HYDROLOGIC INFORMATION FOR LAND-USE PLANNING, FAIRBANKS VICINITY, ALASKA

OPEN-FILE REPORT 78-959

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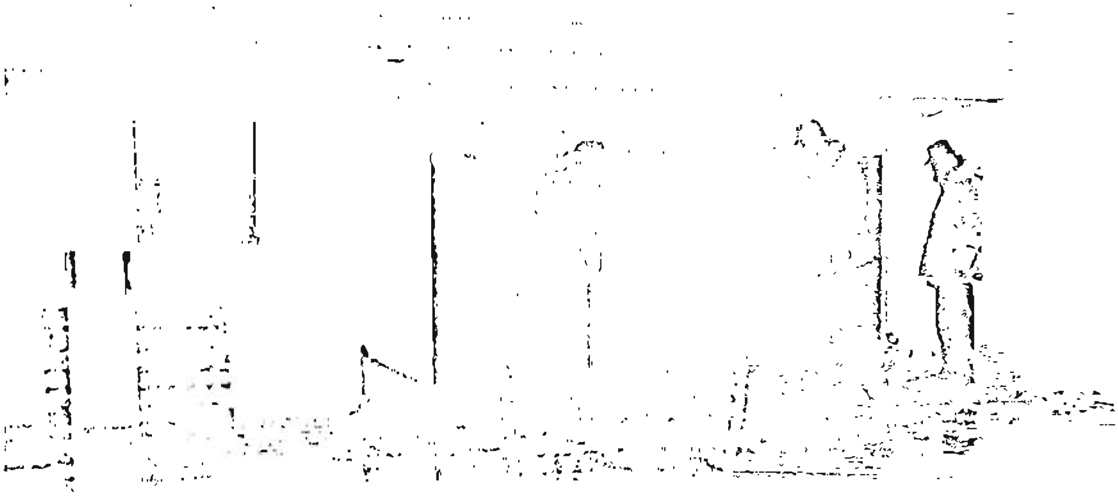

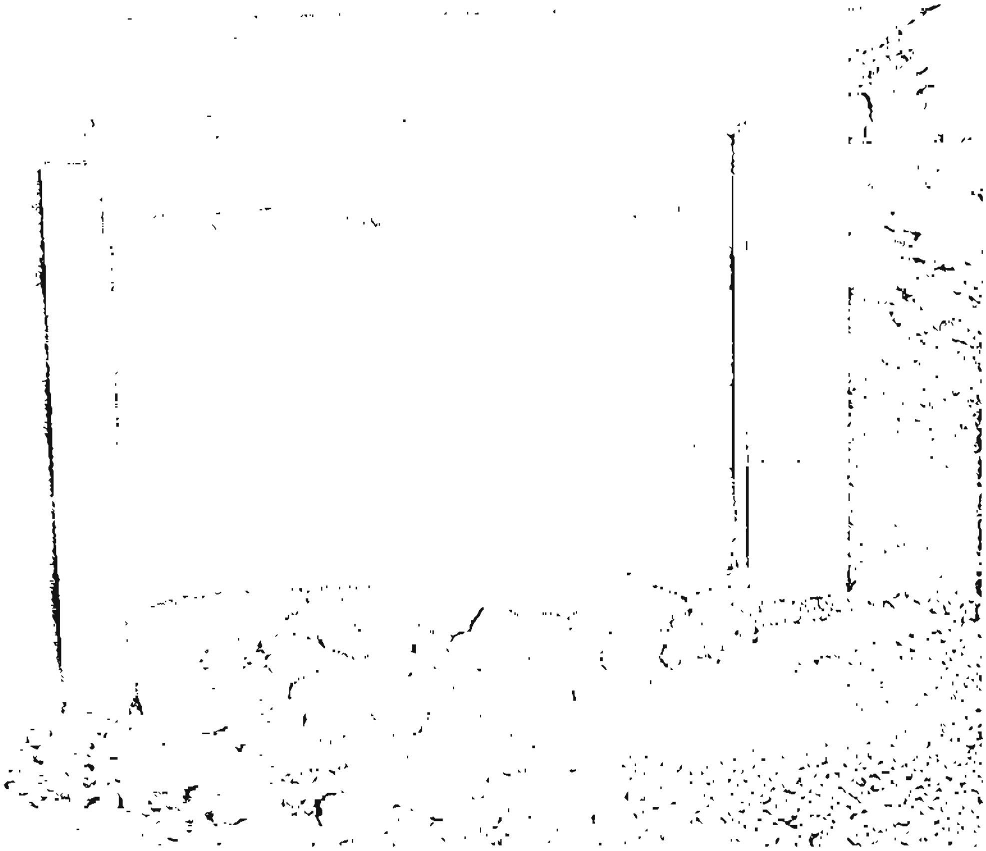

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Prepared in cooperation
with the Fairbanks
North Star Borough,
U.S. Environmental
Protection Agency,
and U.S. Army Corps
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HYDROLOGIC INFORMATION FOR LAND-USE PLANNING

FAIRBANKS VICINITY, ALASKA

by

Gordon L. Nelson

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Anchorage, Alaska

1978

UNITED STATES DEPARTMENT OF THE INTERIOR

Cecil B. Andrus, Secretary

GEOLOGICAL SURVEY

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FIGURES--Continued

INCH-POUND UNITS AND SI UNITS EQUIVALENTS

SI, International System of Units, is a modernized metric system of measurement. All values have been rounded to four significant digits. Note that the style "meter²" rather than "square meter" has been used for convenience in finding units in this table. Where the units are spelled out in the text, Survey style is to use "square meter".

Multiply Inch-pound unit	by	to obtain SI unit equivalent
Length		Length
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		Area
foot² (ft²)	0.09290	meter² (m²)
acre	0.4047	hectare (ha)
Volume		Volume
gallon (gal)	3.785	liter (L)
Volume per unit time (flow)		Volume per unit time (flow)
foot³ per second (ft³/s)	0.02832	meter³ per second (m³/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
Hydrologic properties		Hydrologic properties
Transmissivity		Transmissivity
foot² per day (ft²/d)	0.09290	meter² per day (m²/d)
Unit runoff or recharge		Unit runoff or recharge
gallon per year per acre [(gal/yr)/acre]	1.532	liter per year per hectare [(L/yr)/ha]
Hydraulic conductivity		Hydraulic conductivity
foot per day (ft/d)	0.3048	meter per day (m/d)
Gradient		Gradient
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)

HYDROLOGIC INFORMATION FOR LAND-USE PLANNING

FAIRBANKS VICINITY, ALASKA

By Gordon L. Nelson

NONTECHNICAL SUMMARY

Eielson Air Force Base, Fort Wainwright, and the cities of North Pole and Fairbanks are on the flood plain of the Chena and Tanana Rivers. The flood-plain area has abundant water resources in the rivers and an alluvial aquifer.

The rolling hills to the north of the flood plain are underlain by bedrock. A layer of wind-blown silt overlies bedrock in many areas. The thickness of the silt layer on any hill increases in a downslope direction. Over the entire area, the silt cover is thinner to the north.

Permafrost, which is a barrier to ground-water movement, underlies most north-facing slopes and lower parts of south-facing slopes, and occurs sporadically throughout the rest of the uplands and the flood plains. Well-drained south-facing slopes are generally free of permafrost.

Most of the 11.22 inches per year (in./yr) of precipitation (rain and snow) which falls on Fairbanks either runs off as surface flow or is lost to the atmosphere by evaporation or the activity of vegetation. Only a small fraction infiltrates to the water table. From 1972-76 when this study was made, precipitation was about 26 percent less than the long-term average.

During the summer the Tanana River is fed by rainfall and by meltwater from glaciers and snowfields in the Alaska Range. The cooler weather which often accompanies heavy rains decreases the rate of melting; hot weather during periods of no rain increases the rate of melting. Thus the two sources compensate each other. The year's maximum discharge usually occurs in July, and its minimum occurs during late winter when the river is fed by ground water and glacial meltwater.

The Chena River receives water from spring snowmelt, rainfall, and ground water. It commonly has two periods of high discharge each year. The first is caused by spring snowmelt and the second is caused by late summer rainstorms.

Flooding on both rivers will be controlled by the Chena Lakes Flood Control Project being constructed by the U.S. Army Corps of Engineers.

This project consists of a dam across the Chena River northeast of North Pole, a levee along the north bank of the Tanana River, and three drainage ditches north of the levee.

Most ground water in the aquifer under the flood plain flows northwesterly. The Tanana River is the major source of recharge to the aquifer; the Chena River and direct infiltration of precipitation may seasonally contribute some water to the aquifer. At most times the aquifer loses water to the Chena River downstream of the Chena Lakes Dam. Large supplies of ground water (many millions of gallons per day) can be produced from the alluvial aquifer. Heavily pumped wells (such as municipal-supply wells or industrial-use wells) and construction-site dewatering may cause ground-water levels to drop below pump intakes in some shallow wells. However, the capacity of deeper wells should be little diminished.

Poor drainage conditions caused by high ground-water levels may occur near the rivers during periods of sustained high discharge. Ground-water seepage has damaged homes and commercial buildings near the Chena River. High ground-water levels may occur during the winter along Chena Slough and other channels which drain the aquifer.

Water from most sources on the flood plain requires treatment to make it potable. Ground water may require treatment for bacteria, iron, manganese, or odor. Some high-quality ground water requiring no treatment may be available where the aquifer is oxygenated, generally near a source of recharge.

The entire flood plain area is highly susceptible to pollution by septic-tank effluent discharged to seepage pits emplaced within 4 feet (ft) of the water table. If seepage pits are emplaced in permafrost, raw sewage may flow to the land surface. In most areas on the flood plain, wells constructed north, northwest, or west of sources of pollutants (such as seepage pits) will be more susceptible to pollution than those constructed in other directions from these sources.

Ground water from the bedrock aquifer is the principal source of water for domestic consumption in the hills north of the flood plain (the uplands). The depth to water and the yields of wells in the bedrock are highly variable over short distances (on the order of a few hundred feet). However, there appear to be few sites in which a well cannot obtain an adequate domestic supply from the bedrock.

Water enters the bedrock aquifer by direct infiltration of precipitation and snowmelt and leaves it as subsurface flow and as flow from springs on the lower slopes of the hills. Spring discharge has been measured for many of the drainage basins in the Fairbanks area. This amount of water is also a minimum estimate of aquifer recharge in a basin. The annual outflow of ground water from these springs is 8,000-16,000 gallons per acre for basins south of Goldstream and Engineer Creeks. Basins at higher altitudes to the north and east of these creeks yield larger quantities of ground water as springflow (as much as 100,000 gallons per acre for Caribou Creek during 1972).

Most of the water pumped from wells is used and then returned to the ground via septic tanks and seepage pits. Only that part of pumpage that is evaporated or runs off as streamflow actually decreases the quantity of ground water in the aquifer. The difference between pumpage and water returned to the aquifer is the net pumpage, and it is this quantity which diminishes the water stored in the aquifer; the water table will be lowered regardless of whether net pumpage is less or more than actual recharge. Over a period of years a pumpage-induced decline in water levels may cause a reduction in springflow on the lower hills. If net pumpage exceeds the springflow for many years, springs may become dry. This may cause changes in natural vegetation and wildlife habitat in the valley bottoms. Reduction of springflow and reduction of yields to wells might become most pronounced when the drawdowns are superimposed on a period of naturally declining water levels. Net pumpage may also be increased by water waste. Plugged seepage pits cause water waste by allowing effluent to flow to the land surface where it runs off or is evaporated and transpired. Unchecked flowing artesian wells may cause very large water wastage.

The amount of precipitation which recharges the aquifer may be increased by diverting runoff into dry wells or by catchments which hold spring snowmelt until the ground thaws enough to permit infiltration.

Most wells in the uplands yield water of suitable quality for drinking. However, wells that yield water polluted by arsenic and nitrate occur sporadically throughout the uplands. A map by Johnson and others, approved for publication, shows locations of many of these wells. Depending on personal preferences, some homeowners may find that their wells yield water that contains objectionable concentrations of iron and manganese or is excessively hard or has an objectionable odor. No wells in the uplands are known to be polluted by bacteria from septic-tank effluent. The generally great depth to the water table (several tens of feet or more) and good filtering capacities of the silt and some types of decomposed bedrock cause the area to have low pollution susceptibility.

GLOSSARY

Alluvial - Consisting of silt, sand, and gravel deposited by rivers.

Aquifer - A mass of earth material that yields ground water to wells or springs.

Artesian well - Well in which the water level is above the top of the aquifer.

Bedrock - Solid rock underlying unconsolidated surface material (as soil).

Domestic supply - A water supply for a home; 5-15 gallons per minute is considered adequate.

Drawdown - The decline in ground-water levels caused by pumping water from wells.

Dry wells - Pits filled with coarse material; runoff (as from a roof) drains into the dry well and then seeps into the ground.

Discharge - The rate at which water is flowing past any given cross section of a river; usually expressed in cubic feet per second.

Flood plain - A nearly flat, valley bottom along the course of a stream.

Ground water - Water contained in earth materials (below land surface).

