Overview of Environmental and Hydrogeologic Conditions on Fire Island, Anchorage, Alaska

By Allan S. Nakanishi

U.S. GEOLOGICAL SURVEY

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Multiply	By	To obtain
millimeter (mm)	0.03937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
hectare (ha)	2.471	acre
liter (L)	0.2642	gallon
square kilometer (km^2)	0.3861	square mile
centimeter per second (cm/s)	0.3937	inch per day
cubic meter per second (m^3/s)	35.31	cubic foot per second
degree Celsius (°C)	°F = 1.8 x °C + 32	degree Fahrenheit (°F)

Sea level:

In this report "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Other abbreviations used in this report:

mg/L, milligram per liter
µg/L, microgram per liter
µS/cm, microsiemen per centimeter at 25 degrees Celsius

Explanation of Local Number

The "Local Number" is derived from the official rectangular subdivision of public lands. The first letter indicates the Seward baseline and principal meridian, and the second letter represents the quadrant formed by the intersection of the baseline and the principal meridian in which the well is located. The first three digits indicate the township in which the well is located, the next three digits the range, and the next two, the section. Letters following the section number indicate the 1/4 1/4 1/4 1/4 subdivisions of the sections. Each of these successively smaller subdivisions is lettered counterclockwise beginning at the northeast corner. The next digit is a sequential number assigned to distinguish between wells that fall within the same site. The last three numbers are assigned sequentially to wells within each section.

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ABSTRACT

The Federal Aviation Administration owns an airway support facility on Fire Island near Anchorage, Alaska. The island is about 17 square kilometers in area and lies in Cook Inlet, 10 kilometers west of Anchorage International Airport. Ground water is available from aquifers about 80 meters below land surface. Wells are subject to salt-water intrusion and are not currently used as a drinking-water source on Fire Islands. Water resources on the island do not appear to be sufficient to support future commercial or industrial activity. The Anchorage municipal water-supply system may be used as an alternative water source.

INTRODUCTION

The Federal Aviation Administration (FAA) owns and (or) operates airway support and navigational facilities throughout Alaska. At many of these sites, fuels and other potentially hazardous materials such as solvents, polychlorinated biphenyls, and pesticides may have been used and (or) disposed of. To determine if environmentally hazardous materials have been spilled or disposed of at the sites, the FAA is conducting environmental studies mandated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or "Superfund Act") and the Resource Conservation and Recovery Act (RCRA). To complete these more comprehensive environmental studies, the FAA requires information on the hydrology and geology of areas surrounding the sites. This report, the product of compilation, review, and summary of existing hydrologic and geologic data by the U.S. Geological Survey, in cooperation with the FAA, provides a brief summary of such information for the FAA facility and nearby areas on Fire Island, Alaska. The FAA facilities at nearby Anchorage International Airport, Lake Hood, and Point Woronzof are discussed in a separate report (Nakanishi and Graham, 1995)..

BACKGROUND

Location

Fire Island is about 17 km^2 in area and lies about 10 km west of the Anchorage International Airport at the head of Cook Inlet between Knik Arm and Turnagain Arm in south-central Alaska (fig. 1). It is in the westernmost part of the Municipality of Anchorage and is separated from the mainland by an unnamed strait about 5 km wide. The FAA facility lies near the center of Fire Island at about lat 61°08' N., long 150°13' W.

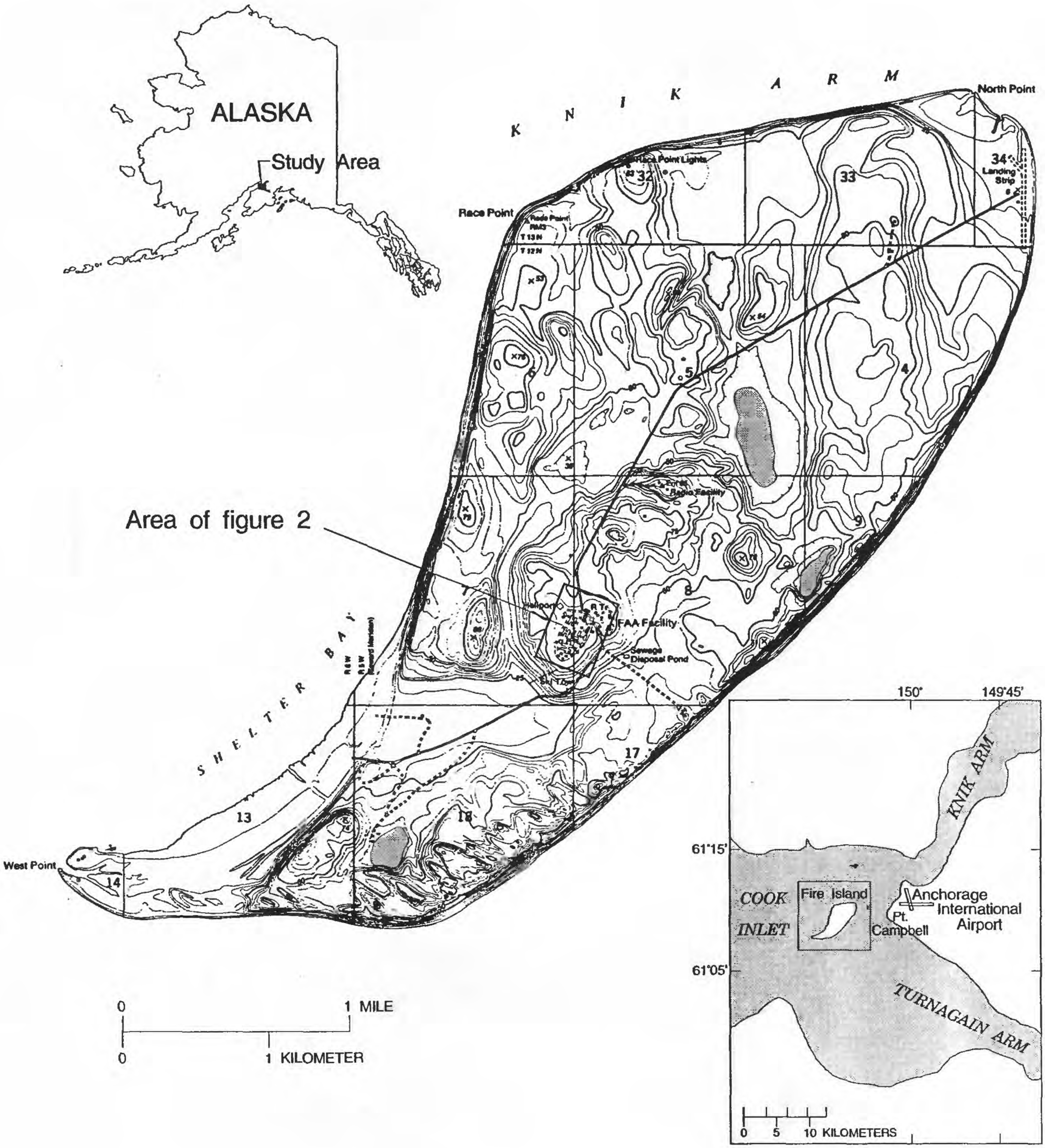

Figure 1. Fire Island and location of the Fire Island Federal Aviation Administration facility, Anchorage, Alaska.

Fire Island and the Fire Island FAA Facility

Anchorage, the largest city in Alaska, had a population of approximately 240,000 in 1990—about 50 percent of the total State population (U.S. Bureau of Census, 1991). Rapid population growth and decreasing availability of undeveloped land has caused Anchorage and the State to look towards Fire Island as a potential site for future commercial and industrial development. City and State agencies and Alaska Native corporations have sponsored feasibility studies exploring the possibility of establishing industries on the island. These industries include a port facility, a shipyard, a wood-pulp mill, concrete/cement plants, a petrochemical refinery, and a microchip manufacturing plant (Manalytics Inc., 1991; Commonwealth North, 1991; CH2MHill Inc., 1991, 1992; Cook Inlet Region, Inc., 1981). Because Fire Island is accessible only by aircraft and boat, a feasibility study to construct a bridge linking Fire Island and Anchorage has been made (R&M Consultants Inc., 1988). Fire Island is not currently occupied by permanent residents but is used seasonally by susbsistence fishermen.

