1	D	-
W 47	442322N0722647.1	1020	HATES WILLIAM	1975	P	6	X	198	W	7	--	--	--	H	2	--	1	D	-
W 48	442655N0722407.1	1170	SMITH ROGER	1973	-	6	X	182	W	4	--	20	9-73	H	6	--	1	D	-
W 49	442651N0722106.1	900	LEONARD RUDOLPH	1969	P	7	X	210	W	19	--	35	6-69	H	3	--	2	D	-
W 50	442134N0723130.1	1650	RUSSELL WILLIAM	1974	P	6	X	190	W	9	--	14	7-74	H	4	--	8	D	P

TABLE 6.--DESCRIPTION OF SELECTED WELLS, TEST WELLS, AND BORINGS -- CONTINUED

LOCAL WELL NUMBER	LATITUDE-LONGITUDE	ALTITUDE OF LSD (FT)	OWNER OR USER	YEAR/ DRILLED	METHOD	WELL: DIAMETER (IN)	WELL: FINISH	WELL: DEPTH (FT)	WELL: USE	FEET TO BEDROCK	WATER-BEARING MATERIAL	WATER: LEVEL (FT)	WATER: DATE MEASURED	WATER: USE	PUMPAGE: YIELD (GPM)	PUMPAGE: DD (FT)	PUMPAGE: TIME (HR)	LOG	QW
			CALAIS --CONTINUED																
W 51	442235N0722947.1	1220	SMITH GERALD D	1974	P	6	X	149	W	8	--	--	--	H	8	--	1	D	-
W 52	442217N0722620.1	900	SILBERMAN R	1972	H	9	X	275	Z	--	--	--	--	H	--	--	--	D	-
X 1	441905N0722626.1	720	US GEOL SURVEY	1973	W	2	X	115	T	--	--	--	--	U	--	--	--	DG*	-
X 2	442215N0722925.1	1150	US GEOL SURVEY	1974	W	2	X	15	T	--	--	--	--	U	--	--	--	DG*	-
X 3	442235N0723006.1	1220	US GEOL SURVEY	1974	W	2	X	31	T	--	--	--	--	U	--	--	--	DG*	-
			MARSHFIELD																
W 1	441824N0722401.1	880	HAWES J S	1958	C	8	X	194	W	5	--	15	--	C	15	--	--	-	-
W 2	441919N0722254.1	810	KIMBALL CHANDLR	--	-	6	X	210	W	100	--	--	--	C	35	--	--	-	-
W 3	441952N0722352.1	1340	PITKIN BELMONT	1946	C	6	X	105	W	10	--	--	--	H	--	--	--	-	-
W 4	442001N0722409.1	1325	PITKIN RONALD	1961	P	5	X	140	W	6	--	25	--	H	2	--	--	-	-
W 5	441948N0722238.1	790	ROBERTS RAYMOND	1964	C	8	X	150	W	98	--	25	--	H	1.5	--	--	-	-
W 6	441945N0722240.1	790	CHURCH R C	1965	A	6	O	87	W	--	--	20	-65	H	20	--	--	D*	-
W 7	441818N0722402.1	880	WELCH JOHN	1961	P	6	X	430	W	--	--	5	--	H	1.5	--	--	-	-
W 8	441633N0722213.1	1330	WILLARD	1964	-	6	X	120	W	20	--	--	--	H	20	--	--	-	-
W 11	441719N0722434.1	755	NELSON DRIVE IN	1972	P	6	X	350	W	10	MH	--	--	C	1.5	--	1	D	-
W 12	441802N0722345.1	870	US GEOL SURVEY	1973	W	1	T	47	T	--	R	3	7-73	U	--	--	2	DG*	-
W 13	442218N0722300.1	1460	ENNIS LEELAND	1971	P	7	X	175	W	3	--	30	3-71	H	12	--	2	D	-
W 14	442205N0722245.1	1320	OATLEY ROBERT	1971	P	7	X	250	W	0	--	2	4-71	H	1	--	1	D	-
W 15	442105N0722326.1	1260	BROWN LEON	1968	P	6	X	125	W	4	--	28	5-68	H	30	--	1	D	-