Hydraulic conductivity - A measure of the ability of earth materials to conduct natural water (usually expressed as feet per day).

Permafrost - Perennially frozen ground.

Potable - Being of acceptable quality for human consumption.

Seepage pit - A pit into which septic-tank effluent is discharged; The effluent seeps from the pit into the ground.

Septic tank - A tank which allows the solids to settle out of sewage and in which bacterial action may help break down the solids.

Transmissivity - A measure of the capacity of an aquifer to transmit ground water (usually expressed as foot^2 per day).

Water table - The top of the water-saturated materials, defined by water levels in wells.

Yield - The quantity of water which can be produced from a well; it is dependent solely on the well and not on the size of the pump.

INTRODUCTION

This report contains hydrologic information that may be of general interest to private industry, government agencies, and residents of the Fairbanks area and that is not readily available from other sources. The emphasis is on those aspects of hydrology that relate to land use planning. Maps illustrating geology, permafrost distribution, foundation conditions, and construction materials have recently been published (Péwé and Bell, 1975 a-s Péwé and others, 1976 a-c), and a map illustrating and discussing water quality is approved for publication (Johnson and others, approved for publication). Discussion of these topics in this report is superficial and is intended only for emphasis or to provide general information which will aid in understanding other aspects of the text.

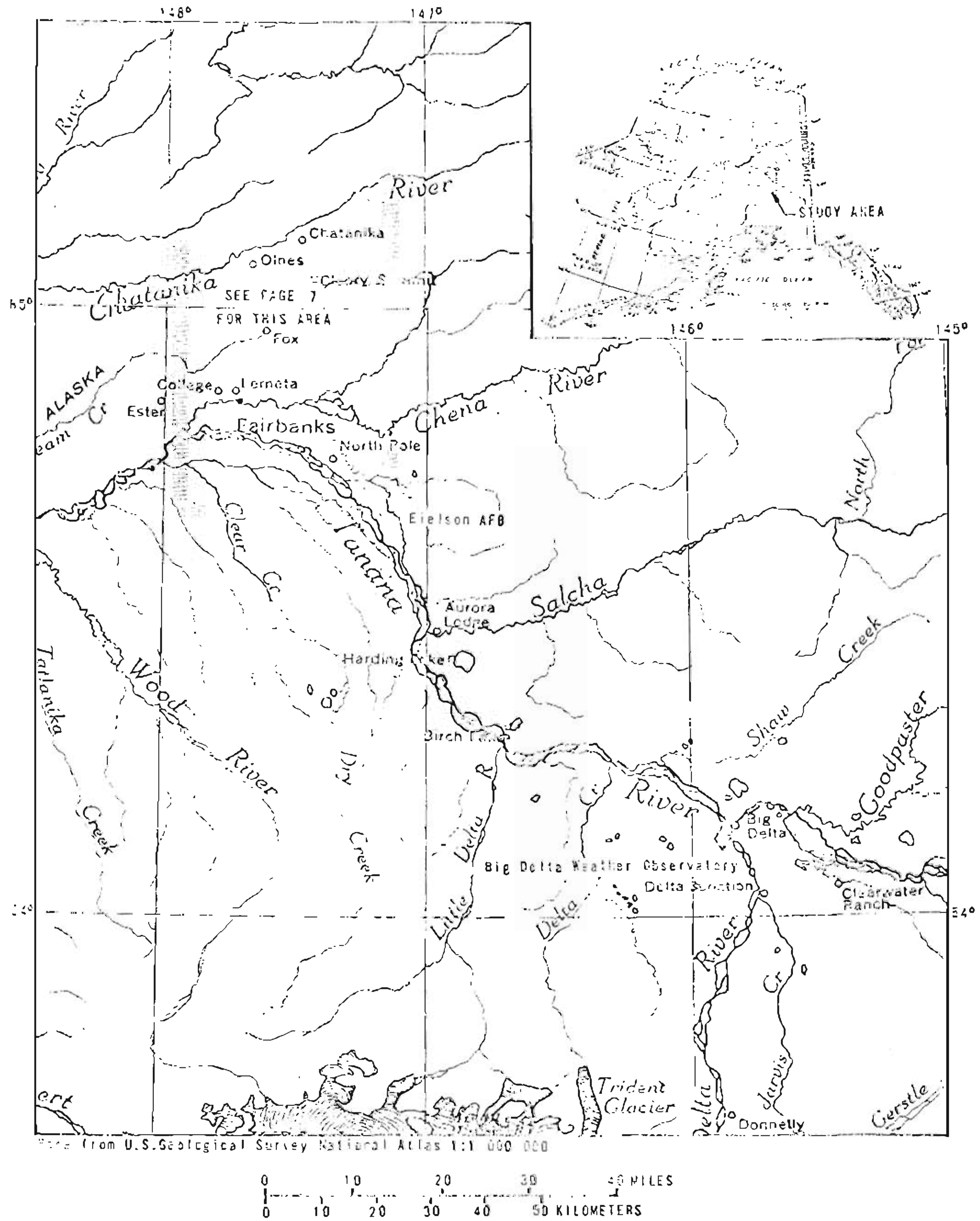
The cities of Fairbanks and North Pole and much of the present residential and commercial development are on the flood plains of the Tanana and Chena Rivers (fig. 1). However, a large part of the residential development and concomitant usage of ground water is occurring in the uplands. Because the flood plain and uplands are hydrologically and physiographically distinct, the problems related to development in one differ significantly from those in the other.

This report is part of a continuing cooperative water-resources investigation between the Fairbanks North Star Borough and the U.S. Geological Survey. The program also received support from the U.S. Environmental Protection Agency during fiscal year 1977, and some of the data on flood-plain hydrology was obtained under an agreement between the U.S. Geological Survey and the U.S. Army Corps of Engineers. The author thanks Fairbanks-area well drillers, consultants, residents, and colleagues at the University of Alaska, all of whom provided much valuable information.

SETTING

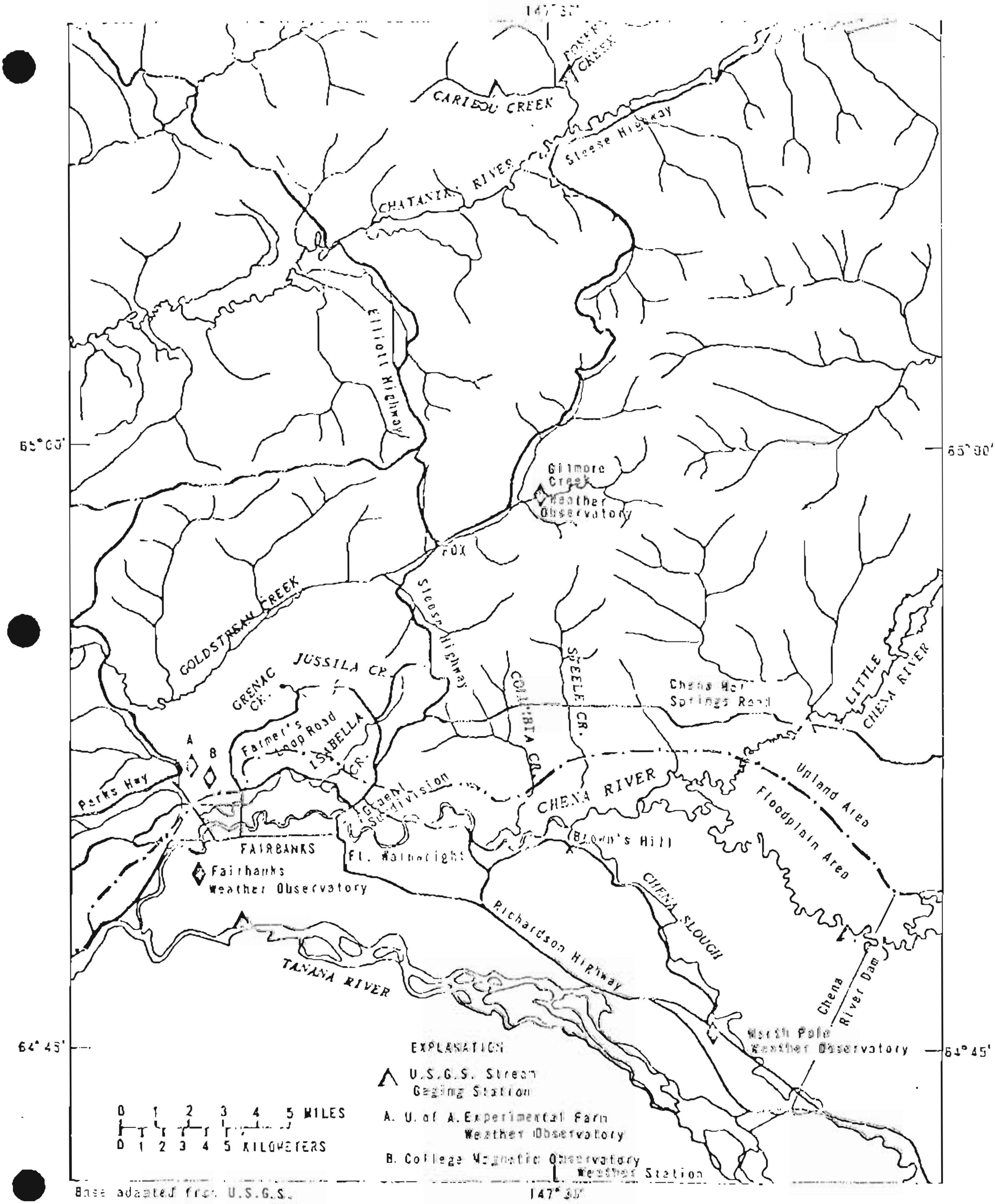
Physiography and geology

The flood plain slopes gently to the west or northwest at about 5 feet per mile (ft/mi). A maximum relief of about 200 ft is provided by Brown's Hill near Badger Road (fig. 1). In the uplands north of the flood plain, some hills reach altitudes greater than 1,500 ft. Some terms which describe physiographic and geologic features of the uplands are illustrated in figure 2. The ridgetop is the zone in which a silt cover is largely absent, although as much as 2 ft of silt may exist in small depressions and near the boundaries between the ridgetop and adjacent zones. North-facing slopes and valley bottoms may be underlain by many tens of feet of permanently frozen silt. The south-facing slopes are subdivided into a lower south slope and an upper south slope. The lower south slope is that part of the hills formed by fluvial redeposition of silt from higher elevations. It is commonly underlain by many tens of feet of permanently frozen silt. The upper south slope is underlain by eolian silt that is not permanently frozen in most places.



Base from U.S. Geological Survey National Atlas 1:1 000 000

Figure 1.--Locations of stream-gaging stations and weather stations of the Fairbanks area and physiographic and geographic features mentioned in the text.



Base adapted from U.S.G.S.
Fairbanks, Alaska, 1:250,000

Figure 1.--Locations of stream-gaging stations and weather stations of the Fairbanks area and physiographic and geographic features mentioned in the text--continued.

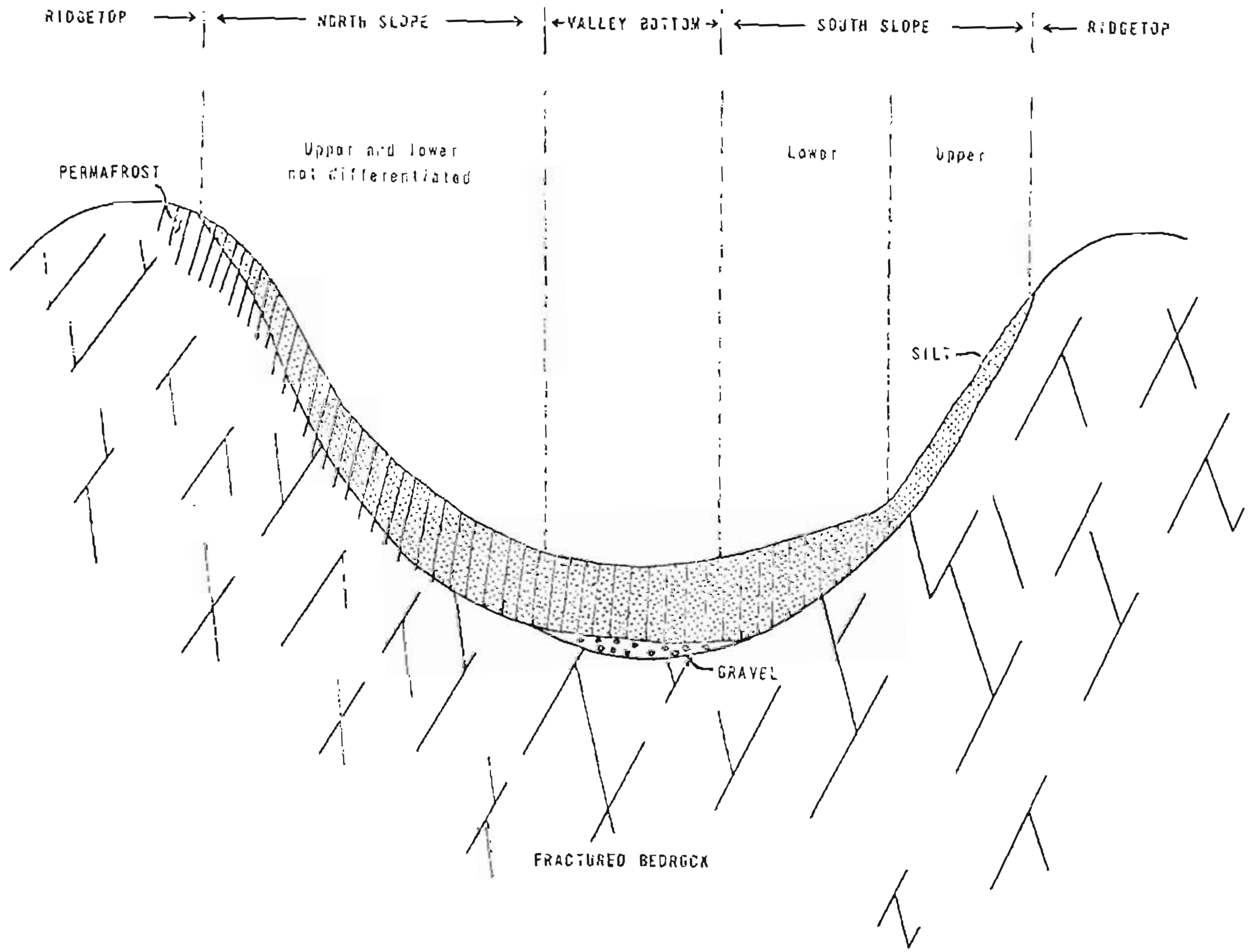


Figure 2.--Schematic section showing physiographic and geologic terms used to describe the uplands.