During 1985 and 1986, the U.S. Air Force voluntarily cleaned up Department of Defense facilities and known environmental hazards at the Fire Island FAA facility. Buildings and related structures that were not owned by the FAA or that were deemed unserviceable were demolished. Currently, the site serves as a navigational aid to aircraft arriving at Anchorage International Airport or flying overhead. A detailed description of FAA facilities at Fire Island and an investigation of potential sources of contamination can be found in a report by Ecology and Environment Inc. (1992).

PHYSICAL SETTING

Topography

The elevation of Fire Island generally ranges from 25 to 90 m above sea level. The island is characterized by hilly and hummocky topography and is almost completely rimmed by steep bluffs that average about 60 m in height. Small areas of tidal marsh are present on the narrow western end and at the northeastern tip of the island.

Climate

Fire Island is in the transitional climate zone, characterized by fluctuations between maritime and continental climatic conditions. Seasonal precipitation patterns in this climatic zone are not sharply defined and may fluctuate from year to year (Hartman and Johnson, 1984). Precipitation in the Anchorage area generally increases with an increase in elevation eastward toward the Chugach Mountains (Patrick and others, 1989). At Anchorage International Airport, the mean annual temperature is 2.1 ^{o}C but temperatures range from a July mean maximum of 18.3 ^{o}C to a January mean minimum of about -13.2 ^{o}C. Mean annual precipitation is about 390 mm and most rainfall occurs in August and September. Mean annual snowfall is approximately 1,760 mm (Leslie, 1989). Mean monthly temperature, precipitation, and snowfall on Fire Island are similar to those for the Anchorage International Airport, which are summarized in table 1.

Table 1. Mean monthly temperature, precipitation, and snowfall for the period 1952-87, Anchorage International Airport, Anchorage, Alaska

[Modified from Leslie (1989); °C, degree Celsius; mm, millimeter]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Temperature (°C)													
Mean maximum	-5.8	-3.3	0.3	5.8	12.4	16.6	18.3	17.2	12.8	4.9	-2.2	-5.8	5.9
	(Record maximum, 29.4 °C, June 1969)												
Mean minimum	-13.2	-11.7	-8.4	-2.3	3.6	8.3	10.7	9.5	4.9	-1.9	-9.0	-12.9	-1.9
	(Record minimum, -36.7°C, January 1975)												
Mean	-9.6	-7.5	-4.1	1.8	8.1	12.4	14.5	13.4	8.9	1.5	-5.7	-9.3	2.1
Precipitation (mm of moisture)	20.3	21.8	16.5	16.0	16.0	25.9	49.8	58.7	63.8	47.2	27.4	26.9	390.4
Snowfall (mm)	223.5	309.9	236.2	154.9	5.1	0	0	0	7.6	193.0	274.3	355.6	1,760.2

Vegetation

Interior-forest vegetation covers much of the land surface on Fire Island and is found predominantly on well-drained hills. Tree species typical of interior forests include white spruce, paper birch, balsam poplar, cottonwood, and willow (Viereck and Little, 1972). Isolated patches of black spruce are scattered around the island in low-relief areas (Anchorage Coastal Resource Atlas, 1982). Shrub vegetation includes alder, wild rose, lingonberry, bunchberry, currant, and Labrador tea. Bogs are found in poorly drained, flat-lying areas where soils are saturated. Bog vegetation includes black spruce, birch, Labrador tea, willows, hemlock, cotton grass, mosses, and sedges. Bogs surround a large unnamed lake near the center of the island and tidal marshes and salt grasses are found at the northern and southern ends of the island.

Geology

Fire Island is underlain by unconsolidated deposits of Quaternary age, weakly lithified deposits of Tertiary age, and metamorphic bedrock of Cretaceous/Jurassic age. The unconsolidated deposits thicken progressively from less than a few meters near the Chugach Mountains (about 25 km east of Fire Island) to about 300 m near Fire Island (Freethey and Scully, 1980). Exposed bluffs on the island consist of interbedded and interfingered lenses of sand and gravel—containing minor amounts of silt and clay—that extend to at least 50 m below sea level (Schmoll and others, 1981).

Nonglacial and glacial surficial deposits on Fire Island were mapped by Schmoll and others (1981). Nonglacial deposits consist of dune, beach, lagoon, pond, and peat deposits. Dune deposits are medium- to fine-grained, well-sorted sand and are found both underlying and overlying the bluffs. Beach deposits ring the island and are medium-grained, well-sorted sand forming low ridges up to a few meters high. Lagoon or tide deposits are silt and (or) very fine-grained sand that occur in low relief areas near the shores of the island. Pond and bog deposits are mostly silt, organic silt, and peat. Drillers' logs (appendix 1) for wells on the island indicate a gravel, sand, and silty sand mixture to depths of more than 100 m.

Soils beneath and surrounding the Fire Island FAA facility are mostly silt loam (Brent and Cox, 1981). The loam is moderately permeable, and runoff over its surface increases with increasing slope. Because these porous soils are unable to prevent the contamination of ground water by infiltration, Brent and Cox (1981) recommend avoiding the construction of seepage lagoons and trench-type sanitary landfills. If other types of contaminants are present, their rapid migration through the soils near the Fire Island FAA facility could potentially threaten ground water.

HYDROLOGY

Surface Water

Cook Inlet has one the world's greatest tidal amplitudes. Tidal currents have a current velocity as high as 80 cm/s and the water is intensely mixed as tides move into and out of the inlet (Anchorage Coastal Resource Atlas, 1982). Estimated monthly mean fresh-water flow into Knik Arm is greater than 1,200 m^3/s in July and is approximately 30 m^3/s in March (Commonwealth North, 1991). During the summer, the concentration of total dissolved solids in Knik Arm ranges from 6,000 to 15,000 mg/L and during the winter, the concentration increases to a nearly constant level of 20,000 mg/L (Commonwealth North, 1991). Suspended-sediment concentrations may reach 2,000 mg/L. The fresh-water inflows produce a net flow of water out of Knik Arm.

Surface-water bodies on Fire Island include three unnamed lakes (fig. 1) and wetland areas containing ponds, bogs, and marshes. Recharge to the lakes occurs from overland runoff and possibly from ground-water recharge. There are no apparent drainages from the lakes and discharge occurs by infiltration through the lakebed and evaporation. No perennially flowing streams are found on the island.

Ground Water

Most of the hydrogeologic information on Fire Island is based on exposed bluffs and from the data from four wells drilled by the U.S. Air Force from 1950 to 1962 (fig. 2, table 2, appendix 1). The depths of the completed wells ranged from 93 to 117 m below land surface and water levels ranged from 77 to 81 m below land surface.

Cook Inlet Region Inc. (1981) and Commonwealth North (1991) report that ground water on the island appears to be unconfined with a water table "just above sea level." Typically, in unconfined marine island aquifers, fresh water—being less dense than salt water—occurs as a thin lens that "floats" on top of the salt water (Freeze and Cherry, 1979). In U.S. Air Force well 2 (U.S. Army Corps of Engineers, 1963a) salt water was encountered at a depth of 108 m below land surface. The well was backfilled and sealed at 104 m below land surface to prevent salt-water flow into upper aquifers. If the aquifer underlying Fire Island is unconfined and distinct from the aquifers in the Anchorage Bowl, then recharge to the aquifer comes solely from infiltration of precipitation on the island. Aquifer discharge most likely takes place through the inlet sea bluff surrounding the island.

