CHEMICAL ANALYSES—Continued

a = field determination using HACH* test kit KI-12; b = field determination using HACH test kit IR-18B; c = estimated from bicarbonate values; d = nitrate sample collected between 1970 and 1976; e = arsenic and nitrate sample collected between February 1976 and September 1977

Map no.	Location	Arsenic (As) (µg/L)	Nitrate NO_3 (as N) (mg/L)	Iron (Fe) (mg/L)	Hardness as $CaCO_3$ (mg/L)	Sampling date
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

CHEMICAL ANALYSES—Continued

a = field determination using HACH test kit KI-12; b = field determination using HACH test kit IR-18B; c = estimated from bicarbonate values; d = nitrate sample collected between 1970 and 1976; e = arsenic and nitrate sample collected between February 1976 and September 1977

Map no.	Location	Arsenic (As) (µg/L)	Nitrate NO_3 (as N) (mg/L)	Iron (Fe) (mg/L)	Hardness as $CaCO_3$ (mg/L)	Sampling date
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

CHEMICAL ANALYSES—Continued

a = field determination using HACH test kit KI-12; b = field determination using HACH test kit IR-18B; c = estimated from bicarbonate values; d = nitrate sample collected between 1970 and 1976; e = arsenic and nitrate sample collected between February 1976 and September 1977

Map no.	Location	Arsenic (As) (µg/L)	Nitrate NO_3 (as N) (mg/L)	Iron (Fe) (mg/L)	Hardness as $CaCO_3$ (mg/L)	Sampling date
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

CHEMICAL ANALYSES—Continued

a = field determination using HACH test kit KI-12; b = field determination using HACH test kit IR-18B; c = estimated from bicarbonate values; d = nitrate sample collected between 1970 and 1976; e = arsenic and nitrate sample collected between February 1976 and September 1977

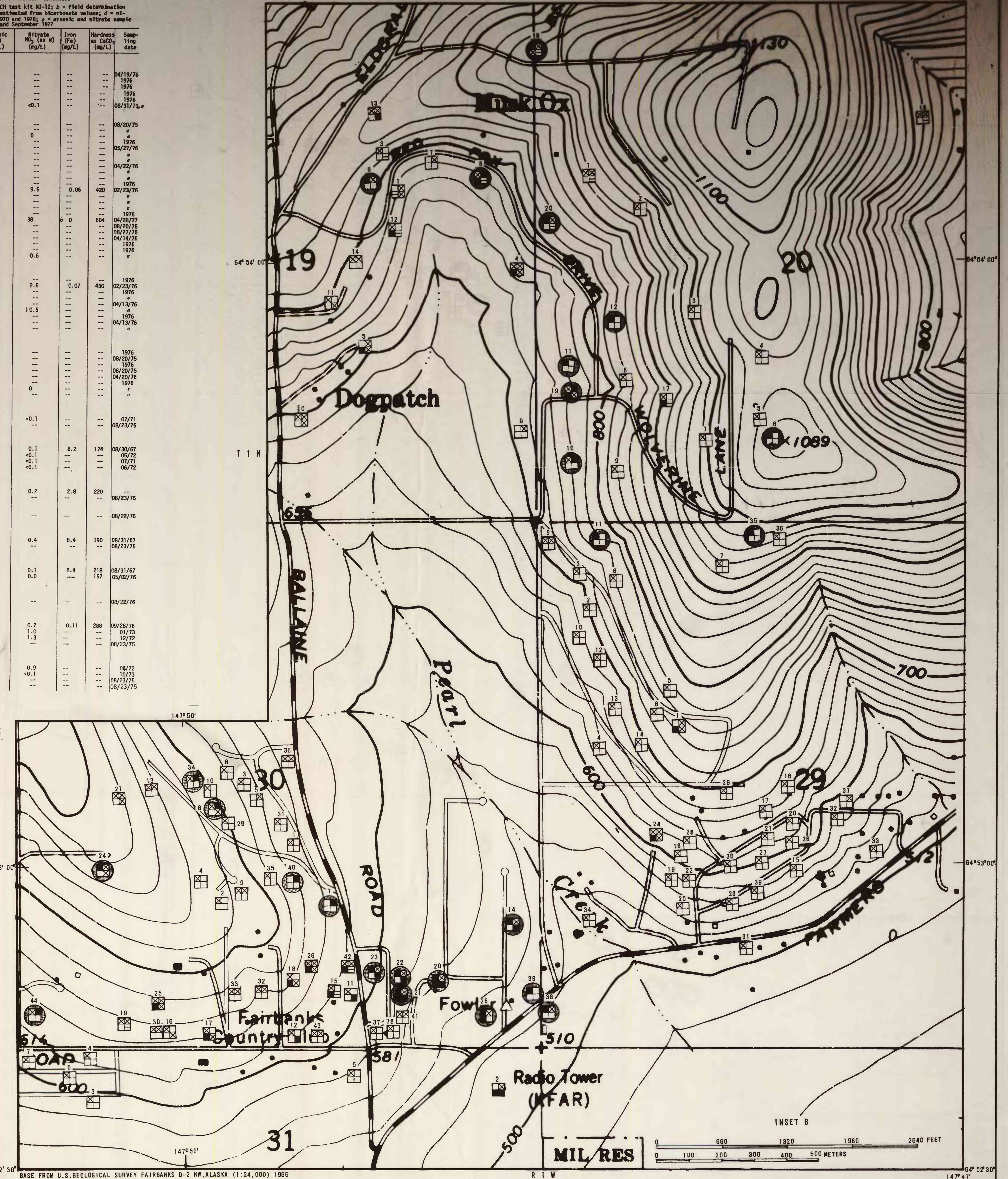
Map no.	Location	Arsenic (As) (µg/L)	Nitrate NO_3 (as N) (mg/L)	Iron (Fe) (mg/L)	Hardness as $CaCO_3$ (mg/L)	Sampling date
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