Bedrock under the Fairbanks area is predominantly a metamorphosed marine mud deposit, termed a pelitic schist. Where the former mud grades into what were limy mud, calcium-carbonate deposits or quartz sands, metamorphosis has resulted in calc-mica schist, marble, or quartzite, respectively. Péwé and others (1976) therefore describe bedrock as "a metamorphic complex composed predominantly of pelitic schist and micaceous quartzite with subordinate calc-mica schist, amphibolite, and marble." The schist is locally intruded by granitic rocks (primarily granite and quartz diorite). Basalt occurs in scattered outcrops east of Fort Wainwright.

The capacity of the various types of bedrock to store and transmit water may vary significantly over distances of only a few feet. Materials sampled by drilling and coring in bedrock in the Fairbanks vicinity have ranged from clay (probably formed of decomposed schist) having an estimated hydraulic conductivity of less than 10^{-4} feet per day (ft/d) to heavily fractured quartzite having an estimated hydraulic conductivity of more than 1,000 ft/d.

In the uplands, bedrock is commonly overlain on the upper slopes by windblown (eolian) silt, or loess, and on the lower slopes by silt which has been reworked by running water and soil creep. In the creek valley bottoms, coarse gravel lies on bedrock and is, in turn, covered by reworked silt.

The loess was derived from the glacial outwash of the Tanana River to the south. As the winds carried the silt northward, the quantity of silt falling from suspension decreased with increasing distance from the source. The ridge system overlooking Farmer's Loop Road therefore has a thicker silt cover than the hills on the north side of the valley of Goldstream Creek. Still farther to the north, the hills overlooking the Chatanika River have little silt.

Reworked silt attains its maximum thickness on the lower slopes and creek valley bottoms. Along the lower flanks of the first ridge system north of the flood plain, this maximum thickness may commonly be more than 100 ft. Reworked loess, locally called muck, is, in most areas, perennially frozen and commonly has a high ice content.

Hydraulic conductivity of thawed silt in the uplands varies, but is uniformly too low to yield significant quantities of water to wells. However, in most areas the vertical hydraulic conductivity of the silt is adequate to allow downward percolation of precipitation and to permit the proper functioning of on-site sewage-disposal systems.

Unconsolidated alluvium deposited by the Chena and Tanana Rivers underlies the flood plain. The maximum thickness of alluvium penetrated by a drill is 616 ft at the Chena River dam site (fig. 1) (Earl Chandler, 1976, oral commun.), although Barnes (1961) reported a seismically determined thickness of 800 ft at a site 2 miles (mi) south of Fairbanks. At Fort Wainwright (fig. 1), numerous wells drilled to depths as great as 326 ft failed to reach bedrock (Feulner, 1961).

Permafrost

The Fairbanks area is underlain by discontinuous permafrost (perennially frozen ground). Maps by Péwé and Bell (1974, 1975d, h, l, p) show the distribution of permafrost in the study area.

In the uplands, permafrost is common on north-facing slopes and in the valley bottoms; south- and west-facing slopes are more likely to be free of permafrost. Where permafrost occurs in the bedrock, it normally has a low ice content, and the land surface is not disrupted when melting occurs. Silt - especially that which has been fluvially redeposited in the valley bottoms - commonly has a high ice content. When this permafrost melts, the land surface and near-surface materials can be disrupted enough to destroy foundations, roads, sewer and water lines, and leach fields.

Permafrost is virtually impervious. However, significant quantities of water may flow upward through thawed conduits in otherwise extensive area of permafrost. Thawed conduits are commonly evident at the land surface as springs and springfed ponds and lakes.

Permafrost underlies much of the flood plain. In general, however, frozen sand and gravel tends to have low ice content, and melting of such materials does not result in significant disruption of the land surface. Slough and swale deposits, which fill old channel scars and topographic depressions, consist of organic-rich silt and may have high ice content. These can be avoided for most construction purposes because they are of small areal extent, and relocation to a more favorable setting is generally possible.

The presence or absence of permafrost on the flood plain has a significant effect on the costs of installing and maintaining a well. In areas free of permafrost, domestic wells are commonly less than 30 ft deep, and many are driven wells constructed by the homeowner at modest expense. In areas underlain by permafrost, wells commonly must be drilled many tens of feet to reach thawed alluvium. Not only is the original construction cost greater in permafrost areas, but keeping wells thawed also increases maintenance costs.

Precipitation

In the vicinity of Fairbanks, the National Weather Service maintains data-collection stations at the College Magnetic Observatory, Fairbanks International Airport, Gilmore Creek tracking station, City of North Pole, and the University of Alaska experimental station (fig. 1). The average precipitation at these stations for the 10-year period from 1968 and 1977 is:

College Magnetic Observatory:	10.84 in.
Fairbanks International Airport:	9.70 in.
Gilmore Creek:	15.17 in.
North Pole:	10.46 in.
University of Alaska experimental station:	10.74 in.

The mean annual precipitation at the Fairbanks International Airport and the University of Alaska Experimental Station is 11.22 inches (in.) and 12.90 in., respectively. About 60 percent falls as rain and the remainder as snow. Streamflow data for the Chena River at Fairbanks since 1948 indicate the annual runoff for the Chena basin is 10.02 inches per year (in./yr). Using an estimate of 6 in./yr for the basin-wide average evapotranspiration, this corresponds to an average precipitation of about 16 in./yr for the entire Chena River basin.

Ground water in the uplands is recharged by local precipitation, and most of the ground-water data in this report were collected between 1972 and 1976. A comparison of precipitation records for four of the Fairbanks-vicinity weather stations for the five years 1972-1976 and the previous five years 1967-1971 shows the period 1972-1976 to be significantly drier than 1967-1971.

	1967-1971	1972-1976	Normal*
College Magnetic Observatory	13.88	9.26	--
Fairbanks International Airport	12.08	8.32	11.22
Gilmore Creek	16.04	14.75	--
University of Alaska	13.87	9.21	12.90

*Climatological normals based on the period 1941-1970 (National Oceanic and Atmospheric Administration, National Climatic Center, 1977).

According to the airport data, precipitation during the period 1972-1976 was 26 percent below normal, and 31 percent below that of the preceeding 5-year period. The net deficiency of precipitation at the Fairbanks Airport from 1972-1976 is illustrated in figure 3.

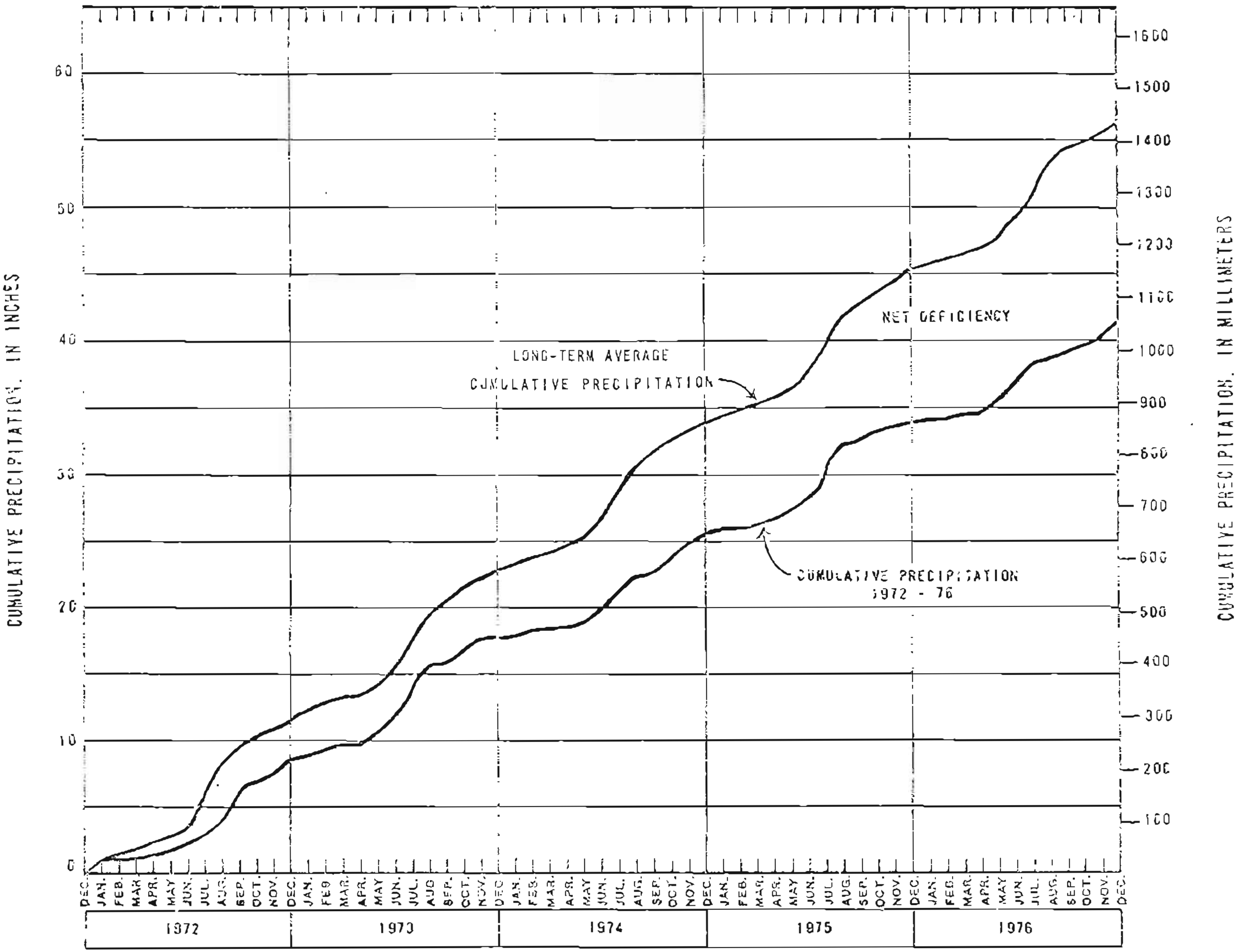


Figure 3.-- Net deficiency of precipitation at Fairbanks International Airport, 1972 - 76.

Evapotranspiration

Evaporation and transpiration, collectively termed evapotranspiration, are difficult to quantify. Evaporation is the loss of water directly to the atmosphere from open bodies of water and moist soils. Transpiration is the release of water to the atmosphere by plants through their leaves. The quantity of water transpired depends on the type of vegetation, temperature, humidity, available soil moisture, and precipitation.

Evapotranspiration has usually been determined as the difference between precipitation and runoff. The calculation thus relies on the assumption that there is no change in ground- or surface-water storage. Dingman (1973) reviewed water-budget studies for Alaska and reported estimates of evapotranspiration ranging from 40 to 78 percent of precipitation. Thus the range of probable evapotranspiration values for the study area is 4.5-9 in./yr. From his own research, Dingman (1971) estimated that 6 in. of water are lost annually to evapotranspiration in a small watershed near Fox, Alaska (fig. 1).

Waste disposal

The cities of Fairbanks and North Pole and the military bases (Eielson Air Force Base and Fort Wainwright) have public sewerage systems. Most other areas are served by on-site systems consisting of a septic tank and soil absorption system (seepage pit or leach field).

State regulations require that on-site sewage-disposal systems consist of a septic tank or package plant and a soil absorption system. In a septic tank, solids and liquids are detained so that biological processes can decompose the mixture. A residual liquid then overflows to the seepage pit where it infiltrates into the earth materials. Cesspools that consist of a single porous-walled crib with no septic tank are illegal under Alaska statutes.