According to U.S. Army Corps of Engineers (1963a and 1963b) and Ecology and Environment Inc. (1992), ground water at Fire Island also exists in deep, confined aquifers that may be hydrologically connected to the aquifer(s) beneath Anchorage. There are insufficient data, however, to confirm this connection. Drillers' logs of the four wells (appendix 1) show one to four water-bearing layers at depths ranging from about 8 to 30 m below sea level. The water surfaces in completed wells are 15 to 26 m above the water-bearing layers and are approximately 1 to 2 m above sea level. Continuous layers made up of fine-grained materials, such as silts and clays appear to overlie water-producing coarser grained layers. If these fine-grained layers are continuous beneath the strait between Fire Island and Anchorage, they may form a partial barrier to salt-water intrusion into the fresh-water aquifer. If these aquifers beneath Fire Island are confined and contiguous with the aquifer(s) beneath Anchorage, then their recharge probably comes from infiltration near the Chugach Mountain front.

Some water samples from wells on Fire Island (appendix 2) indicate high chloride concentrations. The chloride may be from shallow unconsolidated deposits or from deeper sediments underlying Fire Island and Cook Inlet. According to McGee (1977), both the Tertiary sediments and the underlying Mesozoic sediments contain water having salt concentrations that increase with depth. A map contouring the thickness of sediments from ground surface to the base of the fresh-water/salt-water interface (McGee, 1977, plate 6) shows the interface at a depth of between 180 to about 210 m at Fire Island.

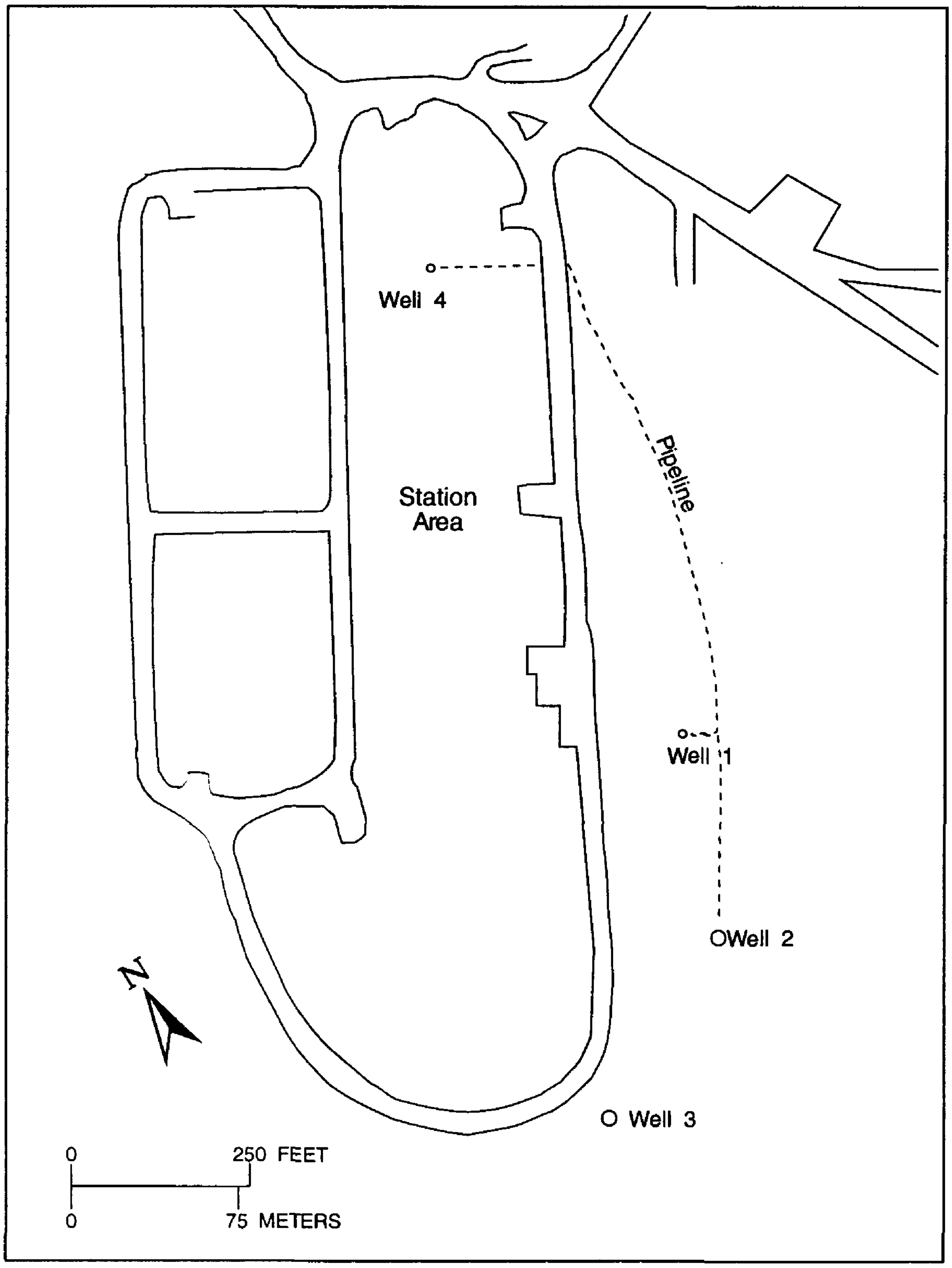

Figure 2. Well locations near Federal Aviation Administration facility on Fire Island.

Table 2. Information about U.S. Air Force wells on Fire Island, Anchorage, Alaska
[See appendix 1 for drillers' logs]

Well No. (fig. 2)	Local well number	Year well constructed	Original use of well	Depth of well (meters)	Water level (meters)
1	SB01200508CCAD1 001	1950	Public supply	104	79.5
2	SB01200508CCAC1 002	1950	Public supply	105	76.7
3	SB01200508CCDB1 003	1955	Public supply	93	78.0
4	SB01200508CBDC1 004	1962	Air conditioning	117	81.3

The relation between lakes and aquifers on Fire Island is not fully understood. The presence of lakes implies an intersection of the water table with the land surface (Cook Inlet Region Inc., 1981). Average lake-water elevations on Fire Island range from 25 to 50 m above sea level. The static water levels in the four wells on Fire Island range from 1 to 2 m above sea level. The difference in water elevations in the lakes and static water elevations in the wells may indicate the presence of perched aquifers that overlie the confined or unconfined aquifer. A perched aquifer is a lens of saturated soil overlying the main water table. Typically, a perched aquifer is underlain by a layer of low permeability.

DRINKING WATER

Present Drinking-Water Supplies

According to Ecology and Environment Inc. (1992), it does not appear that well water is being used as a drinking-water source for FAA facilities on Fire Island. Three of the four wells were abandoned or destroyed during the U.S. Air Force clean-up activities in 1985-86. Only "well 1" (table 2; fig. 2) is known to remain (Ecology and Environment Inc., 1992). The sources of drinking water for the seasonal population on Fire Island are probably local lakes and water hauled to the island. According to a report by the University of Alaska Anchorage (1986), surface- and ground-water resources on the island appear to be insufficient to support proposed commercial and industrial developments.

Water samples were taken between 1956 to 1970 from the four wells on Fire Island (appendix 2). The data show that the water quality is generally within U.S. Environmental Protection Agency (USEPA) (1993) drinking-water regulations for iron, hardness, and silica. Water samples from well 2, however, contained dissolved chloride concentrations as high as 1,100 mg/L, exceeding the USEPA drinking-water maximum contaminant level of 250 mg/L. Data on the water quality of lakes and ponds on Fire Island are not available.