CHEMICAL ANALYSES—Continued

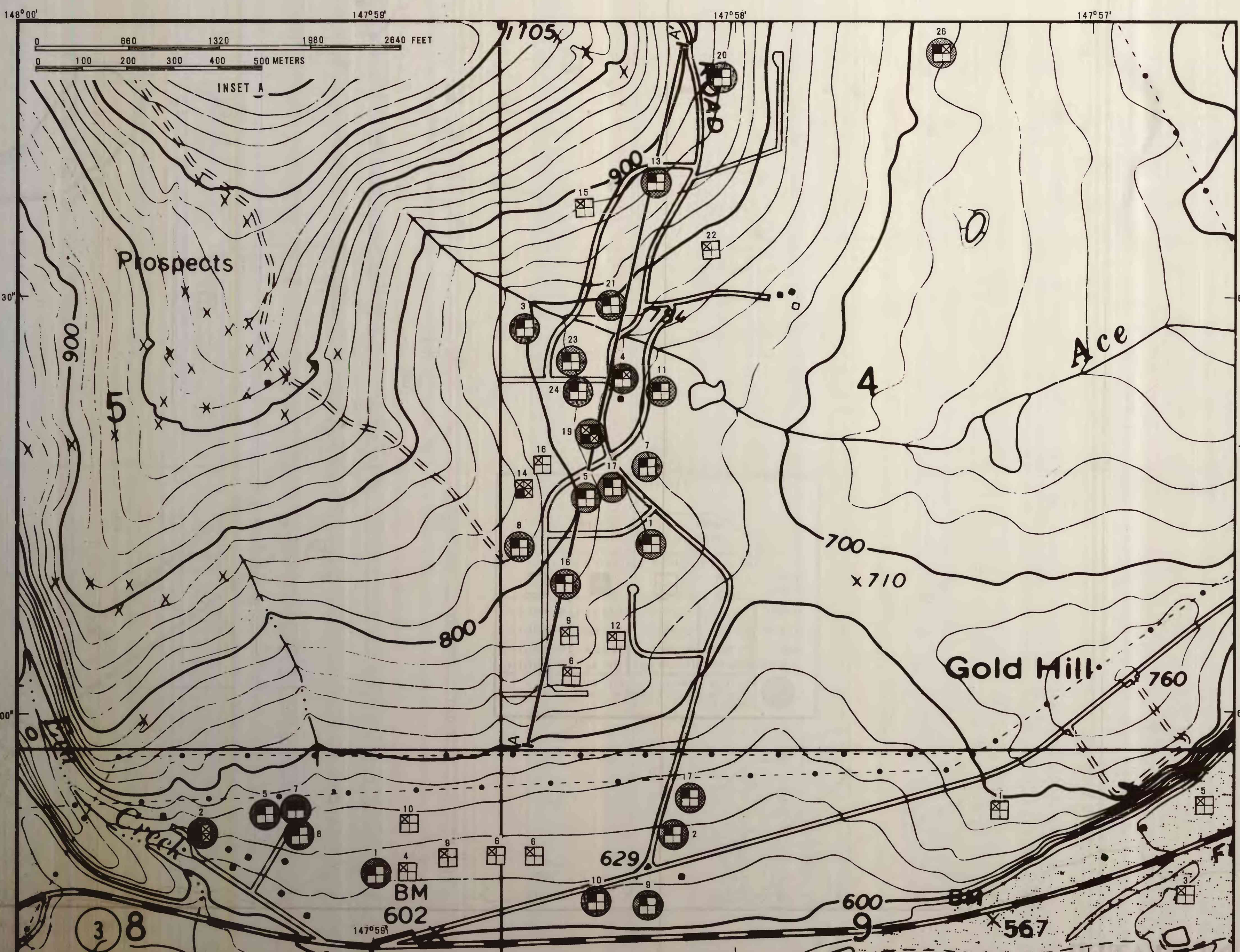
a = field determination using HACH test kit KI-12; b = field determination using HACH test kit IR-18B; c = estimated from bicarbonate values; d = nitrate sample collected between 1970 and 1976; e = arsenic and nitrate sample collected between February 1976 and September 1977