In recognition of the potential for ground-water pollution from sewage-disposal systems, the State of Alaska has established regulations requiring wells to be located not less than 50 ft from a septic tank nor less than 100 ft from a seepage pit. The Alaska Department of Environmental Conservation also may require a developer to obtain percolation tests wich measure, in place, the absorptive capacity of soils.

Septic-tank effluent has a high pollution potential because many chemicals and most detergents and viruses are not decomposed or removed in the septic tank. After the effluent flows from the seepage pit into the earth materials, the chemical and biological constituents are depleted or changed through chemical and physical interactions with the subsurface environment. Reduction in concentration of pollutants in the effluent is principally caused by physical sorption and by dilution. Under certain conditions, decontamination of the waste water may not be complete before the effluent reaches the shallow aquifers or water wells (Schneider, 1970). Additional natural changes in the character of effluent from septic tanks depend on the reactivity of shallow subsurface materials at prevailing temperatures and the rate of effluent movement in these materials.

Attenuation of pollutants in septic-tank effluent increases with the time of travel through surface materials. In the saturated zone (below the water table), the rate of travel depends on the ground-water gradient and the hydraulic conductivity of the materials. In the unsaturated zone (the zone above the water table) travel time depends on the hydraulic conductivity of materials and the depth to the water table. Absorption and biological action are more effective in attenuating pollutants in the unsaturated zone than in the saturated zone. Also in the unsaturated zone, much of the effluent is absorbed by earth materials and dispersed by capillary forces in order to satisfy moisture deficiencies in surface sediments. In order to insure that effluent is exposed to aerobic degradation before it reaches the water table, state regulations prohibit the installation of a soil absorption system that discharges effluent closer than 4 ft to the water table "as measured during the season of the year with maximum water table elevation." State regulations also prohibit the installation of a soil absorption system in permafrost (State of Alaska, 1973, Title 18, Environmental Conservation, chap. 72, Wastewater Disposal).

FLOOD-PLAIN HYDROLOGY

Surface water

Tanana River

The Tanana River derives approximately 85 percent of its annual discharge from the Alaska Range and 15 percent from the Yukon-Tanana uplands (Anderson, 1970). Because a large part of its streamflow is from melting snow and ice in the mountains, an increase in temperature causes increased discharge (fig. 4). High flow in the Tanana River at Fairbanks usually occurs during hot, dry weather when snowmelt in the mountains reaches a maximum. Rainy weather in the basin is usually accompanied by lower temperatures and a decrease in the rate of snowmelt in the mountains. An increase in the rainfall component of streamflow is often offset by a decrease in the snowmelt component.

Snow and ice in the Alaska Range act as reservoirs, storing water during years of abundant precipitation and releasing it during warm, dry years. During prolonged periods of below-normal precipitation, discharge of the Tanana River may remain normal because snowmelt compensates for lack of precipitation.

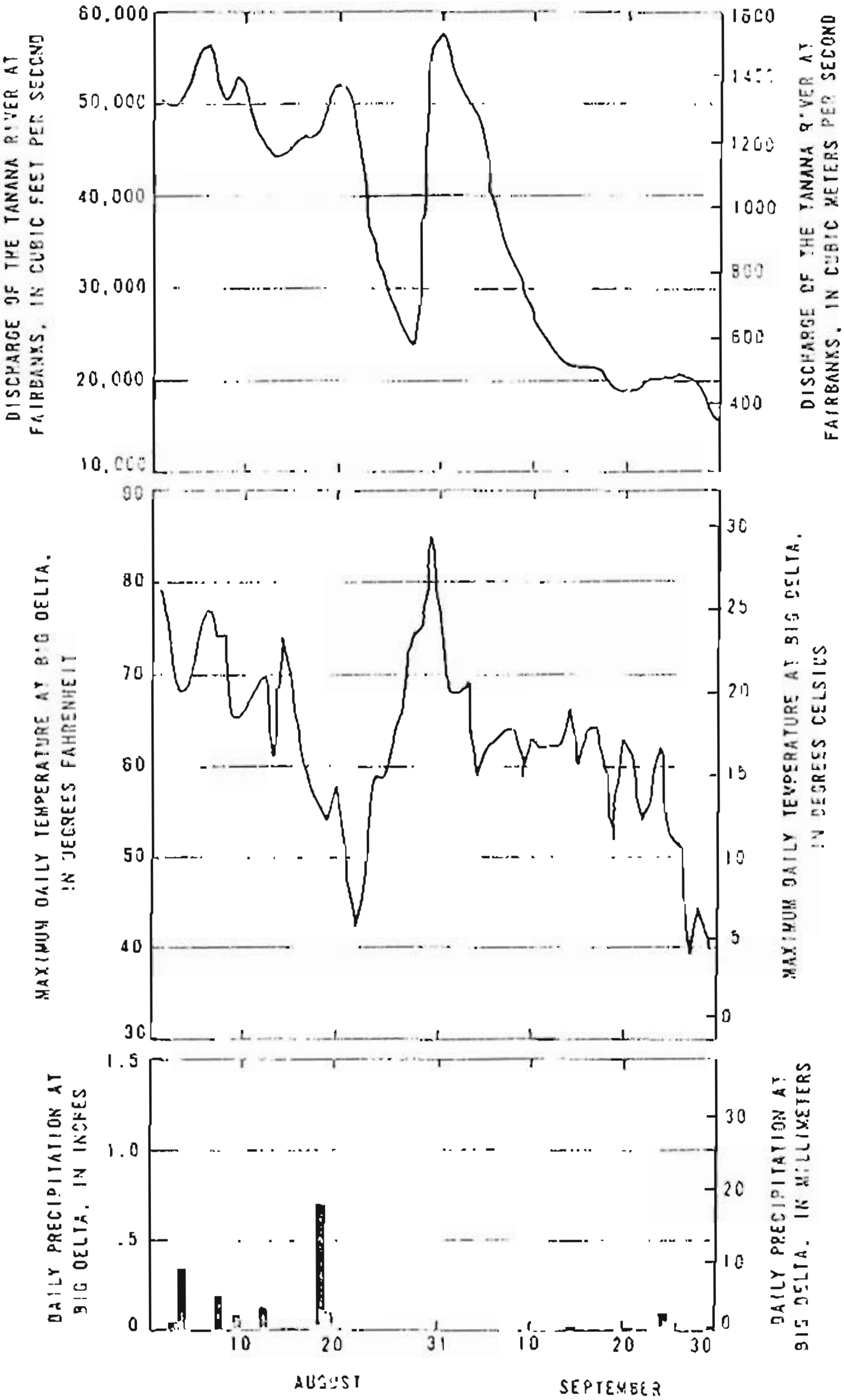


Figure 4.-- Comparison of discharge of the Tanana River at Fairbanks with temperature and precipitation at Big Delta, August and September, 1974. Big Delta is near the mountains about 77 miles southeast of Fairbanks.

Maximum flow in the Tanana River usually occurs in July, and the minimum flow occurs in late winter. Mean-daily discharge of the Tanana River at Fairbanks has ranged from 5,000 cubic feet per second (ft^3/s) to 68,000 ft^3/s since 1973 when the gaging station was established. Average discharge is about 20,000 ft^3/s.

Flood-frequency curves depict the frequency with which a single flood event will exceed a given discharge on the long-term average. Thus a 10-year flood can be expected to be equalled or exceeded on the average of once every 10 years. Figure 5 illustrates the flood-frequency curves for the Tanana River at Nenana and the Chena River at Fairbanks. (The Nenana record is used rather than the Tanana River at Fairbanks because the period of record is too brief at the latter site to depict a reliable curve). The 1967 flood peaks exceeded the reliable parts of both curves.

An additional flood hazard is not represented by these curves. Because flood-frequency curves are based on discharge, they do not present a probability of flooding caused by ice jams. Such floods are caused by constriction of the channel and thus may occur at moderate discharges.

Chena River

The Chena River usually has two periods of high discharge each year, in May and August, owing to spring runoff and to rainstorms, respectively. Since 1948 when a continuous record of discharge began, the maximum recorded flow was 74,400 ft^3/s on August 15, 1967, and the minimum was 120 ft^3/s. The latter occurred during late winter of 1953 and 1958. The average discharge is 1,493 ft^3/s.

The flood-frequency curve for the Chena River can be projected with some confidence to the 50-year recurrence interval (fig. 5). However, the Chena Lakes dam is designed to divert flood waters around the Fairbanks area; after its completion, the flood-frequency curve will no longer pertain to the protected area.

Ground water

The part of the alluvial aquifer considered in this report is bounded on the north by bedrock of the Yukon-Tanana uplands and on the south by the Tanana River. In the flood-plain area, ground water is generally unconfined, that is, it is under water-table conditions. However, where the depth to the water table is less than the depth of annual frost penetration, frozen ground may form a seasonal confining layer. Permafrost also forms a discontinuous confining layer.

Ground water is recharged principally by infiltration from the Tanana River and, to a lesser extent, from the Chena River. At most

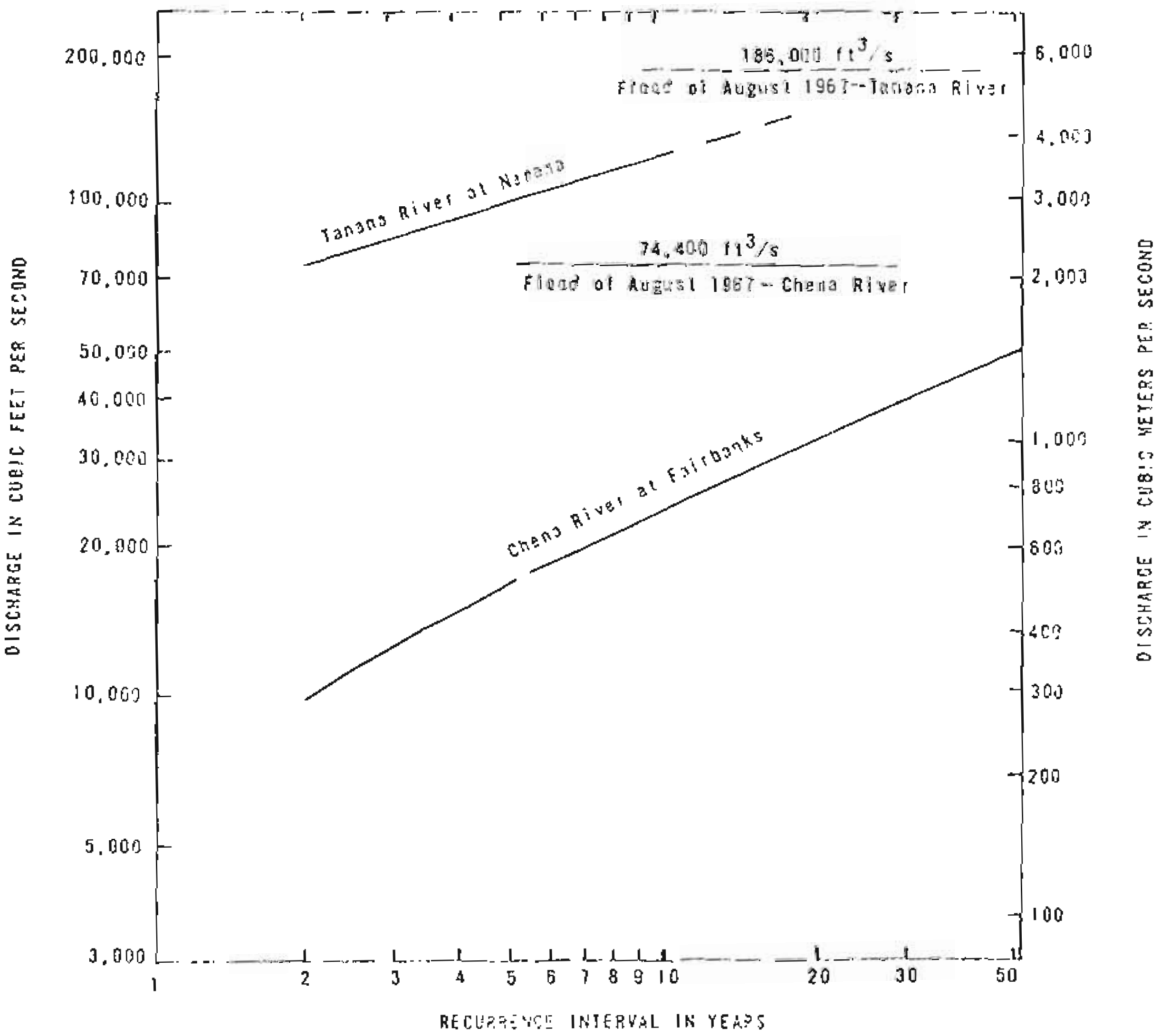


Figure 5.-- Flood frequency curves for Tanana River at Nenana and Chena River at Fairbanks.

times, the water surface of the Tanana River is topographically higher than both the Chena River and its tributary, Chena Slough (hereafter collectively referred to as the Chena system). When this occurs, the aquifer is recharged by the Tanana River and drained by the Chena system. Such conditions are illustrated in figure 6. The flow direction, which is generally in the direction of surface drainage, then has a component from the Tanana River to the Chena system. The water table also slopes away from the Tanana River (fig. 7). When the Chena River is high and the Tanana River is low, a condition common during spring runoff each year, both rivers may contribute water to the aquifer, and the direction of ground-water flow more closely corresponds to the direction of surface drainage (fig. 8).