Alternative Drinking-Water Sources

The FAA has requested information on alternative drinking-water sources that could be used if the present drinking-water source became contaminated. If the aquifers capable of providing drinking water were contaminated, the municipal water supply provided by the Anchorage Water and Wastewater Utility could be used as an alternative supply. The Municipality of Anchorage's water supply combines surface water from Ship Creek and Eklutna Lake with ground water from numerous wells. In 1990, the Anchorage Water and Wastewater Utility had a production capacity of approximately 260 million liters per day, which can serve a population about twice as that of Anchorage (Anchorage Water and Wastewater Utility, written commun., 1990). The municipal water-supply system is currently operating below capacity and the water-distribution system could be expanded to Fire Island. Expansion of the system to Fire Island, however, is unlikely unless a bridge or causeway from the mainland is constructed.

SUMMARY

The Fire Island FAA facility is near the center of the island. A strait of Cook Inlet separates the seasonally inhabited island from Anchorage, the largest city in Alaska. The island consists of hills and hummocks rimmed by steep bluffs. Surficial deposits of Quaternary age are interbedded sand and gravel with minor silt and clay. The surficial deposits are underlain by weakly lithified Tertiary sedimentary rocks. Ground water is available from aquifers reaching depths of about 80 m below ground surface within the Quaternary deposits. Aquifers deeper than 80 m may contain salt water. Ground water is not currently being used as a drinking-water source on Fire Island. Seasonal inhabitants use surface-water sources or haul water to the island. Water resources on the island do not appear to be sufficient to support future commercial or industrial activities. The Anchorage municipal water-supply system could be used as an alternative water source for the island.

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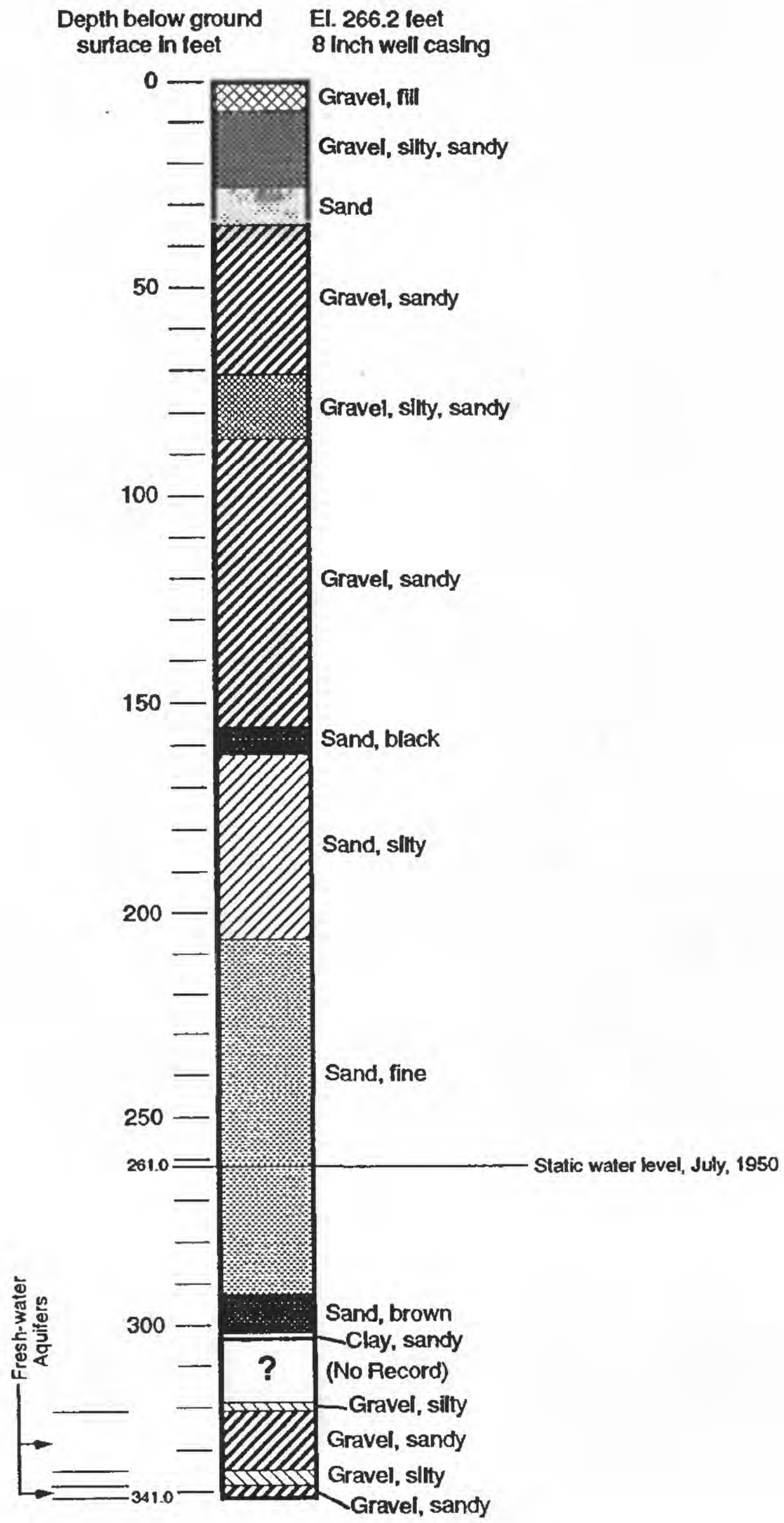
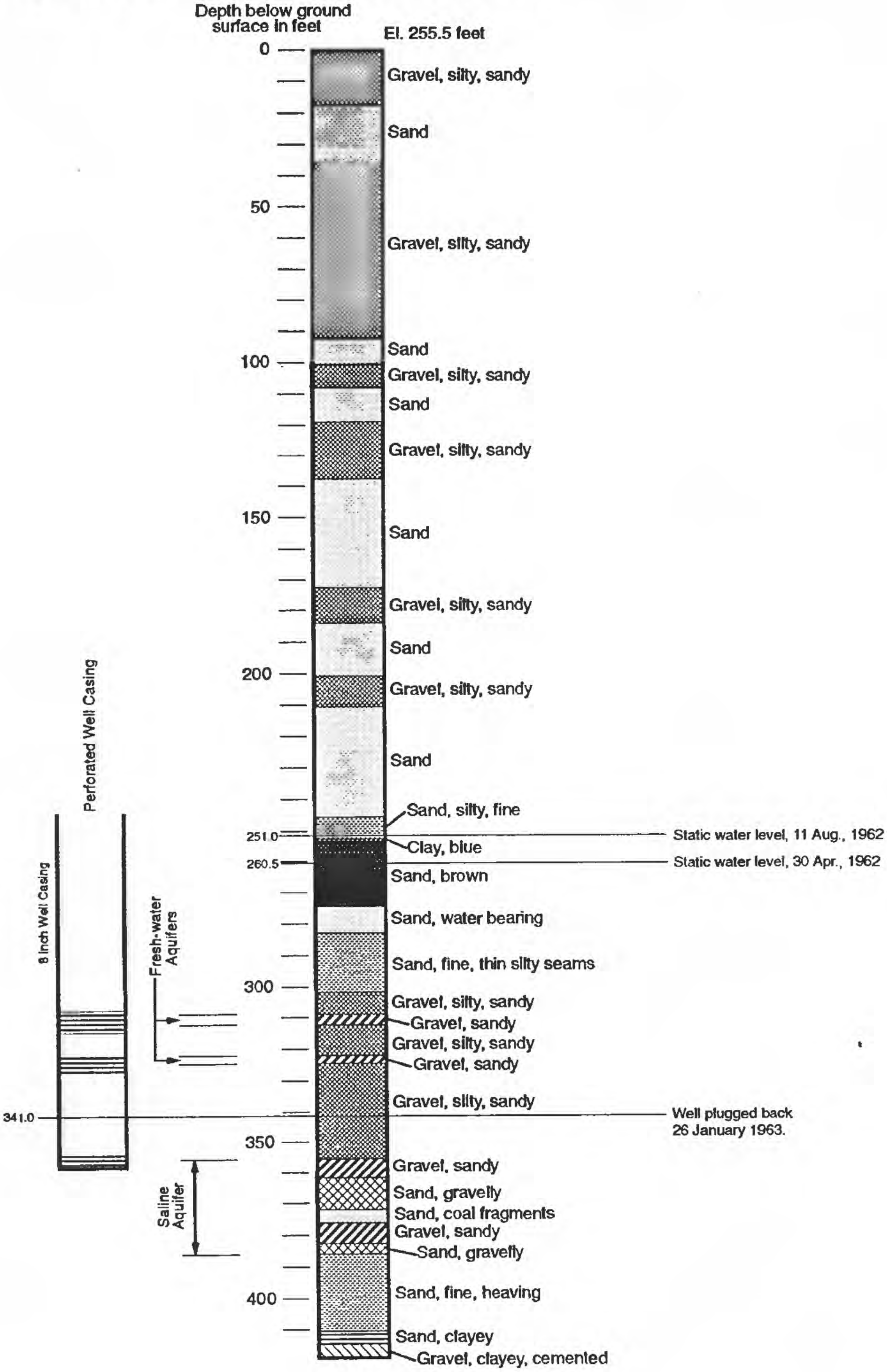
APPENDIX 1