Map no.	Location	Arsenic (As) (µg/L)	Nitrate NO_3 (as N) (mg/L)	Iron (Fe) (mg/L)	Hardness as $CaCO_3$ (mg/L)	Sampling date
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

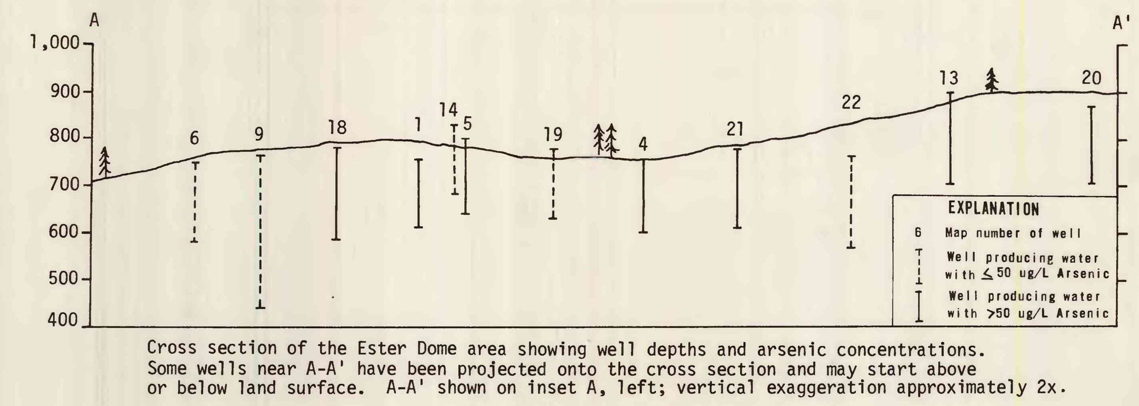
*Use of brand names in this report is for identification only and does not imply endorsement by the U.S. Geological Survey.



BASE FROM U.S. GEOLOGICAL SURVEY FAIRBANKS D-2 NW, ALASKA (1:24,000) 1966



BASE FROM U.S. GEOLOGICAL SURVEY FAIRBANKS D-2 SW, ALASKA (1:24,000) 1966



Cross section of the Ester Dome area showing well depths and arsenic concentrations. Some wells near A-A' have been projected onto the cross section and may start above or below land surface. A-A' shown on inset A, left; vertical exaggeration approximately 2x.