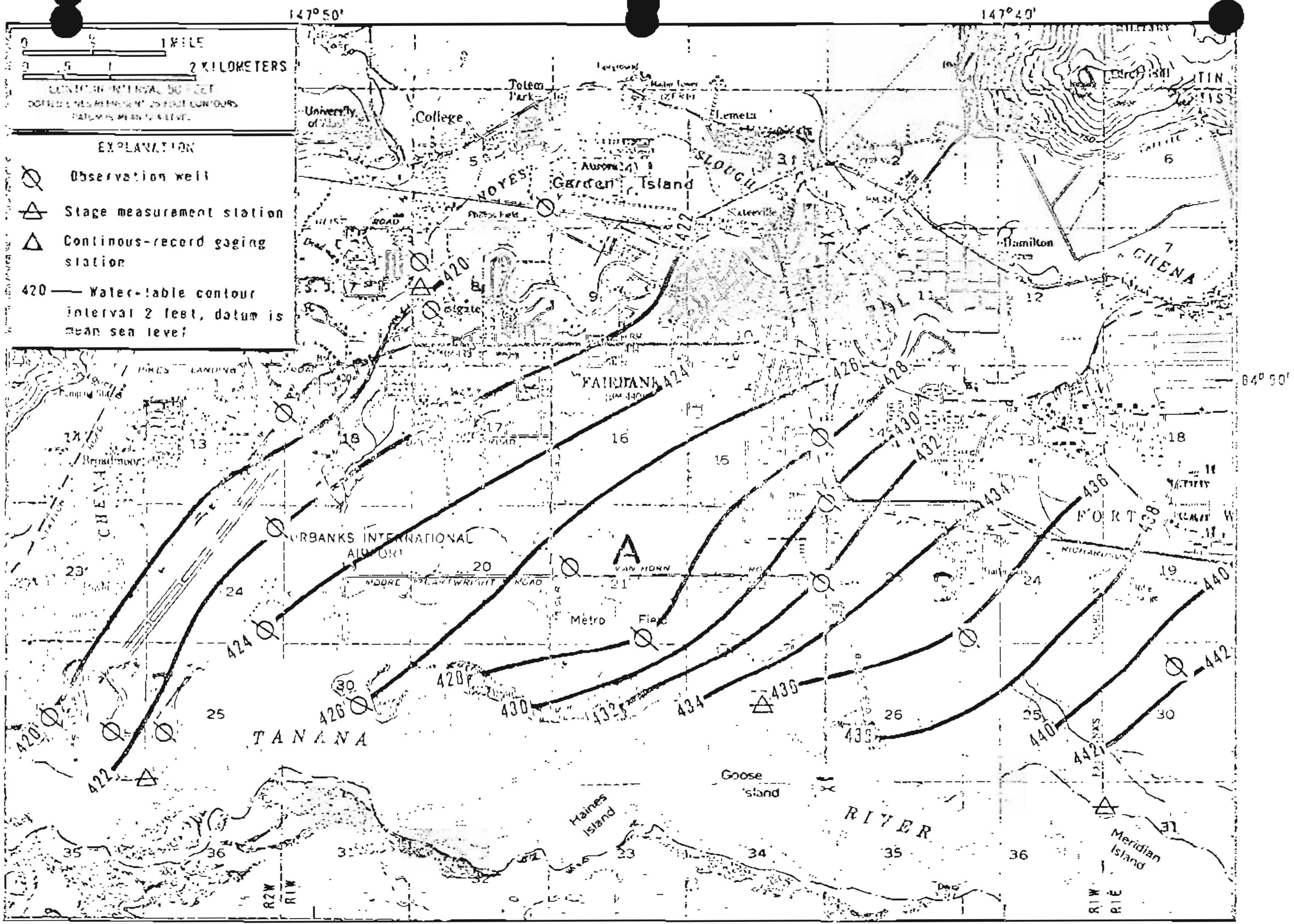
Before one can quantitatively predict aquifer response to stress conditions, such as those caused by heavy pumping, drainage ditches, and other artificial constraints to natural flow, the capacity of the aquifer to store and transmit water must be determined. These capacities, termed the storage coefficient and transmissivity, respectively, are often estimated from pump tests. In the Fairbanks area, pump tests have proven inconclusive in accurately defining these values. However, on the basis of pump tests at Fort Wainwright, Cederstrom (1963) estimated the transmissivity in that area was "several hundred thousand gallons per day per foot." One test described by Feulner (1961) illustrates the prolific capacity of the aquifer. A well at Fort Wainwright was pumped for 24 hours at 1,500 gallons per minute (gal/min). During pumping, the water level in the well declined only 9 ft, and it recovered to static level 15 seconds after pumping ceased. In a similar test at Eielson Air Force Base, the water level in a well pumped for 24 hours at 1,500 gal/min declined 26 ft and recovered to static level within 30 seconds after pumping ceased. In both these tests, the drawdown in the aquifer was less than in the wells, because the wells were pumped far beyond the capacity of the screens to transmit water from the aquifer. When this occurs, a significant part of the measured drawdown results from screen losses.

For designing the Chena Lakes Flood Control Project, the U.S. Army Corps of Engineers (1974) estimated the hydraulic conductivity of the alluvium to be about 1,000 ft/d. For a 600-ft-thick aquifer, the approximate measured thickness at the Chena River dam site, this corresponds to a transmissivity of 600,000 feet squared per day (ft^2/d).

Effects of modifications to the hydrologic system

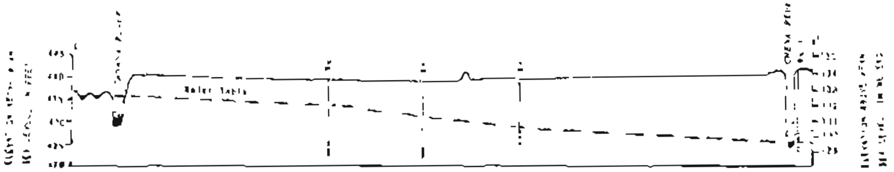
Chena Lakes Flood Control Project

The Chena Lakes Flood Control Project presently being constructed by the Corps of Engineers, U.S.Army, will consist primarily of an earthfill dam across the Chena River, a levee along the North bank of the Tanana River, and several drainage ditches inside the protected area (fig. 9). Under most conditions, streamflow will not be

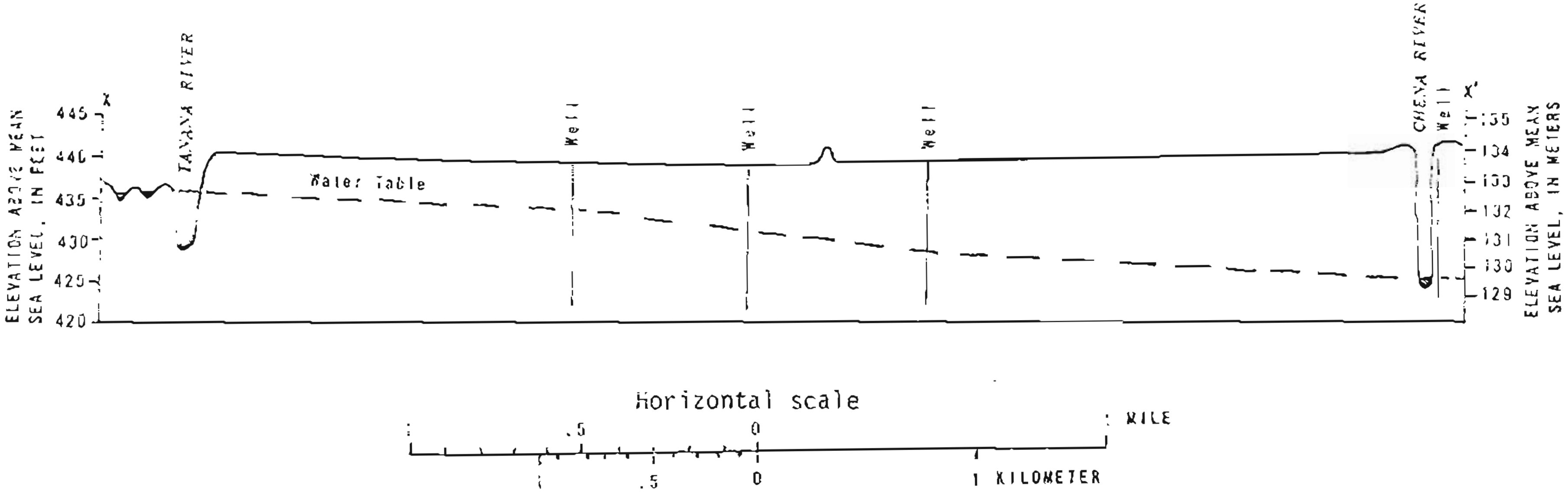


Base from U.S.Geological Survey Fairbanks (D-2), Alaska, 1:63 360

Figure 6.--Water-table configuration when the aquifer is recharged by the Tanana River and drained by the Chena River (data from July 20, 1975). Water-table depressions at A and B are caused by construction-site dewatering.



Geohydrologic section X-X' at map scale in fig. 6. Enlargement below.



Vertical scale greatly exaggerated

Figure 7.-- Geohydrologic section along line X - X' in figure 6. Water table slopes from the Tanana River to the Chena River.