W 16	442100N0722223.1	1280	HEALEY JERI	1966	P	6	X	100	W	15	--	--	--	H	3	--	8	D	-
W 17	442015N0722447.1	1400	MOULTON WILLIAM	1973	P	6	X	148	W	3	--	--	--	H	2	--	1	D	-
W 18	442020N0722423.1	1300	CODLING ROBERT	1969	P	6	X	100	W	15	--	10	8-69	H	1.5	--	1	D	-
W 19	442016N0722405.1	1260	HIGGS ALAN	1970	P	7	X	195	W	46	--	50	11-70	H	25	--	1	D	-
W 20	442009N0722410.1	1320	PITKIN ROYCE	1968	P	6	X	300	W	8	--	50	7-68	H	0.5	--	--	D	-
W 21	442015N0722226.1	780	BRIMBLECOMBE S	1969	P	6	X	114	W	10	--	8	10-69	H	--	--	--	D	-
W 22	441950N0722244.1	800	BURNHAM	1970	P	6	X	100	W	69	--	15	10-70	H	20	--	2	D	-
W 23	441954N0722239.1	800	POWERS KENNETH	1969	P	6	X	100	W	10	--	10	6-69	H	30	--	1	D	-
W 24	441901N0722525.1	1230	WHITCOMB MAHLON	1972	P	6	X	175	W	8	--	15	9-72	H	5	--	2	D	-
W 25	441842N0722522.1	1180	FOWLER FRED	1969	P	6	X	220	W	8	--	--	--	H	6	--	--	D	-
W 26	442050N0721807.1	1480	CHAMBERLAIN C	1969	P	6	X	225	W	20	--	20	7-69	H	1	--	A	D	-
W 27	442058N0721807.1	1460	CHAMBERLAIN B	1969	P	6	X	180	W	30	--	12	6-69	H	5	--	8	D	-
W 28	442016N0721715.1	1620	MORSE CECIL	1972	P	6	O	41	W	--	R	--	--	H	4	--	1	D	-
W 29	441936N0721725.1	1750	CAMPBELL R	1970	P	6	X	150	W	25	--	40	-70	H	1	--	8	D	-
W 30	441749N0722505.1	1060	NUNZIOTO R	1973	P	7	X	315	W	17	--	F	8-73	H	7	--	1	D	-
W 31	441742N0722511.1	1000	LOSO LARRY	1968	P	7	X	255	W	40	--	20	5-68	H	1	--	2	D	-
W 32	441750N0722422.1	940	JOHNSON MARTIN	1973	P	6	X	220	W	18	--	15	11-73	H	4	--	2	D	-
W 33	441753N0722349.1	800	TWINFIELD H S	1969	P	6	X	450	W	158	--	--	--	T	15	--	--	D	-
W 34	441800N0722317.1	920	SCHROTH RICHARD	1968	P	6	X	142	W	60	--	--	--	H	5	--	2	D	-
W 35	441800N0722304.1	960	BLACKBURN GREGG	1968	P	6	O	63	W	--	R	15	10-68	H	4	--	2	D*	-
W 36	441750N0722303.1	1000	JACOBSEN ERLEND	1969	P	6	O	81	W	--	R	40	9-69	H	20	--	2	D*	-
W 37	441747N0722246.1	1040	PEARSON JAMES	1972	P	6	X	151	W	100	--	--	--	H	5	--	1	D	-
W 38	441705N0722236.1	1200	DAVIS NEIL	1973	P	6	O	54	W	--	G	6	6-73	H	8	--	1	D*	-
W 39	441655N0722204.1	1380	HORTON THORSTEN	1968	-	6	X	63	W	15	--	--	--	H	4	--	1	D	-
W 40	441637N0722216.1	1320	NELSON PAUL	1968	P	6	O	32	W	--	G	--	--	H	9	--	2	D*	-
W 41	441547N0722215.1	1410	BOISSE HENRY A	1969	P	6	O	54	W	--	2G	--	--	H	20	--	--	D*	-