CONVERSION TABLE

Multiply American units	by	to obtain metric units
feet (ft)	0.3048	meters (m)
gallons per minute (gal/min)	0.0631	liters per second (L/s)

A microgram, as in micrograms per liter (µg/L), is the standard reporting unit for some chemical constituents, and is 1/1000 of a milligram.

EXPLANATION

ARSENIC — NITRATE — HARDNESS — IRON; Map number assigned within each section (See table of chemical analyses, Sheet 2)

VALUE / SYMBOL				
ARSENIC	<50 µg/L	---	≥ 50 µg/L	No analysis
NITRATE	<10 mg/L	---	≥10 mg/L	No analysis
IRON	<1 mg/L	1-3 mg/L	>3 mg/L	No analysis
HARDNESS	<100 mg/L	100-200 mg/L	>200 mg/L	No analysis

Well with arsenic or nitrate concentration exceeding U.S. Environmental Protection Agency standard.

INTRODUCTION

Ground water from selected wells in the Fairbanks area has been sampled and analyzed by several agencies since 1945. The analyses and interviews with homeowners have indicated that hardness and the concentrations of arsenic, nitrate, iron are the four chemical characteristics of greatest concern to planners and homeowners in the Fairbanks area.

This report, prepared in cooperation with the Fairbanks North Star Borough, the U.S. Environmental Protection Agency (EPA), and the Alaska Department of Environmental Convervation (ADEC), summarizes the arsenic, nitrate, iron and hardness data presently available for ground water in the Fairbanks area. Data are from a number of sampling programs conducted since 1945 by the U.S. Geological Survey (USGS), EPA Alaska Water Laboratory, Center for Disease Control (CDC), and ADEC. In each of these programs, samples were analyzed for the constituents that were of interest at the time. As a result, many of the samples were not analyzed for all four constituents included in this study. For example, USGS samples collected prior to 1975 were generally not analyzed for arsenic; data from the EPA consist of nitrate analyses only; ADEC samples were analyzed only for arsenic and nitrate, and data from CDC consist of arsenic analyses only. The samples were obtained through solicitation of homeowners or at their request; therefore, not every well in the area was sampled. The maps show only the concentration of the selected constituents found in sampled wells. Because water quality may undergo significant changes over short distances, the map should not be used in place of sampling and analysis in the determination of water quality of unsampled wells or areas. However, the presence of several contaminated wells in one area indicates that other wells in the same area have a high probability of being contaminated.

Ground water in the Fairbanks area is drawn from two aquifers, the bedrock aquifer of the uplands and the alluvial aquifer of the lowlands. A line separating the uplands from the lowlands has been arbitrarily drawn at approximately the 500 foot elevation contour. Throughout much of the lowlands, particularly the flood plains of the Tanana and Chena Rivers, the aquifer is capable of yielding hundreds of gallons of water per minute to properly constructed wells. The alluvial aquifer between the Tanana and Chena Rivers is recharged chiefly by the Tanana River. In the uplands a fractured metamorphic-bedrock aquifer is commonly overlain by silt and obtains water from local recharge. Wells in the uplands generally yield 2 to 10 gallons per minute.

DISCUSSION OF CHEMICAL PARAMETERS

Arsenic

A dose of 70,000 micrograms (µg), or less than 1 ounce of pure arsenic, is toxic to humans (Luh and others, 1973). The toxic level may vary with the tolerance of the individual and probably depends on the chemical form of the arsenic (National Academy of Sciences, National Academy of Engineering, 1974). Smaller quantities taken over a long period of time can accumulate in the body and produce chronic or acute arsenic poisoning. Its varied symptoms include fatigue, skin growths, nervous system disturbances, and gastro-intestinal, kidney and liver ailments. In Taiwan the consumption of water containing more than 300 µg/L arsenic has been correlated with increased incidences of skin cancer.

Because of the health problems associated with the ingestion of arsenic, the State of Alaska and the EPA recommend that arsenic concentrations not exceed 50 µg/L in drinking water (U.S. Environmental Protection Agency, 1975).