Drillers' logs from wells on Fire Island

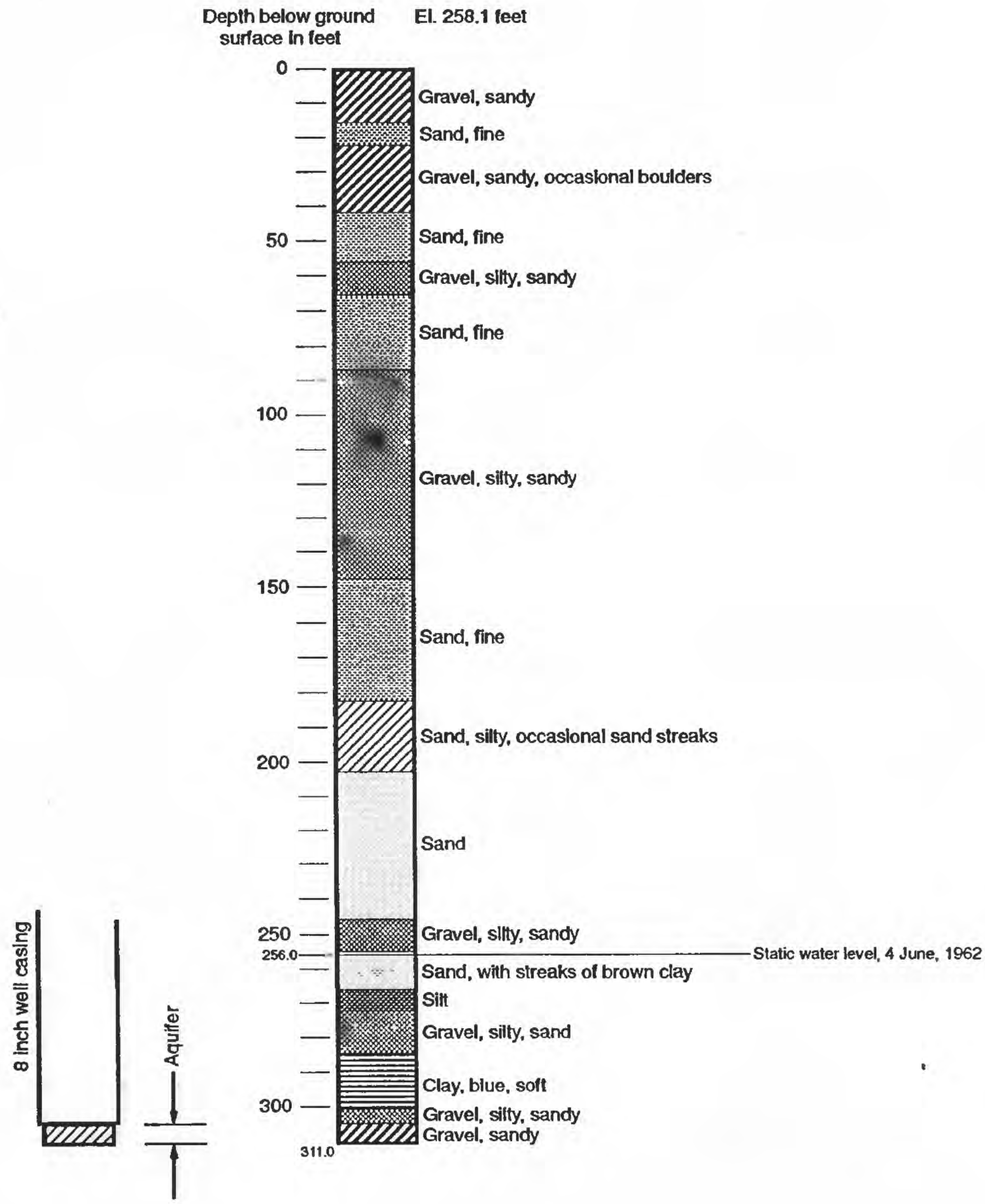
Fire Island Well No.1 (SB01200508CCAD1 001)
(modified from U.S. Army Corps of Engineers, 1963)



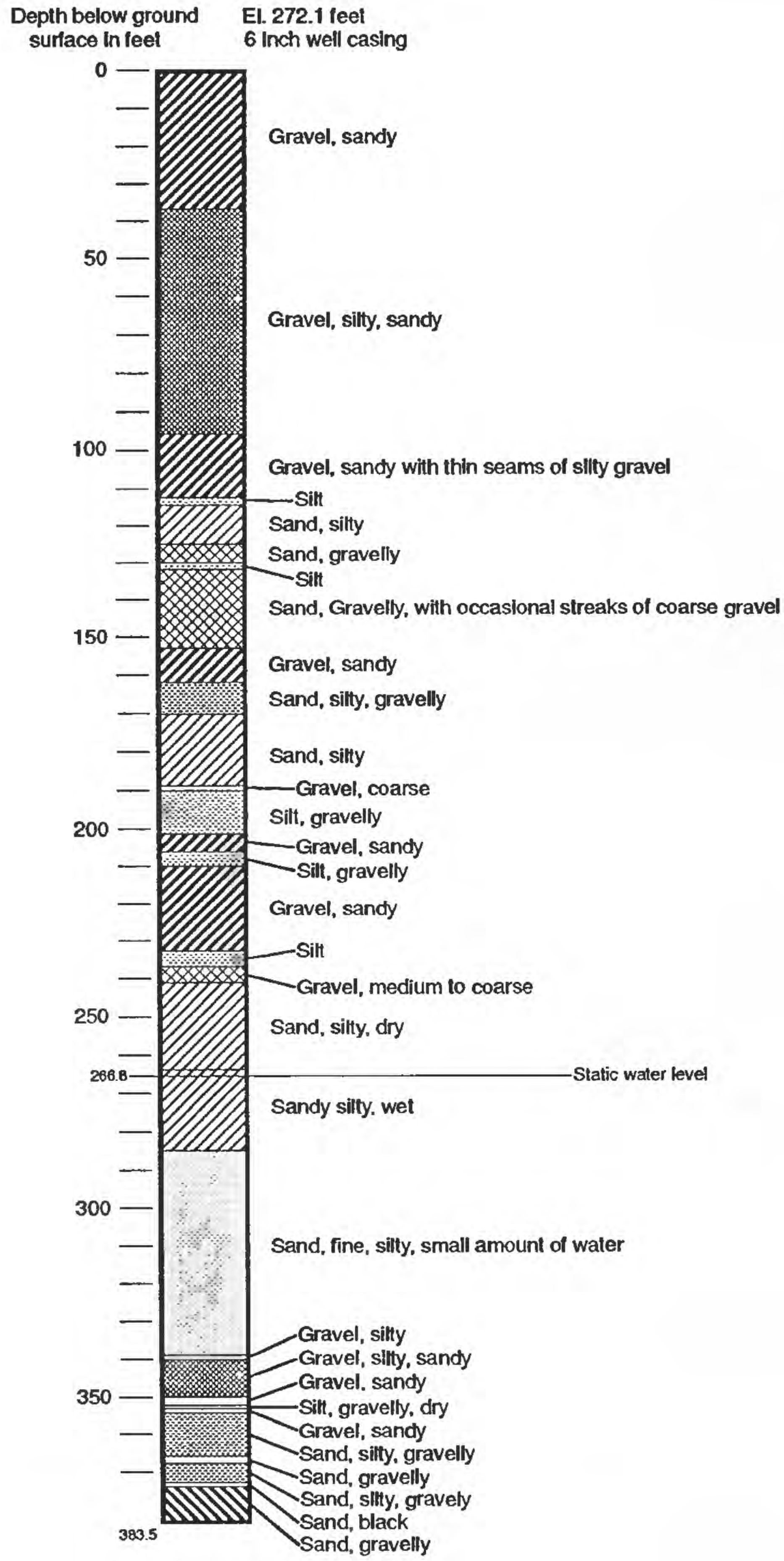
Fire Island Well No. 2 (SB01200508CCAC1 002)
(modified from U.S. Army Corps of Engineers, 1963)