W 42	441740N0722350.1	760	BROWN STANLEY	1970	P	6	X	275	W	87	--	F	7-70	C	6	--	2	D	-
W 43	441710N0722452.1	760	ORTON EDWIN L	1970	P	6	X	160	W	70	--	1	7-70	H	6	--	--	D	-
W 44	441633N0722430.1	1180	BATES EVELYN	1968	P	6	X	160	W	8	--	6	7-68	H	4	--	--	D	-
W 45	442142N0722210.1	1260	LINDNER DANIEL	--	-	6	X	125	W	--	--	--	--	H	--	--	--	-	P
W 46	441615N0722201.1	1420	FRANKS ROBERT	1970	P	6	X	225	W	198	--	30	4-70	H	30	--	--	D	-
W 48	441857N0722527.1	1200	RABIN JULES	--	-	6	X	165	W	--	--	--	--	H	--	--	--	D	P
X 1	442126N0721950.1	1060	US GEOL SURVEY	1974	W	2	X	44	T	--	--	--	--	U	--	--	--	DG*	-
			WOODBURY																
W 1	442402N0722452.1	935	BEAUCHAMP L C	1941	D	48	W	12	W	--	--	7	--	H	5	3	8	-	-
W 2	442456N0722524.1	1040	US GEOL SURVEY	1973	W	1	T	30	T	--	3R	5	7-73	U	90	--	2	DG*	
W 3	442602N0722746.1	1175	US GEOL SURVEY	1973	W	1	T	35	T	--	R	3	7-73	U	30	--	3	DG*	
W 4	442620N0722458.1	1260	US GEOL SURVEY	1974	W	1	T	25	T	--	R	3	6-74	U	10	--	--	DG*	-
W 5	442421N0722220.1	1480	BILLINGHAM D	1968	P	6	X	180	W	25	--	--	--	H	30	--	1	D	-
W 6	442421N0722439.1	1140	TUCKER ELWIN	1968	P	6	O	51	W	--	R	14	4-68	H	15	--	1	D*	-
W 7	442420N0722614.1	1180	OSIER RICHARD	1973	-	6	X	325	W	--	--	--	--	H	15	--	--	-	-
W 8	442503N0722736.1	1200	VOZZELLA M	1970	P	6	X	160	W	10	--	5	8-70	H	4	--	--	D	-
W 9	442618N0722424.1	1360	LENARD ROY A	1973	-	6	X	90	W	18	--	12	10-73	H	10	--	1	D	-
W 10	442625N0722456.1	1180	COOKSON & HATCH	1968	P	7	X	150	W	21	--	15	5-68	H	10	--	1	D	-
W 11	442800N0722429.1	1140	SELIGA D	1973	P	6	O	155	W	--	R	--	--	H	30	--	1	D*	-
W 12	442830N0722345.1	920	FLETCHER HOWARD	1973	-	6	O	48	W	--	R	20	10-73	H	15	--	1	D*	-
W 13	442749N0722418.1	1480	VT FISH & GAME	1975	P	6	X	185	W	7	--	90	5-75	T	15	--	1	D	-
W 14	442630N0722644.1	1260	GALLAGHER JOHN	1969	P	6	X	130	W	30	--	--	--	H	4	--	--	D	-
W 15	442933N0722530.1	1440	WILLIAMS G	1969	P	6	X	247	W	24	--	--	--	H	30	--	--	D	-
W 16	442933N0722521.1	1440	WILLIAMS JOE	1974	P	6	X	130	W	50	--	--	--	H	10	--	1	D	-
W 17	442858N0722621.1	1480	COURCHAINE F	1973	-	6	X	101	W	17	--	18	9-73	H	4	--	1	D	-
W 18	442737N0722504.1	1220	POTVIAN BRADLEY	1973	P	7	X	180	W	36	--	15	6-73	H	6	--	1	D	-
W 19	442700N0722500.1	1240	MCCOY ALICE D	1973	-	6	X	185	W	20	--	--	--	H	15	--	--	D	-
W 20	442523N0722135.1	1370	RODWIN LLOYD	1974	P	6	X	173	W	24	--	16	8-74	H	10	--	1	D	-