The primary source of arsenic and the mechanisms by which it enters ground water in the Fairbanks area have not been conclusively demonstrated. However, mineralized bedrock in the Fairbanks area commonly contains an arsenic-bearing material, arsenopyrite (FeAsS). Scorodite ($FeAsO_4 \cdot 2H_2O$), a mineral formed by the weathering of arsenopyrite, may also be a source of arsenic within the bedrock. A bedrock source is indicated because all the wells with water having arsenic concentrations above EPA standards are completed in bedrock.

Although a study in Nova Scotia concluded that, in that area, leachate from mine tailings may have significantly increased arsenic concentrations in shallow aquifers (Grantham and Jones, 1977), arsenic contamination of ground water near Fairbanks does not seem to correlate with placer or other mining activities. Many wells contaminated by arsenic do not occur in areas of mining activity. For example, wells in sec. 20, T. 1 N., R. 1 W. are remote from mining activities and are upgradient from creeks which might contain leachate from mine tailings.

Arsenic concentrations in Fairbanks-area ground water range from 0 to 10,000 µg/L. No ground water containing more than 50 µg/L arsenic was found on the flood plain, but many wells in the uplands to the north yield water with more than 50 µg/L arsenic. Distribution of arsenic-contaminated wells is sporadic. In many places, arsenic-contaminated wells and those with low arsenic concentrations are only a few hundred feet apart (for example wells 7 and 8 in sec. 14, T. 1 N., R. 1 W.). In some places, this is caused by the presence of two or more intervals bearing water with different concentrations of arsenic (Nelson, 1978). The concentration of arsenic in the well water depends on which interval was tapped. If two or more intervals are tapped by a well, the arsenic concentration may also vary with the yield of each zone. The concentration of arsenic may also vary with the duration of pumping, the settling time in a pressure tank, and precipitation reactions in the water.

Homeowners in the uplands should be aware of the sporadic distribution of arsenic-contaminated wells and realize the potential health hazards of arsenic. As sampling density increases, the extent of arsenic contamination in wells will become better defined.

Arsenic dissolved in water is colorless, odorless, tasteless and is not removed by water-treatment systems commonly used by homeowners.

Nitrate

The element nitrogen (N) occurs in ground water in many forms, including nitrate (NO_3), nitrite (NO_2) and ammonium ion (NH_4). Nitrogen is most commonly found in ground water as nitrate (NO_3). Most samples in this report were analyzed for the sum of nitrate plus nitrite. The results may be reported as NO_3 or N. To convert a NO_3 value to its equivalent as N, divide by 4.4. In this report, all nitrate values are reported as N.

Ingestion of water containing more than 10 milligrams per liter (mg/L) nitrate may be related to hypertension, cancer, and, in some infants under 3 months of age, potentially fatal anemia. Bacterial conversion of the nitrate ion to the nitrite ion may occur in the digestive tract of infants less than 3 months of age (National Academy of Sciences, National Academy of Engineering, 1974). Nitrite absorbed into the bloodstream combines with the hemoglobin, reducing the oxygen-carrying capacity of the blood. The result, called methemoglobinemia, is oxygen starvation and results in the so-called "blue baby", a condition which can be recognized and reversed. However, many infants have consumed water containing more than 10 mg/L nitrate with no adverse effects. Factors which may affect susceptibility to nitrate poisoning include heredity, the ingestion of nitrate-rich vegetables and vitamin C-rich foods, and the use of certain medications which affect nitrate metabolism. Because of the possibility of causing methomoglobinemia, hypertension and cancer, the EPA has set the recommended maximum nitrate concentration in drinking water at 10 mg/L.

Metamorphic minerals such as those in bedrock of the Fairbanks area do not contain oxidized nitrogen. Thus, in the Fairbanks area nitrate in ground water probably originates near the surface, where septic tank effluents, fertilizers or natural soil nitrates are possible sources.

Nitrate and chloride are major components of human and animal wastes, and abnormally high concentrations of both suggest pollution by these wastes (Brown, Skougstad and Fishman, 1970). In the Fairbanks area, ground water with concentrations of nitrate above EPA standards does not have high chloride concentrations. Fertilizers may also contribute nitrates to the soil, but they have not been used extensively in most of the study area.