Fire Island Well No.3 (SB01200508CCDB1 003)
(modified from U.S. Army Corps of Engineers, 1963)



Fire Island Well No.4 (SB01200508CBDC1 004)



APPENDIX 2

Water-quality data from wells on Fire Island

Local Well Number	Date	Color (Pt-Co Units)	Specific Conductance (us/cm)	pH (standard units)	CO_2, dis-solved (mg/L)	Alkalinity (mg/L as HCO_3)	Bicarbonate (mg/L as HCO_3)	Carbonate (mg/L as CO_3)	Nitrate, dissolved (mg/L as N)	Phosphate, dissolved (3mg/L as PO_4)
SB01200508CCDB1 003	04-06-56	--	473	7.9	5.0	202	250	0	0.00	--
SB01200508CCDB1 003	03-23-59	0	607	7.8	6.3	205	250	0	0.020	--
SB01200508CCDB1 003	09-20-62	5	484	8.1	2.9	187	230	0	0.050	--
SB01200508CCDB1 003	05-31-63	--	--	--	--	--	--	--	--	--
SB01200508CCDB1 003	07-13-64	5	509	7.8	5.8	186	230	0	0.050	--
SB01200508CCDB1 003	07-01-65	5	536	7.6	9.6	195	240	0	0.180	--
SB01200508CCDB1 003	01-04-66	10	539	--	--	188	230	0	0.110	--
SB01200508CCDB1 003	04-03-67	5	534	7.6	9.6	197	240	0	0.090	--
SB01200508CCDB1 003	08-08-68	5	534	7.9	4.7	192	230	0	0.110	--
SB01200508CCDB1 003	02-05-69	0	533	7.8	5.9	192	230	0	0.140	--
SB01200508CBDC1 004	04-22-63	0	380	8.3	1.5	151	180	2	0.020	--
SB01200508CBDC1 004	09-30-63	--	--	--	--	--	--	--	--	--
SB01200508CBDC1 004	04-01-64	0	982	8.0	2.9	147	180	0	0.090	--
SB01200508CBDC1 004	10-05-64	5	1330	8.0	2.8	142	170	0	0.110	--
SB01200508CBDC1 004	02-24-65	5	2450	7.9	3.5	142	170	0	0.140	--
SB01200508CBDC1 004	07-01-65	5	3110	7.8	4.7	151	180	0	0.050	--
SB01200508CBDC1 004	01-04-66	10	3280	8.2	1.9	151	180	0	0.140	--
SB01200508CBDC1 004	07-05-66	10	1690	7.7	5.7	148	180	0	0.070	--
SB01200508CBDC1 004	07-26-66	--	2510	--	--	--	--	--	--	--
SB01200508CBDC1 004	04-03-67	5	656	7.8	4.9	159	190	0	0.090	--
SB01200508CBDC1 004	05-15-67	--	535	--	--	--	--	--	--	--

Local Well Number	Date	Color (Pt-Co Units)	Specific Conductance (us/cm)	pH (standard units)	CO_2, dis-solved (mg/L)	Alkalinity (mg/L as HCO_3)	Bicarbonate (mg/L as HCO_3)	Carbonate (mg/L as CO_3)	Nitrate, dissolved (mg/L as N)	Phosphate, dissolved (mg/L as PO_4)
SB01200508CBDC1 004	12-18-67	--	900	--	--	--	--	--	--	--
SB01200508CBDC1 004	03-04-68	--	546	8.0	--	--	--	--	--	--
SB01200508CBDC1 004	07-01-68	--	482	8.2	--	--	--	--	--	--
SB01200508CBDC1 004	10-28-68	--	1960	--	--	--	--	--	--	--
SB01200508CBDC1 004	12-02-68	--	1290	7.9	--	--	--	--	--	--
SB01200508CBDC1 004	03-10-69	--	1950	7.9	--	--	--	--	--	--
SB01200508CBDC1 004	05-12-69	--	1250	--	--	--	--	--	--	--
SB01200508CBDC1 004	08-18-69	--	2250	--	--	--	--	--	--	--
SB01200508CBDC1 004	12-01-69	--	1060	--	--	--	--	--	--	--
SB01200508CBDC1 004	01-06-70	--	1730	--	--	--	--	--	--	--
SB01200508CCAC1 002	09-24-56	0	475	8.1	3.1	198	240	0	0.00	--
SB01200508CCAC1 002	10-18-57	0	476	8.0	3.8	194	240	0	0.00	--
SB01200508CCAC1 002	02-18-58	0	490	7.9	5.0	205	250	0	0.00	--
SB01200508CCAC1 002	02-25-58	0	488	7.8	6.2	201	250	0	0.050	--
SB01200508CCAC1 002	04-01-59	0	492	7.7	7.8	201	250	0	0.020	--
SB01200508CCAC1 002	04-20-61	0	483	7.6	9.6	195	240	0	0.020	0.0
SB01200508CCAC1 002	09-22-62	--	--	--	--	--	--	--	--	--
SB01200508CCAC1 002	04-01-63	0	1030	8.0	3.7	190	230	0	0.140	--
SB01200508CCAC1 002	03-31-65	--	1020	7.2	2.8	23	28	0	0.140	--
SB01200508CCAC1 002	04-27-65	--	974	--	--	--	--	--	--	--