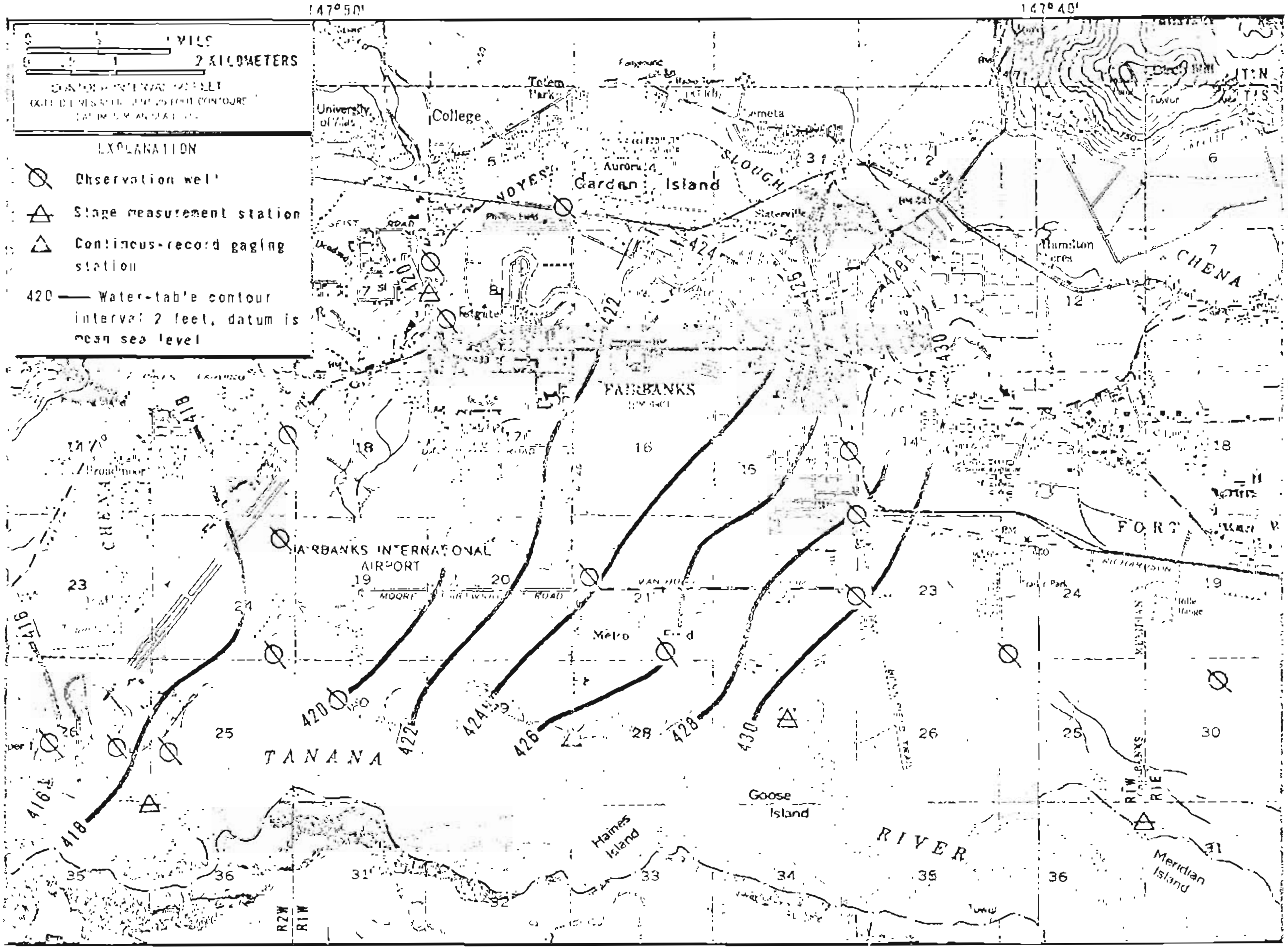
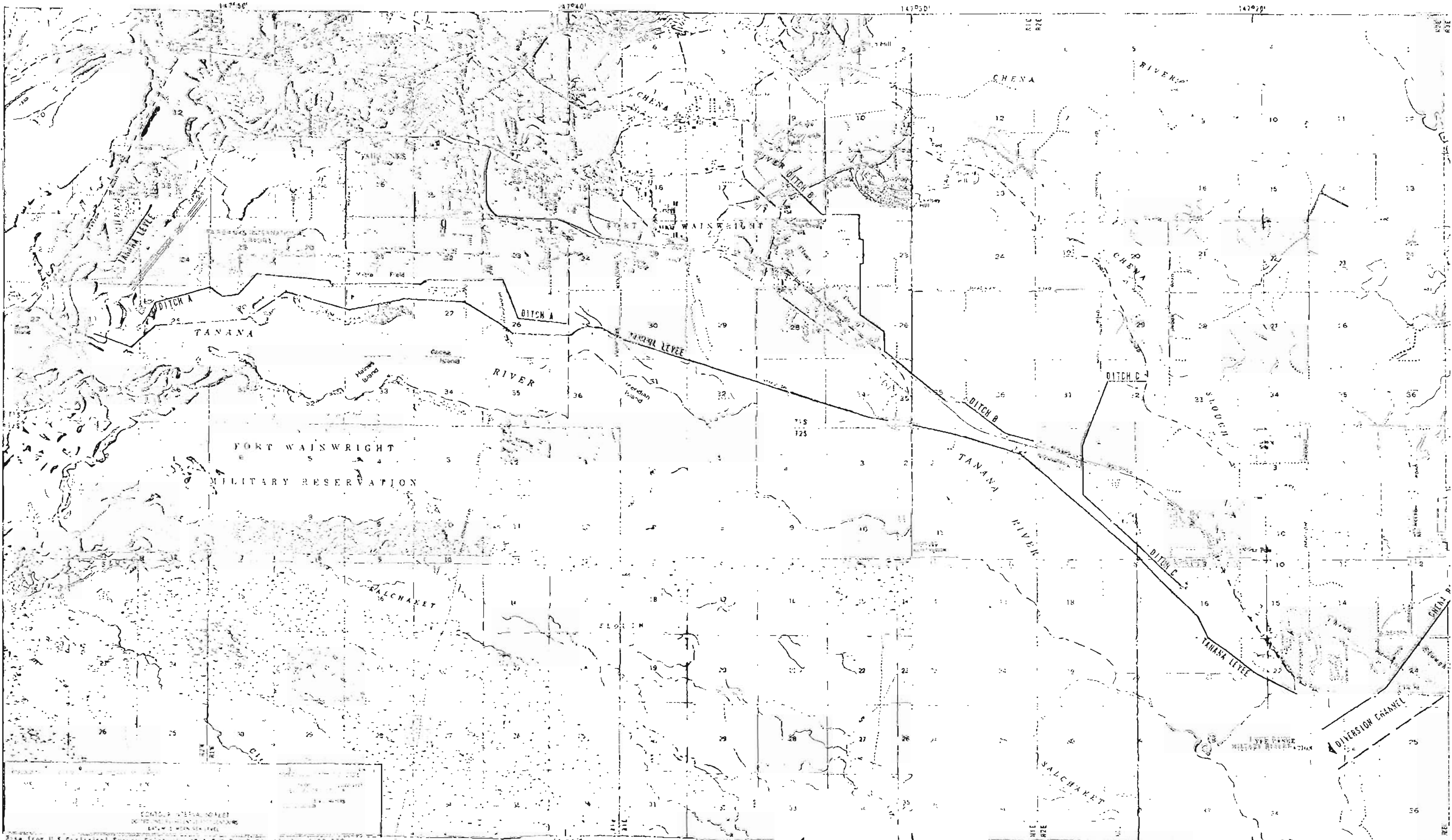
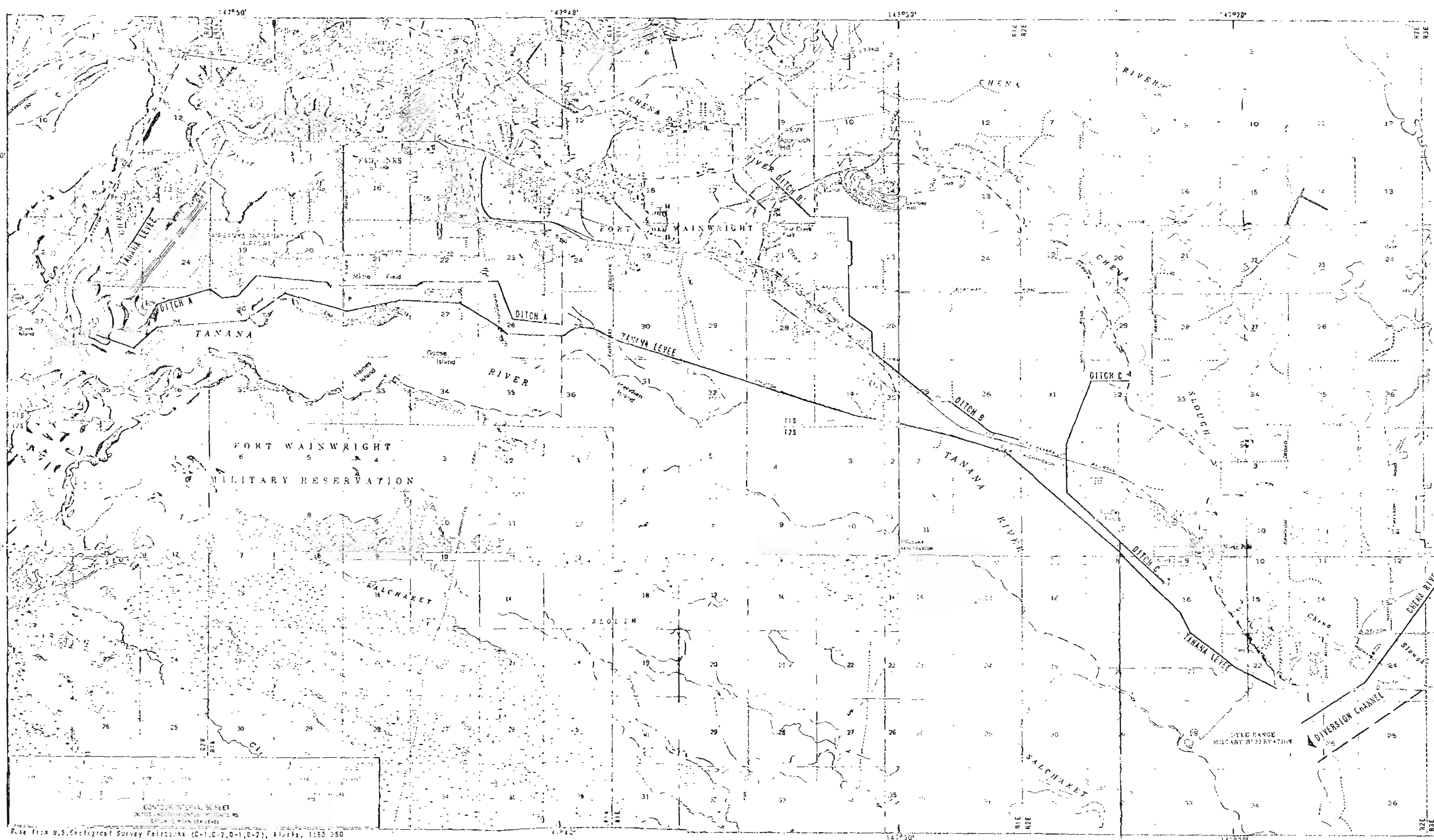


Figure 8.--Water-table configurations when both the Chena and Tanana Rivers are recharging the aquifer (data from May 20, 1974).



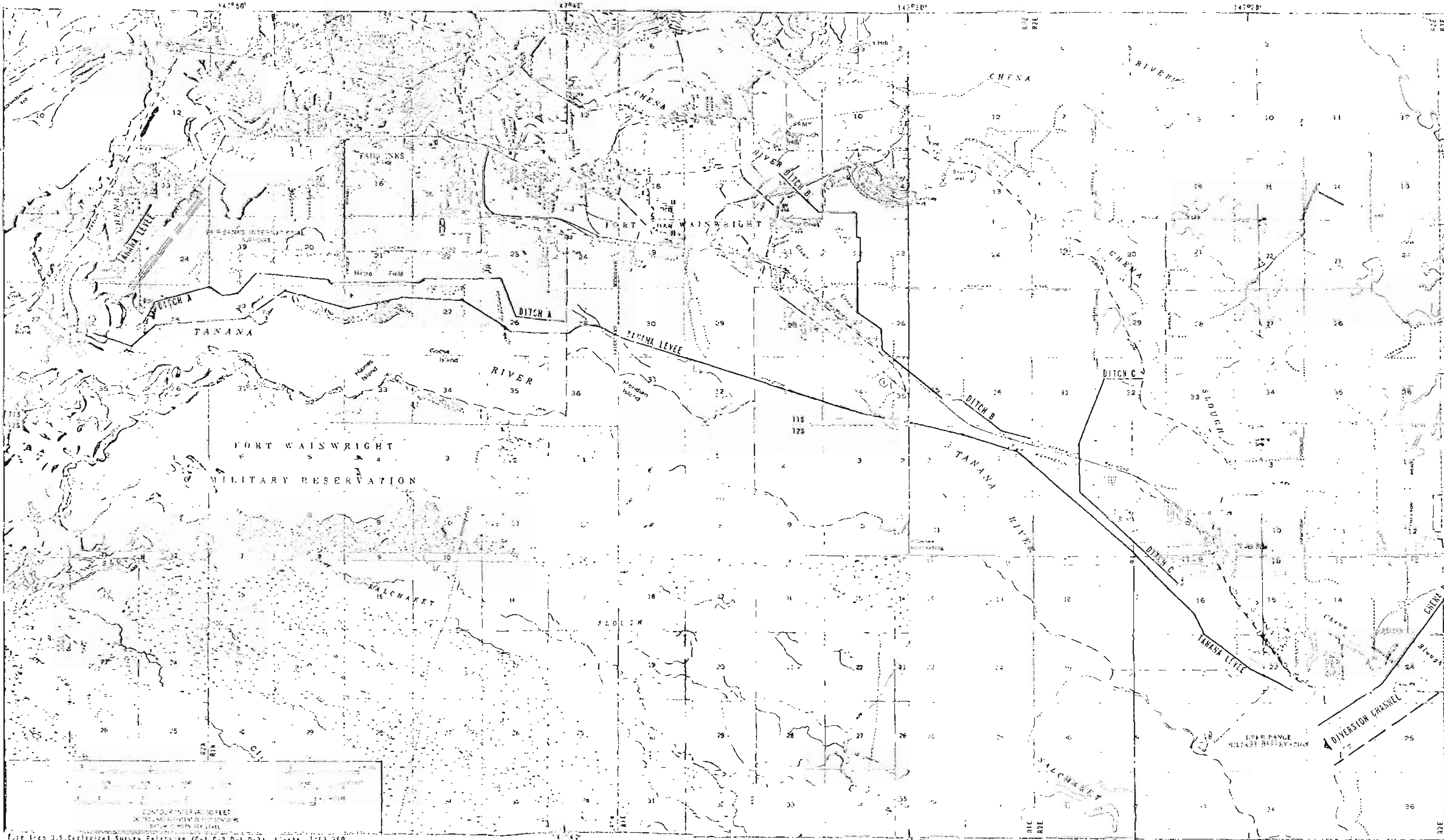
Base from U.S. Geological Survey Fairbanks (C-1, C-2, D-1, D-2), Alaska, 1:63 360

Figure 9.--Fairbanks Vicinity, Alaska, showing principal features of the Chena Lakes Flood Control project: the dam, levee, and interior drainage ditches.



Base from U.S. Geological Survey Fairbanks (C-1, C-2, D-1, D-2), Alaska, 1:63 360

Figure 9. Fairbanks Vicinity, Alaska, showing principal features of the Chena Lakes Flood [illegible] project: the [illegible], levee, and interior drainage ditches.