Water sampled in the Fairbanks area had nitrate concentrations ranging from 0 to 59 mg/L; in most wells concentrations were less than 10 mg/L. Seventy-nine percent of the wells yielding water with more than 10 mg/L nitrate are at altitudes of 600-800 ft (180-240 m). Only one sample on the flood plain exceeded 10 mg/L nitrate.

The occurrences of high nitrate concentrations in ground water are unpredictable. As the sampling density increases, the extent of the nitrate contamination in wells will become better defined. Until the source of nitrate and the areas affected by high nitrate concentrations are better known, all homeowners using private wells should be aware of the potential health hazard.

Nitrate is another colorless, odorless and tasteless constituent that is not removed by conventional water treatment systems commonly used by homeowners.

Iron

Water rich in iron becomes unpalatable long before harmful effects to humans are noticed. Even small amounts of iron can make water smell and taste bad and cause staining of laundry and appliances. The EPA has set 0.3 mg/L as the recommended maximum concentration of iron in public water supplies (U.S. EPA, 1976). Only 16 percent of the sampled wells in the Fairbanks area have iron concentrations less than this limit, and many homeowners in the Fairbanks area have expressed satisfaction with their water if it contains less than 1 mg/L of iron. Staining caused by water with iron concentrations of less than 1 mg/L can be effectively controlled by cleaning agents and bleaches. At concentrations between 1 and 3 mg/L, water may become unpalatable and staining becomes more difficult to control. Water with more than 3 mg/L of iron is esthetically unpleasant to many people, turns alcohol or coffee black, and makes staining difficult to control without the use of iron filters. Based on these considerations, three ranges of concentrations are portrayed on the map: less than 1 mg/L, 1 to 3 mg/L, and more than 3 mg/L.

The decomposition of organic matter in soils consumes oxygen from ground water and produces oxygen-deficient environments in which iron is more readily dissolved. Such conditions are common in the alluvium of the Tanana River floodplain and in creek valley bottoms. With few exceptions, iron concentrations in these areas exceed 1 mg/L, and most wells yield water with more than 3 mg/L of iron.

Iron concentrations in ground water are generally high in the Fairbanks area, the known maximum being 26 mg/L. They are lower near the ridgetops and in a small percentage of wells near the river. On the high ridgetops near Fairbanks, precipitation commonly falls directly onto bedrock or on a thin cover of wind-blown silt (loess) and infiltrates with little exposure to buried organic material. Iron is less soluble in such water and ground water under the ridgetops may be influenced by this source of water low in iron. Water in 60 percent of the sampled wells completed in bedrock contains less than 1 mg/L of iron. The iron concentrations generally increase downslope from the ridgetops. This increase may result from exposure of percolating ground water to buried organic material in hillside colluvium or alluvium of the upper creek valleys. It may also result from inorganic oxidation reactions during the increased time the water is underground as it moves from the recharge area on the ridgetops toward the valleys.

When iron-rich water is oxygenated as it is in home water systems, the iron precipitates and causes iron stains. Iron-removal systems which oxidize household water and filter the resulting precipitated iron are commercially available.

Certain bacteria speed the oxidation and precipitation of iron (Hem, 1970). These bacteria live in many wells and cause some of the iron to precipitate before it reaches a plumbing outlet. They produce a jelly-like slime that can eventually plug the pore spaces in the aquifer near the wells and slow the influx of water. Slimy masses can break loose and plug pipes and filters. Heavy chlorination of the wells at frequent intervals minimizes the development of iron bacteria; however, once they are established in an aquifer near a well, there is no known effective method of removing or destroying them.

Hardness

Hardness of water is caused mainly by the presence of dissolved calcium and magnesium and is expressed as an equivalent quantity of calcium carbonate. Hard water not only retards the cleaning action of soap and detergents, but can also form scale on cookware, in water heaters, and in boilers. However, the hardness of water can be controlled by commercially available softeners. Hard water may also have some beneficial effects. In the United States, a tentative correlation has been suggested between areas of hard water and areas where the death rate from cardiovascular diseases is lower than average (Muss, 1962).