Local Well Number	Date	Phosphorus, dissolved (mg/L as P)	Hardness, total (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
SB01200508CCDB1 003	04-06-56	--	220	23	67	14	13
SB01200508CCDB1 003	03-23-59	--	30	0	7.9	2.4	120
SB01200508CCDB1 003	09-20-62	--	220	31	64	14	16
SB01200508CCDB1 003	05-31-63	--	--	--	--	--	--
SB01200508CCDB1 003	07-13-64	--	230	42	28	38	17
SB01200508CCDB1 003	07-01-65	--	240	45	62	21	16
SB01200508CCDB1 003	01-04-66	--	240	49	66	18	13
SB01200508CCDB1 003	04-03-67	--	250	57	50	31	16
SB01200508CCDB1 003	08-08-68	--	240	5	76	13	16
SB01200508CCDB1 003	02-05-69	--	230	42	71	14	17
SB01200508CBDC1 004	04-22-63	--	170	18	53	8.8	17
SB01200508CBDC1 004	09-30-63	--	--	--	--	--	--
SB01200508CBDC1 004	04-01-64	--	360	220	110	20	43
SB01200508CBDC1 004	10-05-64	--	460	87	140	28	76
SB01200508CBDC1 004	02-24-65	--	730	590	210	51	220
SB01200508CBDC1 004	07-01-65	--	760	600	210	55	330
SB01200508CBDC1 004	01-04-66	--	760	610	220	53	330
SB01200508CBDC1 004	07-05-66	--	410	260	17	89	150
SB01200508CBDC1 004	07-26-66	--	--	--	--	--	--
SB01200508CBDC1 004	04-03-67	--	190	35	38	24	62
SB01200508CBDC1 004	05-15-67	--	--	--	--	--	--

Local Well Number	Date	Phosphorus, dissolved (mg/L as P)	Hardness, total mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
SB01200508CBDC1 004	12-18-67	--	--	--	--	--	--
SB01200508CBDC1 004	03-04-68	--	--	--	--	--	--
SB01200508CBDC1 004	07-01-68	--	--	--	--	--	--
SB01200508CBDC1 004	10-28-68	--	--	--	--	--	--
SB01200508CBDC1 004	12-02-68	--	--	--	--	--	--
SB01200508CBDC1 004	03-10-69	--	--	--	--	--	--
SB01200508CBDC1 004	05-12-69	--	--	--	--	--	--
SB01200508CBDC1 004	08-18-69	--	--	--	--	--	--
SB01200508CBDC1 004	12-01-69	--	--	--	--	--	--
SB01200508CBDC1 004	01-06-70	--	--	--	--	--	--
SB01200508CCAC1 002	09-24-56	--	220	20	66	13	14
SB01200508CCAC1 002	10-18-57	--	220	22	65	13	15
SB01200508CCAC1 002	02-18-58	--	230	21	56	21	16
SB01200508CCAC1 002	02-25-58	--	230	28	62	18	15
SB01200508CCAC1 002	04-01-59	--	6	0	2.0	0.20	120
SB01200508CCAC1 002	04-20-61	0.00	210	13	62	13	15
SB01200508CCAC1 002	09-22-62	--	--	--	--	--	--
SB01200508CCAC1 002	04-01-63	--	150	0	51	5.1	160
SB01200508CCAC1 002	03-31-65	--	250	230	78	14	85
SB01200508CCAC1 002	04-27-65	--	--	--	--	--	--

Local Well Number	Date	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, dissolved (mg/L)	Nitrogen, Nitrate, dissolved (mg/L as NO_3)
SB01200508CCDB1 003	04-06-56	3.4	26	17	0.10	14	275	0.0
SB01200508CCDB1 003	03-23-59	2.8	16	29	0.10	12	316	0.10
SB01200508CCDB1 003	09-20-62	3.4	38	21	0.10	11	280	0.20
SB01200508CCDB1 003	05-31-63	--	40	--	--	--	--	--
SB01200508CCDB1 003	07-13-64	0.40	43	25	0.10	12	275	0.20
SB01200508CCDB1 003	07-01-65	4.1	44	26	0.10	12	303	0.80
SB01200508CCDB1 003	01-04-66	1.2	47	12	0.30	11	282	0.50
SB01200508CCDB1 003	04-03-67	2.7	46	23	0.10	12	299	0.40
SB01200508CCDB1 003	08-08-68	3.0	44	22	0.10	12	302	0.50
SB01200508CCDB1 003	02-05-69	3.5	49	22	0.20	12	304	0.60
SB01200508CBDC1 004	04-22-63	2.6	24	19	0.20	12	227	0.10
SB01200508CBDC1 004	09-30-63	--	100	--	--	--	--	--
SB01200508CBDC1 004	04-01-64	0.50	190	36	0.10	12	506	0.40
SB01200508CBDC1 004	10-05-64	0.70	310	57	0.0	11	704	0.50
SB01200508CBDC1 004	02-24-65	16	660	110	0.10	9.6	1350	0.60
SB01200508CBDC1 004	07-01-65	16	860	140	0.20	12	1710	0.20
SB01200508CBDC1 004	01-04-66	5.5	880	98	0.40	11	1680	0.60
SB01200508CBDC1 004	07-05-66	7.3	400	57	0.20	10	825	0.30
SB01200508CBDC1 004	07-26-66	--	680	--	--	--	--	--
SB01200508CBDC1 004	04-03-67	3.8	98	35	0.10	110	467	0.40
SB01200508CBDC1 004	05-15-67	--	60	--	--	--	--	--

Local Well Number	Date	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, dissolved (mg/L)	Nitrogen, Nitrate, dissolved (mg/L as NO_3)
SB01200508CBDC1 004	12-18-67	--	180	--	--	--	--	--
SB01200508CBDC1 004	03-04-68	--	72	--	--	--	--	--
SB01200508CBDC1 004	07-01-68	--	45	--	--	--	--	--
SB01200508CBDC1 004	10-28-68	--	500	--	--	--	--	--
SB01200508CBDC1 004	12-02-68	--	230	--	--	--	--	--
SB01200508CBDC1 004	03-10-69	--	490	--	--	--	--	--
SB01200508CBDC1 004	05-12-69	--	290	--	--	--	--	--
SB01200508CBDC1 004	08-18-69	--	620	--	--	--	--	--
SB01200508CBDC1 004	12-01-69	--	260	--	--	--	--	--
SB01200508CBDC1 004	01-06-70	--	430	--	--	--	--	--
SB01200508CCAC1 002	09-24-56	3.5	25	18	0.0	13	271	0.0
SB01200508CCAC1 002	10-18-57	3.3	30	19	0.10	12	273	0.0
SB01200508CCAC1 002	02-18-58	3.1	31	19	0.10	12	281	0.0
SB01200508CCAC1 002	02-25-58	2.9	32	16	0.10	12	279	0.20
SB01200508CCAC1 002	04-01-59	0.60	30	19	0.10	14	304	0.10
SB01200508CCAC1 002	04-20-61	3.1	19	12	0.20	14	255	0.10
SB01200508CCAC1 002	09-22-62	--	1100	--	--	--	--	--
SB01200508CCAC1 002	04-01-63	5.4	200	22	0.20	12	572	0.60
SB01200508CCAC1 002	03-31-65	9.9	270	51	0.30	1.6	520	0.60
SB01200508CCAC1 002	04-27-65	--	210	--	--	--	--	--

Local Well Number	Date	Manganese (ug/L as Mn)	Iron (ug/L as Fe)	Elev. of land surface datum (m above NGVD)	Depth of hole, total (m)	Depth of well, total (m)	Depth to top of sample interval (m)	Depth to bottom of sample interval (m)
SB01200508CCDB1 003	04-06-56	40	0	79	95	93.00	93	94
SB01200508CCDB1 003	03-23-59	0	40	79	95	93.00	93	94
SB01200508CCDB1 003	09-20-62	0	100	79	95	93.00	93	94
SB01200508CCDB1 003	05-31-63	--	--	79	--	93.00	--	--
SB01200508CCDB1 003	07-13-64	100	30	79	95	93.00	93	94
SB01200508CCDB1 003	07-01-65	--	20	79	95	93.00	93	94
SB01200508CCDB1 003	01-04-66	--	40	79	95	93.00	93	94
SB01200508CCDB1 003	04-03-67	90	0	79	95	93.00	93	94
SB01200508CCDB1 003	08-08-68	--	--	79	95	93.00	93	94
SB01200508CCDB1 003	02-05-69	150	360	79	95	93.00	93	94
SB01200508CBDC1 004	04-22-63	80	30	83	117	117.00	114	117
SB01200508CBDC1 004	09-30-63	--	--	83	117	117.00	114	117
SB01200508CBDC1 004	04-01-64	300	50	83	117	117.00	114	117
SB01200508CBDC1 004	10-05-64	290	20	83	117	117.00	114	117
SB01200508CBDC1 004	02-24-65	--	20	83	117	117.00	114	117
SB01200508CBDC1 004	07-01-65	--	20	83	117	117.00	114	117
SB01200508CBDC1 004	01-04-66	--	40	83	117	117.00	114	117
SB01200508CBDC1 004	07-05-66	0	20	83	117	117.00	114	117
SB01200508CBDC1 004	07-26-66	--	--	83	117	117.00	114	117
SB01200508CBDC1 004	04-03-67	90	0	83	117	117.00	114	117
SB01200508CBDC1 004	05-15-67	--	--	83	117	117.00	114	117