Base from U.S. Geological Survey Fairbanks (C-1, C-2, D-1, D-2), Alaska, 1:63 360

Figure 9. Fairbanks Vicinity, Alaska, showing principal features of the Chena Lakes Flood Control project: the dam, levee, and interior drainage ditches.

impeded. However, when flood conditions occur on the Chena River, water will be temporarily detained until the flood threat passes. If the impoundment area is filled, water will be diverted through a spillway into the Tanana River. In order to prevent the Tanana River from flooding the protected area, a levee will be constructed along its north bank from the Chena River dam to the mouth of the Chena River and extending 2 mi upstream along the south bank of the Chena River. Drainage ditches within the protected area are designed to intercept ground water seeping under the dam and levee and divert it to the Chena or Tanana Rivers. Drainage ditches will be excavated below the present ground-water table, and ground water seeping into the channel will sustain flow throughout the year. In this respect they will be similar to Chena Slough, which now drains ground water within a similar area.

The steep water-table gradient between the Tanana River and the ditches will cause high pore pressures in soils on the protected side of the levee. According to Cedergren (in Corps of Engineers, 1974), seepage under the levee can be expected to cause seeps, pin boils, and quicksand where permeabilities are high.

Effects of heavy pumping

Significant modification of the natural ground-water flow caused by pumping from wells in the alluvial aquifer has not been detected. A well near the Fort Wainwright south power plant produced over 2 million gallons in a 24-hour pumping test. The drawdown produced in an observation well 204 ft away was less than 1 in. (Feulner, 1961). Based on pump tests at Eielson Air Force Base, Fort Wainwright, and the south Fairbanks area, it appears that such negligible effects are typical of much of the flood plain.

Modifications to the natural ground-water system caused by heavy pumping to dewater excavations have been slight. Construction-site dewatering usually does not depress the water table more than about 10 ft, and the aquifer is commonly more than 300 ft thick. Dewatering therefore does not decrease the saturated thickness of the aquifer by more than a few percent. Because the yield to wells is in part related to the thickness of saturated materials, most wells are not significantly affected by construction-site dewatering unless the water table falls below the level of the pump intake.

Most drilled wells have pump intakes 20 ft or more below the water table and are able to obtain adequate supplies during dewatering. However, many domestic wells consist of sand points driven less than 7 ft into the saturated materials. Dewatering may dry up some of these wells. During the summer and fall of 1976, for example, construction dewatering along the Chena River dam and spillway produced a local depression in the water table in the area of the spillway and the main borrow pit.

The pumping rate for dewatering reached a maximum of 85,000 gallons per minute (gal/min) from the spillway construction area and 40,000 gal/min from the main borrow pit. Some homeowners complained of malfunctioning wells during this period.

Drainage problems affecting development

Chena Slough is similar to the proposed flood-control ditches in both function and orientation. It is approximately parallel to, and from 1 to 5 mi from, the Tanana River. It intercepts ground water flowing northward from the Tanana River and diverts it to the Chena River. Because the primary source of its flow is ground water, it flows throughout the winter, when thick overflow ice, or aufeis, occurs in some reaches. According to records from the Alaska Department of Highways (Millard Kahler, 1976, oral commun.), the formation of aufeis in Chena Slough is accompanied by a rise in ground-water levels. The artificially lowered water table near the proposed ditches may be subject to similar seasonal fluctuations. Figure 10 illustrates the apparent mechanism by which this winter rise in water table occurs. During the summer, the channel drains water from the ground, and the water table slopes toward the flowing stream. During the winter, the channel is choked with ice and is unable to effectively drain the ground water. As a result, the water table rises.

The proposed drainage ditches will cause a similar local depression of the water table during the summer. Contractors or homeowners building in the vicinity of Chena Slough or the drainage ditches may be unaware that high water table conditions can occur during midwinter. As a result, basements and other subsurface structures may be emplaced near the summer water table. These may be damaged by ground-water seepage during the winter. Such damage has already occurred along Chena Slough near Plack Road, where in one case aufeis inundated the basement during the winter (cover photo).

The water table also fluctuates in response to changes in stage of the Chena and Tanana Rivers. These fluctuations, which are commonly as much as 6 ft near the Chena River and 4 ft near the Tanana River, are attenuated with increasing distance from the rivers. Subsurface structures emplaced during periods of low water tables may experience seepage during prolonged periods of high stage in the rivers. Several commercial buildings in the central business district and in Graehl (fig. 1) have experienced ground water seepage under such conditions. Such damage is avoidable if building designs take into account the probable range of water-table fluctuations.

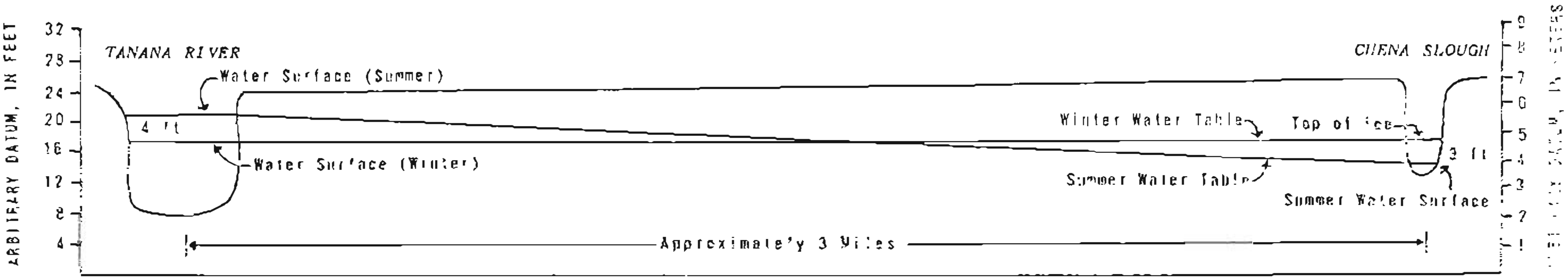


Figure 10.--Generalized hydrologic section showing seasonal changes in the slope of the water table between the Tanana River and Chena Slough. During the summer, Chena Slough is an effective drain and lowers the water table. During the winter, it becomes occluded by ice, and is an ineffective drain. The water table then rises.

Quality of water

Quality of water must be discussed in terms of the use for which the water is intended. For example, there may be no limit prescribed for the amount of silica in drinking water, yet even 1 milligram per liter (mg/L) of silica is too much for feed water to high-pressure boilers. As another example, the acceptable concentration of fecal coliform bacteria may be much higher in water used for recreational purposes (swimming and boating) than for drinking water. For most properties or constituents, the most stringent requirements are for drinking water, and it is in this context that the natural-water characteristics are discussed in the following paragraphs. Unless otherwise specified, the term "drinking water standards" refers to those defined by the Environmental Protection Agency (EPA) (1975).

Surface water

The Tanana River contains hard water of calcium bicarbonate type. In 26 samples collected at Nenana, the dissolved solids ranged from 76 to 180 milligrams per liter (mg/L). All chemical constituents except manganese and cadmium were within EPA-recommended maximum levels for drinking water. Manganese concentrations were above the recommended maximum of 0.05 mg/L in all six samples analyzed for dissolved metals. Four of the six samples contained less than the recommended maximum of 0.01 mg/L of dissolved cadmium; however, in two samples, the cadmium contents were 0.14 and 0.32 mg/L, more than 10 times the recommended limit for drinking water. Because cadmium is toxic and the Tanana River is the source of ground water near Fairbanks, additional samples are being collected and analyzed for cadmium.

Much of the suspended sediment in the Tanana River consists of glacial flour, which is silt- and clay-sized rock particles produced by glaciers. The suspended-sediment concentration relates to the rate of glacial melting and is, therefore, highest during the summer. During the winter, when glacial melt is at a minimum, the river is clear; during the summer, the sediment content rises to more than 1,000 mg/L.

Water from the Chena River is also of calcium bicarbonate type and ranges in dissolved solids from 50 to 170 mg/L. As in the Tanana River, the concentration of manganese is generally higher than the maximum recommended level for drinking water. Other constituents are within the EPA-recommended limits. Suspended-sediment concentration increases with streamflow; the maximum measured was 510 mg/L (August 14, 1967).

Ground water

Ground water from the alluvial aquifer is of calcium bicarbonate type. Hardness of the 91 samples ranged from 92 to 670 mg/L. Water from most wells sampled on the flood plain contains more dissolved iron and manganese than the recommended limits for drinking water of 0.3 mg/L and 0.05 mg/L, respectively. Contamination of wells by arsenic or nitrate, a moderately common problem in uplands wells, is rare on the flood plain. The highest concentration of arsenic detected in 10 samples from wells on the flood plain is 0.025 mg/L, half the maximum defined by the drinking water standards. Of more than 100 samples analyzed for nitrate (Johnson and others, approved for publication), only one contained more than the recommended limit of 10 mg/L (reported as nitrogen).

Methane (swamp gas) and hydrogen sulfide (which has the odor of rotten eggs) are also noted in some wells. These products indicate an anaerobic environment in which oxygen has been consumed by decomposing organic matter. Under these conditions iron is more soluble, and bacterial action may produce the methane and hydrogen sulfide. The most desirable water for drinking is found in sand and gravel deposits that have small amounts of organic detritus and are close to a source of recharge by oxygenated surface water.

Environmental considerations of septic systems

The following discussion of pollution susceptibility is based both on local conditions and on studies conducted outside Alaska. Statements made are generalities for the entire flood-plain area and can be used as guidelines for area-wide planning. Local variations in geology and hydrology must be considered in planning systems for a specific site. The principal geohydrologic characteristics that determine the effect of infiltrating pollutants on ground water in the flood-plain area are depth to the water, distance to surface-water bodies, and permeability and sorptive capacity of surficial materials.

On the flood plain, septic systems with seepage pits are commonly constructed to discharge waste water at a depth of 10-12 ft in order to avoid seasonally frozen ground. Where the water table is closer than 15 ft to the land surface during high water conditions, it is likely that many septic systems will seasonally discharge effluent within 4 ft of the water table, in violation of State of Alaska regulations, and the probability of ground-water contamination is high. Because there are few areas on the flood plain where the depth to the water table is greater than 15 ft during high water table conditions, the entire flood-plain area must be regarded as highly susceptible to ground-water pollution from septic-tank sytems.

Where the hydraulic conductivity of sediments is insufficient to accept the discharge of a septic system, effluent may overflow the pit and eventually rise to the surface. On the flood plain, most seepage pits are situated in permeable sand and gravel that can adequately accept the effluent from on-site systems. However, if seepage pits are constructed in areas of shallow permafrost, the impermeable frozen soil prevents the dispersion of effluent from the discharge point. In this situation, a health hazard may be caused by nearly raw sewage reaching the land surface. State of Alaska regulations prohibit the emplacement of seepage pits in permafrost.

Because the alluvium consists of lenses and discontinuous layers of silt, sand, and gravel, seepage pits normally discharge to a variety of materials. The coarsest of these will normally conduct most of the effluent from the pit. A hypothetical example (fig. 11) shows a seepage pit discharging effluent to a saturated multilayered medium. The upper and lower layers are silt. Hydraulic conductivities of these units are so low that flow through them is negligible compared to the gravel and fine sand. The fine-sand layer is 9 ft thick and has a hydraulic conductivity of 1 ft/day. The gravel layer is 1 ft thick and has a hydraulic conductivity of 1,000 ft/day. In this example, although the fine sand composes 90 percent of the permeable material, 99 percent of the effluent will be transmitted through the gravel.

Concentration of flow in the coarse materials is significant for several reasons. First, coarse material is not as effective at filtering solids and bacteria as is fine material. Second, coarse material causes less attenuation of pollutants by adsorption than does fine material. And third, the rate at which pollutants travel through coarse material is much greater than the overall ground-water-flow rate. Again, the hypothetical example (fig. 11) portrays the relative rates of travel in the two layers. If a person injected a tracer into the tank and then observed the point-to-point distances it travelled in any time interval, he would observe that the distance traveled is nearly 1,000 times greater in the gravel than in the sand.