The hardness of ground water depends on the length of time the water has been in contact with minerals, the nature of the minerals, and the corrosiveness (acidity) of the water. Calcium carbonate, a common mineral in bedrock of the Fairbanks area, is particularly susceptible to attack by acidic water and may contribute to the hardness of local ground water.

Hem (1970) stated that waters containing less than 100 mg/L hardness are generally acceptable for domestic use, although the optimum amount is a matter of consumer preference. At levels above about 200 mg/L, hardness becomes evident in all uses. The EPA provides no recommended maximum or minimum levels of concentration for hardness of water. In light of Hem's observations, three ranges are portrayed on the map: less than 100 mg/L, 100 to 200 mg/L, and more than 200 mg/L.

Hardness of ground-water samples from the Fairbanks area ranges from 17 to 1,220 mg/L. Hardness was more than 200 mg/L in 50 percent of the wells sampled and less than 100 mg/L in only 7 percent. All but one of the samples containing less than 100 mg/L hardness were from wells situated along the ridgetops at altitudes of more than 950 ft (290 m). Hardness appears to increase downslope and is higher in wells at the base of the uplands.

REFERENCES CITED

Brown, Eugene, Skougstad, M.W., and Fishman, M.J., 1970, Methods for collection and analysis of water samples for dissolved minerals and gases: U.S. Geological Survey Techniques for Water Resources Investigations, Book 5, Chapter A-1, 160 p.

Grantham, D.A., and Jones, J.F., 1977, Arsenic contamination of water wells in Nova Scotia: American Water Works Association Journal, v. 69, no. 12, p. 653-657.

Hem, J.D., 1970, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 1473, 363 p.

Luh, M.D., Baker, R.A., and Henley, D.E., 1973, Arsenic analysis and toxicity - A review: Science of the Total Environmental, v. 2, no. 1, p. 1-12.

Muss, D.L., 1962, Relationship between water quality and deaths from cardiovascular disease: American Water Works Association Journal, v. 54, p. 1371-1378.

National Academy of Sciences, National Academy of Engineering, 1974, Water quality criteria, 1972: U.S. Government Printing Office, 594 p.

Nelson, G.L., 1978, Packer tests identify arsenic-producing zones in bedrock wells (abs): Ground Water, v. 16, no. 5, p. 363.

U.S. Environmental Protection Agency, 1975, National interim primary drinking water regulations: Federal Register, v. 40, no. 248, Wednesday, December 24, 1975, Part IV, p. 59566-59587. [Effective June 24, 1977.]

U.S. Environmental Protection Agency, 1976 [1977], Quality criteria for water: U.S. Government Printing Office, 256 p.

PUBLICATIONS RELATING TO WATER-QUALITY REGULATIONS AND CRITERIA

Mandatory Limits - Primary drinking water regulations

Microbiological, physical, and selected inorganic and organic chemical constituents:

U.S. Environmental Protection Agency, 1975, National interim primary drinking water regulations: Federal Register, v. 40, no. 248, Wednesday, December 24, 1975, Part IV, p. 59566-59587. [Effective June 24, 1977.]

Recommended Limits - Secondary drinking water regulations

U.S. Environmental Protection Agency, 1977, National secondary drinking water regulations: Federal Register, v. 42, no. 62, Thursday, March 31, 1977, Part I, p. 17143-17147.

Water-quality Criteria

National Academy of Sciences, National Academy of Engineering, 1974, Water quality criteria, 1972: U.S. Government Printing Office, 594 p.

U.S. Environmental Protection Agency, 1976 [1977], Quality criteria for water: U.S. Government Printing Office, 256 p.

State water-quality reports

State of Alaska, Title 18, Environmental Conservation, Chapter 10, Water Quality Standards. [In revision as of April 1978.]

ARSENIC, NITRATE, IRON, AND HARDNESS IN GROUND WATER, FAIRBANKS AREA, ALASKA

By PAULA JOHNSON, D.E. WILCOX, W.D. MORGAN, JOSEPHINE MERTO, AND RUTH McFADDEN

1978