Local Well Number	Date	Manganese (ug/L as Mn)	Iron (ug/L as Fe)	Elev. of land surface datum (m above NGVD)	Depth of hole, total (m)	Depth of well, total (m)	Depth to top of sample interval (m)	Depth to bottom of sample interval (m)
SB01200508CBDC1 004	12-18-67	--	--	83	117	117.00	114	117
SB01200508CBDC1 004	03-04-68	--	--	83	117	117.00	114	117
SB01200508CBDC1 004	07-01-68	--	--	83	117	117.00	114	117
SB01200508CBDC1 004	10-28-68	--	--	83	117	117.00	114	117
SB01200508CBDC1 004	12-02-68	--	--	83	117	117.00	114	117
SB01200508CBDC1 004	03-10-69	--	--	83	117	117.00	114	117
SB01200508CBDC1 004	05-12-69	--	--	83	117	117.00	114	117
SB01200508CBDC1 004	08-18-69	--	--	83	117	117.00	114	117
SB01200508CBDC1 004	12-01-69	--	--	83	117	117.00	114	117
SB01200508CBDC1 004	01-06-70	--	--	83	117	117.00	114	117
SB01200508CCAC1 002	09-24-56	--	0	78	128	105.00	--	--
SB01200508CCAC1 002	10-18-57	20	0	78	128	105.00	--	--
SB01200508CCAC1 002	02-18-58	20	0	78	128	105.00	--	--
SB01200508CCAC1 002	02-25-58	20	0	78	128	105.00	--	--
SB01200508CCAC1 002	04-01-59	10	50	78	128	105.00	--	--
SB01200508CCAC1 002	04-20-61	20	140	78	128	105.00	--	--
SB01200508CCAC1 002	09-22-62	--	--	78	128	105.00	--	--
SB01200508CCAC1 002	04-01-63	20	20	78	128	105.00	--	--
SB01200508CCAC1 002	03-31-65	20	0	78	128	105.00	--	--
SB01200508CCAC1 002	04-27-65	--	--	78	128	105.00	--	--

Local Well Number	Date	pH, water (stan.. units)	Carbon dioxide dissolved (mg/L as CO_2)	Alkalinity (mg/L as $CaCO_3$)	Bicaronate (mg/L as HCO_3)	Carbonate (mg/L as CO_3)	Nitrogen, dissolved (mg/L as N)	Hardness, total (mg/L as $CaCO_3$	Hardness, noncarbonate (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)
SB01200508CCAC1 002	11-30-65	8.0	3.5	181	220	0	0.160	260	81	79	16
SB01200508CCAC1 002	02-02-66	--	--	--	--	--	--	--	--	--	--
SB01200508CCAD1 001	12-02-54	7.7	7.4	190	230	0	0.00	210	23	64	13
SB01200508CCAD1 001	09-26-56	8.0	3.6	186	230	0	0.00	210	21	60	14
SB01200508CCAD1 001	10-18-57	8.1	3.1	197	240	0	0.00	220	27	65	15
SB01200508CCAD1 001	02-17-58	7.8	6.2	199	240	0	0.020	220	16	60	16
SB01200508CCAD1 001	02-25-58	7.9	4.9	198	240	0	0.020	220	22	52	22
SB01200508CCAD1 001	10-30-59	7.7	7.2	186	230	0	0.00	220	32	31	34
SB01200508CCAD1 001	12-03-59	7.8	5.7	185	230	0	0.050	210	28	46	24
SB01200508CCAD1 001	01-01-60	8.2	2.3	189	230	0	0.00	6	0	2.0	0.20
SB01200508CCAD1 001	04-27-65	7.8	3.7	118	140	0	0.050	120	4	34	9.0
SB01200508CCAD1 001	11-30-65	8.0	2.5	127	150	0	0.140	160	32	35	17
SB01200508CCAD1 001	02-02-66	8.0	2.5	128	160	0	0.110	150	18	37	13
SB01200508CCAD1 001	04-14-66	8.1	2.2	139	170	0	0.200	150	10	36	14

Local Well Number	Date	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, dissolved (mg/L)
SB01200508CCAC1 002	11-30-65	32	0.80	97	12	0.50	10	357
SB01200508CCAC1 002	02-02-66	--	--	130	--	--	--	--
SB01200508CCAD1 001	12-02-54	13	2.4	28	19	0.0	11	264
SB01200508CCAD1 001	09-26-56	15	3.4	28	19	0.0	10	261
SB01200508CCAD1 001	10-18-57	15	3.6	30	19	0.10	13	279
SB01200508CCAD1 001	02-17-58	18	2.6	30	19	0.10	11	276
SB01200508CCAD1 001	02-25-58	18	2.6	30	19	0.10	11	274
SB01200508CCAD1 001	10-30-59	16	3.4	32	21	0.0	11	260
SB01200508CCAD1 001	12-03-59	17	3.1	28	22	0.10	120	372
SB01200508CCAD1 001	01-01-60	120	0.40	32	16	0.20	13	296
SB01200508CCAD1 001	04-27-65	300	6.5	440	26	0.20	1.4	885
SB01200508CCAD1 001	11-30-65	190	0.40	310	12	0.50	1.2	646
SB01200508CCAD1 001	02-02-66	180	5.1	290	12	1.3	0.90	618
SB01200508CCAD1 001	04-14-66	160	5.0	250	68	0.30	2.3	617

Local Well Number	Date	Manganese (ug/L as Mn)	Iron (ug/L as Fe)	Elev. of land surface datum (m above NGVD)	Depth of Hole total (m)	Depth of well, total (m)	Depth to top of sample interval (m)	Depth to bottom of sample interval (m)
SB01200508CCAC1 002	11-30-65	--	--	78	128	105.00	105	105
SB01200508CCAC1 002	02-02-66	--	--	78	128	105.00	--	--
SB01200508CCAD1 001	12-02-54	--	0	81	104	104.00	--	--
SB01200508CCAD1 001	09-26-56	20	0	81	104	104.00	--	--
SB01200508CCAD1 001	10-18-57	20	40	81	104	104.00	--	--
SB01200508CCAD1 001	02-17-58	20	0	81	104	104.00	--	--
SB01200508CCAD1 001	02-25-58	20	0	81	104	104.00	--	--
SB01200508CCAD1 001	10-30-59	380	20	81	104	104.00	--	--
SB01200508CCAD1 001	12-03-59	350	70	81	104	104.00	--	--
SB01200508CCAD1 001	01-01-60	0	20	81	104	104.00	--	--
SB01200508CCAD1 001	04-27-65	40	250	81	104	104.00	--	--
SB01200508CCAD1 001	11-30-65	--	18400	81	104	104.00	--	--
SB01200508CCAD1 001	02-02-66	--	–	81	104	104.00	--	--
SB01200508CCAD1 001	04-14-66	0	60	81	104	104.00	--	--