TABLE 6.--DESCRIPTION OF SELECTED WELLS, TEST WELLS, AND BORINGS -- CONTINUED

LOCAL WELL NUMBER	LATITUDE-LONGITUDE	ALTITUDE OF LSD (FT)	OWNER OR USER	YEAR/	METHOD DRILLED	WELL: DIAMETER (IN)	WELL: FINISH	WELL: DEPTH (FT)	WELL: USE	FEET TO BEDROCK	WATER-BEARING MATERIAL	WATER: LEVEL (FT)	WATER: DATE MEASURED	WATER: USE	PUMPAGE: YIELD (GPM)	PUMPAGE: DD (FT)	PUMPAGE: TIME (HR)	LOG	QW
			WOODBURY --CONTINUED																
W 21	442611N0722530.1	1340	SILK MERTON	1972	P	6	X	247	W	15	--	--	--	H	1	--	--	D	-
W 22	442610N0722540.1	1350	RUDIN ANDY	1973	-	6	X	182	W	4	--	12	10-73	H	4	--	1	D	-
W 23	442500N0722448.1	1080	LAMPHERE C	1971	P	6	X	230	W	7	--	--	--	H	3	--	--	D	-
X 1	442600N0722742.1	1175	US GEOL SURVEY	1975	W	2	X	20	T	--	--	--	--	U	--	--	--	DG*	-
X 2	442710N0722516.1	1190	US GEOL SURVEY	1973	W	2	X	21	T	--	--	--	--	U	--	--	--	DG*	-
X 3	442710N0722516.2	1190	US GEOL SURVEY	1973	W	2	X	8	T	--	--	--	--	U	--	--	--	DG*	-
			WORCESTER																
W 1	442205N0723307.1	750	US GEOL SURVEY	1973	W	1	T	63	T	--	R	+2	8-73	U	45	--	2	DG*	P
W 2	442230N0723258.1	740	US GEOL SURVEY	1973	W	1	T	135	T	136	4R	19	6-73	U	1	--	9	DG*	-
W 3	442102N0723331.1	760	LAMOUNTAIN W JR	1970	P	6	X	201	W	12	--	12	5-70	H	6	--	1	D	P
W 4	442103N0723340.1	710	MALLERY JOHN	1970	P	6	X	242	W	35	--	8	9-70	H	1	--	1	D	-
W 5	442131N0723251.1	1110	DODGE RICHIE	1971	P	6	X	125	W	5	--	--	--	H	5	--	--	D	-
W 6	442156N0723231.1	1070	MARTIN RUDOLPH	1967	P	6	X	156	W	14	--	4	3-67	H	4	--	3	D	-
W 7	442154N0723230.1	1080	DODGE HARRY	1971	P	6	X	215	W	40	--	40	10-71	H	2	--	--	D	-
W 8	442159N0723232.1	1020	WELCH SCOTT	1968	P	6	X	126	W	12	--	3	2-68	H	1.5	--	2	D	-
W 9	442206N0723233.1	920	PERRY LAWRENCE	1968	P	6	X	101	W	8	--	10	9-68	H	3	--	1	D	P
W 10	442147N0723350.1	750	STEFFEN OTTO H	1969	P	6	X	500	U	39	--	--	--	H	Z	--	2	D	-
W 11	442147N0723350.2	750	STEFFEN OTTO H	1969	P	6	X	295	U	65	--	--	--	H	Z	--	2	D	-
W 12	442142N0723340.1	690	NELSON JERRY	1974	P	6	O	61	W	--	R	7	10-74	H	50	--	1	D*	-
W 13	442227N0723308.1	790	RICHARDSON W	1971	P	6	X	182	W	16	--	24	3-71	H	12	--	1	D	-
W 14	442231N0723314.1	780	MAXHAM SUPPLY	1973	P	6	X	121	W	45	--	F	3-73	N	30	--	1	D	-
W 15	442232N0723233.1	780	DODGE SHELDON S	1968	P	6	O	102	W	--	R	4	5-68	H	20	--	4	D*	-
W 16	442232N0723233.2	780	DAY DAVID	1974	P	6	X	149	W	125	--	15	6-74	H	6	--	1	D	-
W 17	442237N0723234.1	760	HEARTHSIDE ENT.	1972	P	6	X	202	W	85	--	4	9-72	H	20	--	1	D	-
W 18	442241N0723235.1	770	MAXHAM DAVID	1969	P	6	X	162	W	12	--	0	1-69	H	6	--	1	D	-
W 19	442300N0723138.1	1020	IDOL	1968	P	6	X	190	W	95	--	15	6-68	H	10	--	2	D	-
W 20	442317N0723219.1	840	BEAUREGARD R G	1968	P	6	X	202	W	10	--	4	8-68	H	6	--	2	D	-
W 21	442403N0723138.1	1100	WILDER DARWIN	1970	P	6	X	122	W	2	--	F	8-70	H	20	--	1	-	-
W 22	442403N0723138.2	1100	WILDER WAYNE	1974	P	6	X	90	W	10	--	--	--	H	25	--	1	D	-
W 23	442405N0723140.1	1080	WILDER RAYMOND	1970	P	6	X	142	W	2	--	6	8-70	H	3	--	1	D	-
W 24	442408N0723138.1	1080	LONSKE RONALD	1970	P	6	X	145	W	8	--	10	7-70	H	20	--	2	D	-
W 25	442552N0723207.1	930	DODGE HEATH	1967	P	6	X	115	W	30	--	--	--	H	25	--	8	D	-
W 26	442418N0723309.1	840	NOVAK JOHN C	1971	P	6	X	134	W	45	--	50	6-71	H	20	--	1	D	-
W 27	442359N0723309.1	820	LEE NEWTON JR	1971	P	6	X	141	W	4	--	--	--	H	20	--	1	D	-
W 28	442257N0723312.1	780	RICHARDSON W	1967	P	6	X	35	W	7	--	35	10-67	H	9	--	2	D	-
W 29	442250N0723355.1	900	HODGES ARTHUR L	1970	P	6	X	89	W	2	--	12	11-70	H	6	--	1	D	P
W 30	442305N0723406.1	940	MORSE ROBERT	1968	P	6	X	82	W	16	--	6	9-68	H	50	--	1	D	-
W 31	442529N0723348.1	1240	WINTER	1972	P	6	X	225	W	50	--	--	--	H	1.5	--	8	D	-
W 32	442522N0723409.1	1400	BARRETT JAMES	1968	P	6	X	100	W	23	--	15	7-68	H	7	--	2	D	-
W 33	442358N0723423.1	1240	COURCHAINE P	1972	P	6	X	61	W	20	--	F	11-72	H	4	--	1	D	-
W 34	442319N0723423.1	1080	SWEETSER CLYDE	1973	P	6	X	180	W	17	--	20	8-73	H	2	--	1	D	-
W 35	442322N0723423.1	1100	HOVEY WILLARD	1973	P	6	X	215	W	15	--	70	8-73	H	20	--	1	D	-
W 36	442340N0723515.1	1160	SMITH FAY	1969	P	6	X	150	W	22	--	--	--	H	3	--	--	D	-
W 37	442337N0723512.1	1130	IRWIN MARTIN	1971	-	6	X	130	W	49	--	20	11-71	H	2	--	1	D	P
W 38	442407N0723531.1	1420	MARTIN HOWARD	1971	P	6	X	102	W	12	--	5	7-71	H	4	--	1	D	-
W 39	442309N0723418.1	950	DUHUCE JOSEPH	1971	P	6	X	52	W	30	--	F	10-71	H	15	--	1	D	-
W 40	442254N0723427.1	1170	FRAZIER DOUGLAS	1972	P	6	X	130	W	3	--	4	8-72	H	6	--	1	D	-
W 41	442251N0723427.1	1140	NELSON JERRY	1973	P	6	X	63	W	25	--	F	9-73	H	8	--	1	D	-
W 42	442243N0723422.1	1160	FRAZIER KENNETH	1972	P	6	X	122	W	3	--	3	9-72	H	3	--	1	D	-
W 43	442311N0723513.1	1340	NYBERG JOE	1968	P	6	X	220	W	1	--	--	--	H	1	--	2	D	-
W 44	442306N0723517.1	1420	BLOCK JOHN	1972	P	6	X	241	W	0	--	F	6-72	H	1	--	1	D	-
W 45	442253N0723556.1	1440	HULTS WILLIAM	1970	P	6	X	82	W	17	--	8	5-70	H	6	--	1	D	-
W 46	442246N0723543.1	1420	HULL DOUGLAS	1968	P	7	X	210	W	18	--	10	5-68	H	1	--	1	D	-
W 47	442244N0723538.1	1430	MARDEN FORD	1971	P	6	X	62	W	18	--	--	--	H	10	--	1	D	-
W 48	442246N0723534.1	1430	WOOTERS FRED	1971	P	6	X	122	W	10	--	--	--	H	6	--	1	D	-
W 49	442219N0723242.1	740	MAXHAM DAVID	1964	-	6	O	118	W	118	--	60	--	P	26	--	--	D	P
W 50	442253N0723306.1	770	J J SNACK BAR	--	-	6	-	82	W	--	--	--	--	C	--	--	--	-	P
W 51	442257N0723419.1	1150	GREEN JAMES	1975	-	6	X	140	W	32	--	--	--	H	5	--	--	D	-
X 1	442233N0723305.1	750	US GEOL SURVEY	1973	W	2	X	21	T	--	--	--	--	U	--	--	--	DG*	-
X 2	442233N0723305.2	750	US GEOL SURVEY	1973	W	2	X	19	T	--	--	--	--	U	--	--	--	DG*	-
X 3	442304N0723304.1	740	US GEOL SURVEY	1974	W	2	X	32	T	--	--	--	--	U	--	--	--	DG*	-
X 4	442301N0723258.1	730	US GEOL SURVEY	1974	W	2	X	70	T	--	--	--	--	U	--	--	--	DG*	-
X 5	442303N0723258.1	730	US GEOL SURVEY	1974	W	2	X	25	T	--	--	--	--	U	--	--	--	DG*	-
X 6	442203N0723319.1	750	US GEOL SURVEY	1974	W	2	X	87	T	--	--	--	--	U	--	--	--	DG*	-
X 7	442219N0723242.1	740	US GEOL SURVEY	1974	W	2	X	21	T	--	--	--	--	U	--	--	--	DG*	-
X 8	442240N0723302.1	770	US GEOL SURVEY	1974	W	2	X	62	T	--	--	--	--	U	--	--	--	DG*	-

Table 7.--Drillers' logs of selected wells and borings
(Depths are given in feet below land surface.)

	Depth
CABOT W5.	
Clay, dry	0 - 6
Sand, fine, saturated	6 - 8
CABOT W9.	
Gravel, and dirt	0 - 10
Hardpan (till?)	10 - 35
Rock, green	35 - 122
CABOT W21.	
Sand; gravel; some brown clay balls	0 - 21
Sand, medium to coarse; gravel	21 - 26
Gravel, fine to medium; some coarse sand	26 - 36
Silt, gray; and very fine sand	36 - 37
Sand, dark gray; and gravel; some clay; cobbles	37 - 42.5
Boulder or bedrock	42.5 - 45.1
CALAIS W7.	
Sand, fine, brown, and very fine sand; silt; some gravel	0 - 15.1
Sand, fine, brown, and very fine sand; silt; trace of gravel some cementing of sand	15.1 - 21.2
Sand, fine, brown; very fine sand; silt (increasing with depth)	21.2 - 37.4
Sand, fine, brown; very fine sand; silt; with cemented layer	37.4 - 44.5
Sand, medium, some fine sand, some coarse sand to fine gravel	44.5 - 59.5
Gravel, fine to medium, dark in color; some fine to medium sand; broken, coarse gravel	59.5 - 65
Sand, coarse; coarse gravel; some fine to medium sand	65 - 73
Sand, fine, gray	73 - 78
Gravel, fine; and brown sand	78 - 84
Clay, gray; and fine, sharp gravel (till?); takes water rapidly at 95 feet	84 - 95.5
Silt; medium to coarse sand; gravel	95.5 - 100.7
Sand, medium to coarse, gray, sharp; gray wash water; alternately takes all water	100.7 - 110.2
Sand, fine to medium, gray to green; fine, white, quartz sand	110.2 - 115
Sand, fine to medium, gray; some clay; takes most wash water	115 - 127.4
Sand, fine to medium, gray; some clay; coarse, gray sand	127.4 - 132.7
Sand, coarse, gray; and fine, sharp gravel; some fine, gray sand; gray wash water	132.7 - 138
Sand, fine, gray; and coarse, gray sand; medium gravel; gray wash water	138 - 143.3
Sand, fine, gray; and medium gravel; sand increases with depth, grains sharp and angular	143.3 - 149.4
Sand, fine to coarse, gray; some fine gravel; takes wash water readily	149.4 - 159.9
Sand, very fine to medium, gray, brown flecks, sharp grains	159.9 - 165.3
Sand, fine to coarse, gray; fine sand increases with depth, takes water readily	165.3 - 170.6
Sand, medium to coarse	170.6 - 176.3
Sand, fine to medium, gray, could not penetrate further	176.3 - 191.6
CALAIS W16.	
Gravel, and clay	0 - 8
Sand and clay	8 - 70
Gravel	70 - 81
CALAIS W45.	
Sand	0 - 70
Gravel	70 - 76
CALAIS X1.	
Sand, fine to medium, yellow-brown; minor gravel	0 - 15.0
Sand, very fine to fine, clayey to silty, gray; some fine to medium, yellow-brown sand with gravel (probably from 0 to 15 ft zone)	15.0 - 19.8
CALAIS X1 (Cont.).	
Silt, gray; minor, very fine to fine sand	19.8 - 24.4
Clay, gray; silt; very fine sand.	24.4 - 39.6
Silt and clay, gray	39.6 - 45.9
Silt, clay, gray; minor very fine sand .	45.9 - 51.2
Clay, gray; silt; very fine sand.	51.2 - 61.5
Sand, very fine, gray; silt; some clay	61.5 - 68.0
Silt, gray; very fine sand; some clay	68.0 - 78.1
Silt, gray; very fine sand; clay.	78.1 - 83.3
Silt; very fine sand; trace of gray clay; sand may be increasing with depth	83.3 - 87.8
Silt; very fine sand; trace of clay; could drive casing only to 105 ft; washed ahead to 115 ft	87.8 - 115
CALAIS X2.	
Fill	0 - 3
Organic swamp deposit, gray-black	3 - 7
Boulders	7 - 8
Silt, brown; and gray clay	8 - 14
Silt, brown; gray clay; till fragments; could not penetrate further	14 - 15
CALAIS X3.	
Fill	0 - 4
Organic swamp material	4 - 5
Silt, brown; some very fine sand.	5 - 15
Silt, brown; some very fine sand; trace of pebbles	15 - 20
Silt, gray; pebbles	20 - 25
Silt, gray; clay	25 - 26
Silt, gray; small flat pebbles (concretions?)	26 - 30
Till; could not penetrate further	30 - 30.8
MARSHFIELD W6.	
Clay, blue	0 - 87
Gravel	87 - 98
MARSHFIELD W12.	
Clay; sand; gravel; topsoil; static water level at 2.0 feet below land surface	0 - 18.8
Clay, gray; sand; gravel	18.8 - 24.0
Sand, very fine, gray; silt	24.0 - 35.6
Sand, fine, gray	35.6 - 40.9
Sand, medium to coarse, gray to yellow; gravel; some silt balls; most rock fragments are broken granite	40.9 - 46.1
Till, very sandy, yellow-gray; high percentage of granitic fragments in medium to coarse sand and gravel	46.1 - 52.4
Till; broke off drill rod at 57.5 ft	52.4 - 57.5
MARSHFIELD W35.	
Sand	0 - 40
Clay	40 - 50
Gravel; sand	50 - 63
MARSHFIELD W36.	
Sand; boulders	0 - 40
Gravel, fine	40 - 81
MARSHFIELD W38.	
Boulders and gravel	0 - 54
MARSHFIELD W40.	
(Sand?)	0 - 20
Gravel	20 - 35
MARSHFIELD W41.	
Sand, fine; boulders	0 - 45
Gravel, fine	45 - 54
MARSHFIELD X1.	
Silt, gray, wet at 6 feet	0 - 8
Sand, medium to coarse; fine gravel; saturated	8 - 23
Sand, very fine to medium, gray	23 - 25
Sand, very fine to medium, gray; clay; gravel	25 - 30
Sand, very fine, gray	30 - 39
Clay; fine gravel	39 - 40
Cobbles; some sand; clay	40 - 44
Boulders; cobbles; could not penetrate further	at 44

Table 7.--Drillers' logs of selected wells and borings (Continued)
(Depths are given in feet below land surface.)

	Depth
WOODBURY W2.	
No sample; static water level at 0.5 feet below land surface....	0 - 11
Sand, fine, gray-brown; very fine sand; some silt; traces of fine gravel; coarse sand; no clay...	11 - 24
Sand, medium; coarse gravel......	24 - 25.5
Sand, medium; fine gravel; coarse sand....................	25.5 - 30
Sand, very fine to coarse; some clay; takes water readily......	30 - 31
Could not penetrate further......	at 32.4
WOODBURY W3.	
Sand, brown; fine, sharp gravel; sand fraction increasing below 16 feet...................	0 - 20.5
Gravel; fine and very fine, gray sand; (laminated?); gravel increasing at 30-31 feet.......	20.5 - 31
Sand, fine, dark gray; fine pebbles; some silt; (probably matrix around cobbles).........	31 - 34.6
Drove casing to 33.6 ft; could not penetrate further; washed ahead...................	to 34.6
WOODBURY W4.	
Sand, medium to coarse, brown; some silt; gravel; cobbles; static water level at 2.5 feet.	0 - 25
Sand, coarse; broken cobbles.....	25 - 30
Cobbles, broken, black and white; some sharp gravel.......	30 - 35
Till; could not penetrate further	35 - 39.8
WOODBURY W6.	
Gravel, fine; fine sand..........	0 - 51
Coarse gravel....................	at 51
WOODBURY W11.	
Sand.............................	0 - 80
Shale (?); gravel................	80 - 110
Sand.............................	110 - 140
Gravel...........................	140 - 157
WOODBURY W12.	
Sand.............................	0 - 30
Gravel, fine.....................	30 - 48
WOODBURY X1.	
Sand, brown; coarse gravel.......	0 - 16
Drove casing to 20.5 feet; could not penetrate further..........	at 20.5
WOODBURY X2.	
Fill, roadway; till..............	0 - 8.5
Could not penetrate further......	at 8.5
WOODBURY X3.	
Fill, roadway; boulders; till....	0 - 21.4
Could not penetrate further......	at 21.4
WORCESTER W1.	
Sand, brown; gravel..............	0 - 18
Clay, gray.......................	18 - 32.4
Clay, gray; silt; artesian flow at 37.6 feet..................	32.4 - 37.6
Silt, gray.......................	37.6 - 53
Silt, gray; sand.................	53 - 54
Gravel, fine; gray silt..........	54 - 63.4
Could not penetrate further (bedrock or boulder)...........	at 63.4
WORCESTER W2.	
Sand; gravel.....................	0 - 12
Sand, fine (muscovite flakes), grades to gray clay............	12 - 20
Clay, gray.......................	20 - 34
Sand, fine, gray; some fine gravel at top; static water level at 3.5 feet..............	34 - 41
Sand, fine gray; gray clay layers	41 - 52
Clay, gray.......................	52 - 67.5
Sand, fine.......................	67.5 - 68
Clay, gray.......................	68 - 75
Sand, fine and medium, gray; some coarse sand; static water level at 14 feet below land surface..	75 - 80
Sand, fine and medium, gray; and clay layers.....................	80 - 85
Sand, fine, clayey, gray; some coarse sand.....................	85 - 90
Sand, fine, clayey, gray; trace of gravel......................	90 - 95
Sand, fine, clayey, gray; some coarse sand; very fine gravel..	95 - 112
WORCESTER W2 (Cont.).	
Sand, fine, clayey, gray; coarse sand increasing; some fine gravel at 120 ft; static water level 1 ft above land surface..	112 - 120
Sand, fine to coarse, sharp; some gravel; clay; static water level 21.4 ft below land surface.....	120 - 130
Sand, coarse, sharp, gray; silt; clay............................	130 - 132
Sand, coarse, gray...............	132 - 135
Weathered rock fragments; sharp, gray to green (bedrock or boulder)..	135 - 136
WORCESTER W12.	
Clay, blue.......................	0 - 20
Silt; fine sand; clay............	20 - 55
Gravel, fine.....................	55 - 61
WORCESTER W15.	
Gravel; fill.....................	0 - 5
Clay.............................	5 - 95
Gravel...........................	95 - 101.5
WORCESTER X1.	
Alluvium.........................	0 - 17.4
Clay, gray; sand; rock fragments.	17.4 - 20.7
Could not penetrate further (bedrock or boulder)...........	at 20.7
WORCESTER X2.	
Alluvium; sand; gravel...........	0 - 14
Clay, gray.......................	14 - 16.5
No sample........................	16.5 - 19.4
Could not penetrate further (bedrock or boulder)...........	at 19.4
WORCESTER X3.	
Sand, brown; silt; pebbles; static water level about 10 ft.	0 - 10
Silt, gray; some clay............	10 - 15
Clay, gray.......................	15 - 30
Clay, gray; rock fragments.......	30 - 31.5
Could not penetrate further (bedrock or boulder)...........	at 31.5
WORCESTER X4.	
Sand, brown; gravel..............	0 - 9
Silt, gray.......................	9 - 15
Clay, gray.......................	15 - 20
Clay, gray; some sharp pebbles...	20 - 25
Silt, gray; clay.................	25 - 39
Silt, gray; clay; some pebbles...	39 - 45
Silt, gray; clay.................	45 - 50
Silt, gray; clay; some pebbles...	50 - 55
Silt, gray; trace of clay........	55 - 60
Silt, gray.......................	60 - 69.7
Could not penetrate further (bedrock or boulder)...........	at 69.7
WORCESTER X5.	
Silt, brown; coarse sand; saturated.	0 - 7
Gravel, coarse, brown............	7 - 9
Clay, gray; stopped at 25 ft.....	9 - 25
WORCESTER X6.	
Gravel, brown....................	0 - 8
Sand, fine, brown................	8 - 15
Clay, gray; dry..................	15 - 21
Clay, gray; silt; very fine sand; layered..................	21 - 25
Clay, gray.......................	25 - 50
Silt, gray; some clay............	50 - 75
Sand, very fine, gray; some silt; fine sand...............	75 - 80
Sand, very fine, gray; trace of gravel......................	80 - 85
Till.............................	85 - 86.6
Could not penetrate further (bedrock or boulder)...........	at 86.6
WORCESTER X7.	
Clay, gray; dry..................	0 - 3
Clay, gray; wet..................	3 - 21
Could not penetrate further (bedrock or boulder)...........	at 21
WORCESTER X8.	
Sand; gravel; wet at 9 feet......	0 - 14
Silt, brown......................	14 - 19
Silt, gray.......................	19 - 20
Clay, gray and brown; laminated..	20 - 25
Clay, gray; silt.................	25 - 45
Clay, gray; trace of pebbles.....	45 - 55
Silt, gray-green.................	55 - 61.5
Could not penetrate further (bedrock or boulder)...........	at 61.5

SELECTED REFERENCES

Cady, W.M., 1956, Bedrock geology of the Montpelier quadrangle, Vermont: U.S. Geol. Survey Geol. Quad. Map GQ-86.

Cervione, M.A., Jr., Mazzaferro, D.L., and Melvin, R.L., 1972, Water resources inventory of Connecticut, part 6, upper Housatonic River basin: Connecticut Water Resources Bull. 21.

Doll, C.G., Cady, W.M., Thompson, J.B., and Billings, M.P., 1961, Centennial geologic map of Vermont: Vermont Geol. Survey.

Doll, C.G., Stewart, D.P., and MacClintock, Paul, 1970, Surficial geologic map of Vermont: Vermont Geol. Survey.

Hall, L.M., 1959, The geology of the St. Johnsbury quadrangle, Vermont and New Hampshire: Vermont Geol. Survey Bull. 13.

Hodges, A.L., Jr., 1967, Ground water favorability map of the Winooski River basin, Vermont: Vermont Dept. Water Resources.

_____1969, Drilling for water in New England: New England Water Works Assoc. Jour., v. 82, no. 4, p. 287-315.

Hodges, A.L., Jr., Butterfield, David, and Ashley, J.W., 1976a, Ground-water resources of the Barre-Montpelier area, Vermont: Vermont Dept. Water Resources.

_____1976b, Ground-water resources of the White River Junction area, Vermont: Vermont Dept. Water Resources.

Konig, R.H., 1961, Geology of the Plainfield quadrangle, Vermont: Vermont Geol. Survey Bull. 16.

Lohman, S.W., 1972, Ground-water hydraulics: U.S. Geol. Survey Prof. Paper 708, 70 p.

National Academy of Sciences and National Academy of Engineering, 1973, Water quality criteria 1972: Washington, D.C., U.S. Environmental Protection Agency, Ecological Research Ser., EPA-R3-73-033, 594 p.

Ryder, R.B., Cervione, M.A., Jr., Thomas, C.E., Jr., and Thomas, M.P., 1970, Water resources inventory of Connecticut, part 4, southwestern coastal river basins: Connecticut Water Resources Bull. 17.

Stewart, D.P., 1971, Geology for environmental planning in the Barre-Montpelier region, Vermont, Environmental Geology No. 1: Vermont Dept. Water Resources.

Stewart, D.P., and MacClintock, Paul, 1969, The surficial geology and Pleistocene history of Vermont: Vermont Geol. Survey Bull. 31.

Woodruff, K.D., Miller, J.D., Jordan, R.R., Spoljaric, N., and Pickett, T.E., 1972, Geology and ground water: Newark, Delaware, University of Delaware.

Yase, Yoshiro, 1972, The pathogenesis of amyotropic lateral sclerosis: The Lancet, Aug. 12, v. 2, p. 292-296.

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☆U.S.GOVERNMENT PRINTING OFFICE: 1978 – A-1093/276