The actual distance pollutants travel depends on the porosity, hydraulic conductivity, and the water-table gradient. For the flood-plain area, the normal gradient is 5-10 (ft/mi) and the minimum allowable spacing between a private well and a seepage pit is 100 ft (State of Alaska, 1973, Title 18, Environmental Conservation, Chap. 72, Wastewater Disposal). The time required for pollutants to travel 100 ft in materials with an assumed porosity of 0.3 and various hydraulic conductivities (k) is:

Material	Gradient = 0.001 (5 ft/mi)
silty sand (k = 0.01 ft/d)	8,000 years
gravelly sand (k = 10 ft/d)	3,000 days
sandy gravel (k = 100 ft/d)	300 days
medium gravel (k = 10,000 ft/d)	3 days

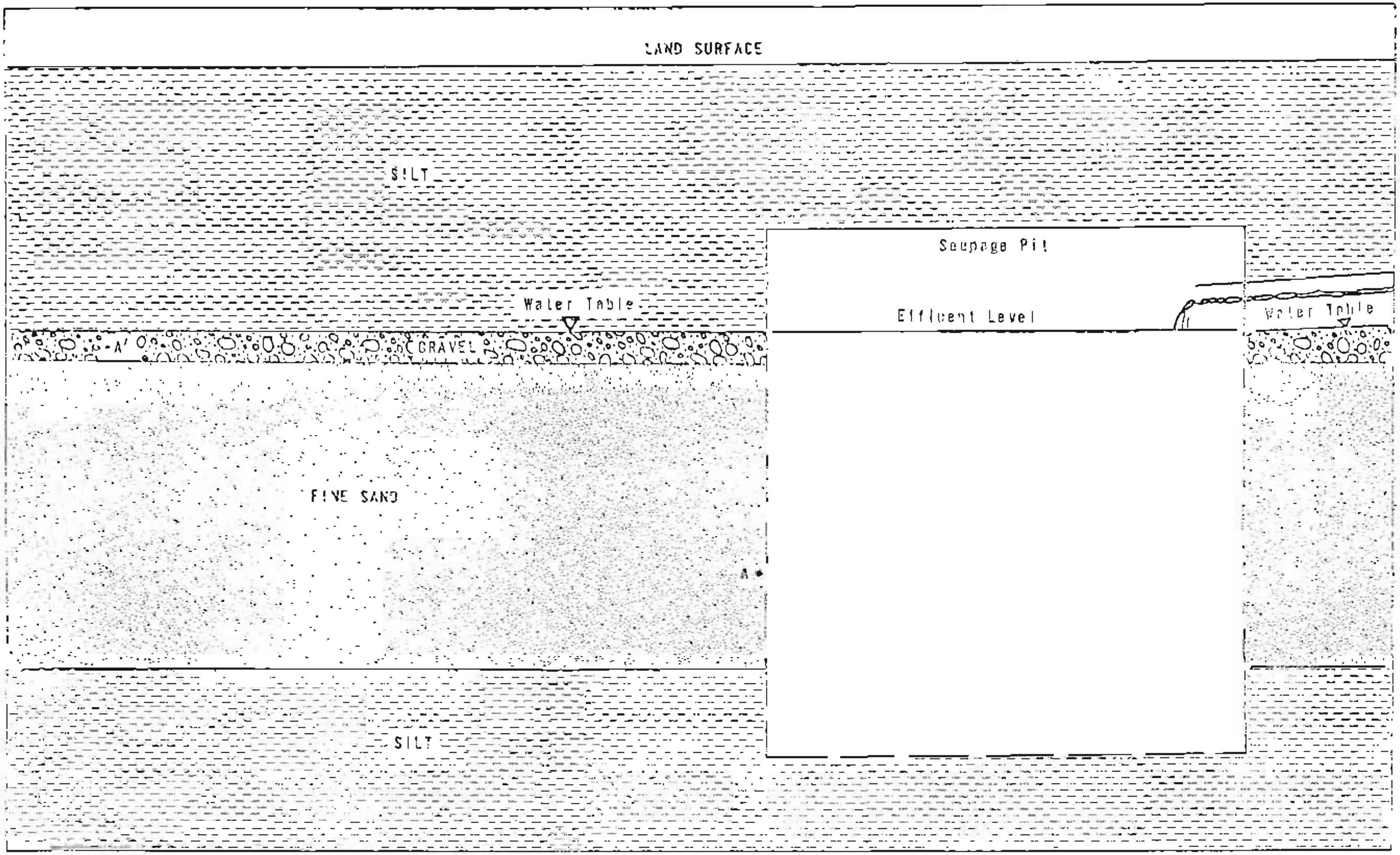


Figure 11.--Sketch of seepage pit emplaced in a saturated multilayered medium. Ninety-nine percent of the effluent travels through the gravel. In the time it takes for effluent to travel to A in silty sand, it has travelled to A' in the gravel.

Theoretical travel-time calculations, such as the above, are useful in providing an order-of-magnitude comparison of flow rates in various materials. However, in the real world, pollutants almost always travel faster than the theoretical rates by following preferred high-permeability paths through nonuniform sediments. Thus, small amounts of pollutants may reach down-gradient wells far ahead of the theoretically predicted times. If the gradients are steeper than the above values, travel times will be further reduced. Along streams, rapid changes in stream levels may temporarily steepen the gradient. Near wells, gradients are also locally steepened during pumping. In either instance, the rate at which pollutants travel through the ground is increased.

The potential for bacterial contamination of wells and surface water can be evaluated on the basis of seepage rates and bacterial survival rates. The latter depend in part on the temperature of the water. Fecal bacteria survive longer at 0-10°C than at higher temperatures. In the Tanana River at 0°C, 3-5 percent of the fecal coliforms and 18-37 percent of enteroccoci survived after 7 days flow time (Gordon, 1973). If survival is comparable in ground water, which is usually 0-2°C in the Fairbanks area, one would expect that sufficient bacteria could remain after 7 days flow time to cause contamination of down-gradient wells. At the gradient existing throughout most of the flood plain, effluent will travel 100 ft in less than 7 days when materials have hydraulic conductivity greater than about 4,200 ft/day. According to Cedergren (1967), the hydraulic conductivity of gravel commonly ranges from about 1,000 to 100,000 ft/day. A study of bacterial pollution in well-sorted gravel in California demonstrated that biological pollutants travelled as far as 232 ft from their source (Franks, 1972).

Increasing the existing 100-ft separation requirement between seepage pits and down-gradient wells or streams will increase travel time and thus tend to decrease the probability of causing bacterial contamination. However, effluent is not likely to contaminate wells 100 ft upgradient or across the gradient from sources of effluent. Requiring greater separation in these directions would produce little benefit. Because gradients, and therefore seepage rates, are greatest near streams or heavily pumped wells, greater separation would provide travel times comparable to other areas of the flood plain.

Both the flow directions and regional gradients may be determined from water-table maps of the flood plain (figs. 6 and 8). Such maps can help a homeowner plan the location of his well so that it is upgradient from potential sources of pollutants. There may be, however, some local variation in flow directions caused by flow to or from streams or by flow to points of heavy pumping. Site-specific, large-scale water-table maps are preferable to maps such as figures 6 and 8 for use in laying out a well and septic system.

UPLANDS HYDROLOGY

Streams

The uplands north of Fairbanks are drained by many small creeks which flow to the Chena, Tanana, and Chatanika Rivers. The hydrology of these streams is greatly affected by the distribution of permafrost.

Permafrost under the valley bottoms, lower slopes, and lower part of the north-facing slopes may confine ground water in unfrozen bedrock and alluvial aquifers. The areas in which these aquifers are confined under sufficient water pressure to cause wells to flow at the surface are collectively termed the artesian zone.

Upslope from the artesian zone, streams are dry during most of the summer. Runoff occurs only during spring snowmelt and after some heavy summer rainstorms. No aufeis forms there during the winter. Within and downslope from the artesian zone, streams commonly flow throughout the year, and large aufeis deposits may overtop the streambanks during the winter.

Low winter discharge, extensive aufeis, and shallow permafrost in the valley bottoms preclude the use of creeks as domestic water sources. During the winter, much of the discharge goes into the formation of aufeis and is not available for withdrawal. If any flow remains, it is often difficult to locate under aufeis that obscures the channel. Even if it were possible to withdraw water from the creeks, it would be difficult to maintain a thawed water-supply line through the zone of continuous permafrost. The creek-valley bottoms are also undesirable for homesites because shallow permafrost inhibits on-site sewage disposal and provides unstable foundation conditions for access roads and buildings. Most housing is thus situated away from the creeks.

Ground water

An analysis of any ground-water system relies on a conceptual model which is based on observations of present and historical conditions. Such a model is rarely a final product for use in determining all future cause-and-effect relationships; it must be continually refined as new data become available. For example, if all data have been collected during a period of low precipitation, annual recharge to the aquifer may be underestimated. Further, if there is a long delay between an event and its consequence, historical records become increasingly important. Lack of a significant historical record makes this analysis of the hydrology of the uplands more qualitative. The following discussion is a best estimate of conditions based on the available information and is likely to be revised as a longer period of record becomes available. It can be argued that, because virtually the entire ground-water record spans a period during which local precipitation has been reported to be

25 percent below normal, it is premature to attempt an analysis. However, it is equally true that some planning decisions, to be based on current estimates of the hydrologic system, cannot be delayed until a longer period of record exists.

The ground-water system

Ground water in the uplands is contained principally in fractured bedrock of the Yukon-Tanana complex (King, 1969). These rocks were formerly considered to be a single metamorphic unit, the Birch Creek Schist (Mertie, 1937). However, they actually consist of two distinct schist units which have been intruded by granitic rocks. Throughout this report the more inclusive term "bedrock aquifer" is used in preference to the locally used term "Birch Creek Schist aquifer".

The bedrock aquifer is nonhomogeneous; that is, its hydrologic properties differ greatly from place to place. Identical stresses on the aquifer may produce very different responses in different areas. A decision to develop a local area based on estimates of available ground water may be appropriate to the basin-wide average supply, yet may cause severe shortages in one area and no shortages elsewhere. Some wells are likely to experience a reduction in yield regardless of the population density.

Bedrock conducts ground water primarily within fractures. The capacity of the rocks to yield water to wells depends in part on their capacity to hold fractures open against the pressure of overlying rocks. In more plastic rocks, fractures either do not form during deformation or close up under the weight of overlying rocks. The best fracture permeability and porosity is thus developed in hard, brittle rocks that fracture readily during deformation and in which open fractures remain. In the study area, water-bearing zones with the greatest yields appear to be in quartz veins, quartzite, and siliceous schist. The less competent mica schist conducts little water and in many places is a confining layer to water within the brittle zones. The mica schist may, however, contain significant quantities of water which it may slowly release to the more permeable units. Under such conditions the softer rocks store water and the brittle rocks collect it and transmit it to wells. The distribution and yield to wells of the brittle zones is irregular, and it is unlikely that sufficient data can be collected to accurately predict the depth at which a well will have a desired yield.

The bedrock aquifer of the uplands maintains a dynamic balance of inflow, outflow, and changes in storage. The principal source of inflow to the aquifer is by local infiltration of precipitation. Outflow from the aquifer occurs in two ways. Some water flows to the surface via thawed conduits through the permafrost in the artesian zone. The rest flows under the permafrost and out to the alluvial aquifer of the adjacent flood plain or creek valley.

There is no direct way to measure the annual recharge to the bedrock aquifer. However, if there are no changes in the amount of water stored in the aquifer, then the annual recharge is equal to the annual outflow. One component of the annual outflow, that which occurs as springs and streams in the artesian zone, can be measured. The other component, that which flows out of an area as ground water, cannot be measured directly. In drainage basins where most of the annual outflow occurs as surface water and where the amount of water stored in the aquifer remains approximately constant from year to year, annual recharge may be accurately determined by measuring ground water lost to the surface. In some drainage basins, such as the southeast side of Chena Ridge (fig. 1), the bedrock aquifer is bounded on one side by a thick alluvial aquifer. In such a hydrologic situation, ground-water underflow is likely to be a significant part of the annual recharge, and natural ground-water discharge therefore poorly represents the annual recharge. Along much of Farmer's Loop Road, where thick permafrost appears to be an obstruction to ground-water underflow, and in some of the basins not bounded by alluvial aquifers, such as Caribou Creek (fig. 1), ground water discharging to the surface may more nearly approximate annual recharge.

If one component of the dynamic balance of the aquifer is modified, the other components must compensate. Withdrawal of ground water from wells is an increase in the rate of outflow. If the annual recharge remains constant, this increased outflow must be compensated by a decrease either in storage or in the rate of natural outflow. The initial change is a decrease in storage. This causes a decline in the potentiometric surface which may, in turn, reduce the hydraulic gradient and the rate of natural outflow. If the potentiometric surface declines below the land surface in the artesian zone, springs will dry up. A new balance may then be reached in which natural ground-water discharge in the artesian zone has been eliminated and the water salvaged is entirely extracted through wells. If the pumpage exceeds the natural ground-water discharge, water levels will continue to decline.

The natural ground-water discharge is a component of base flow, the streamflow which persists after most surface runoff has ceased. Other components of base flow are delayed drainage from tundra and marshy areas, melting of winter icings, and shallow ground water seeping from the seasonally thawed ground above the permafrost. In order to determine the natural discharge from the bedrock aquifer, it is necessary to measure base flow when it consists almost entirely of ground water discharged from the bedrock aquifer. During the winter, when shallow sources of base flow are frozen, most (or possibly all) of the base flow consists of ground water from the deeper - in most places, bedrock - aquifer. During the summer, base flow can be identified as ground water lost from the bedrock where flow from a spring can be defined as having a bedrock source.

In the Fairbanks area, base flows have been measured and the bedrock-leakage component analyzed for Grenac, Jussila, Isabella, Columbia, Steele, and Caribou Creeks, and the Little Chena River (fig. 12). Along Farmer's Loop Road and along Chena Hot Springs Road as far east as Steele Creek, base flows are 3,000 - 16,000 gallons per acre per year [(gal/acre)/yr]. [A base flow of 10,000 (gal/acre)/yr means that each acre within that basin yields an average of 10,000 gal to base flow each year.] Base flow in Little Chena River was 38,000 (gal/acre)/yr in 1975, the only year with good winter records. In Caribou Creek basin, base flow ranged from 35,000 to 106,000 (gal/acre)/yr between 1972 and 1975. Because of extensive aufeis formation in Caribou Creek, base flows during 1976 and 1977 were poorly defined. However, flows were estimated to be less than in any of the previous four years.

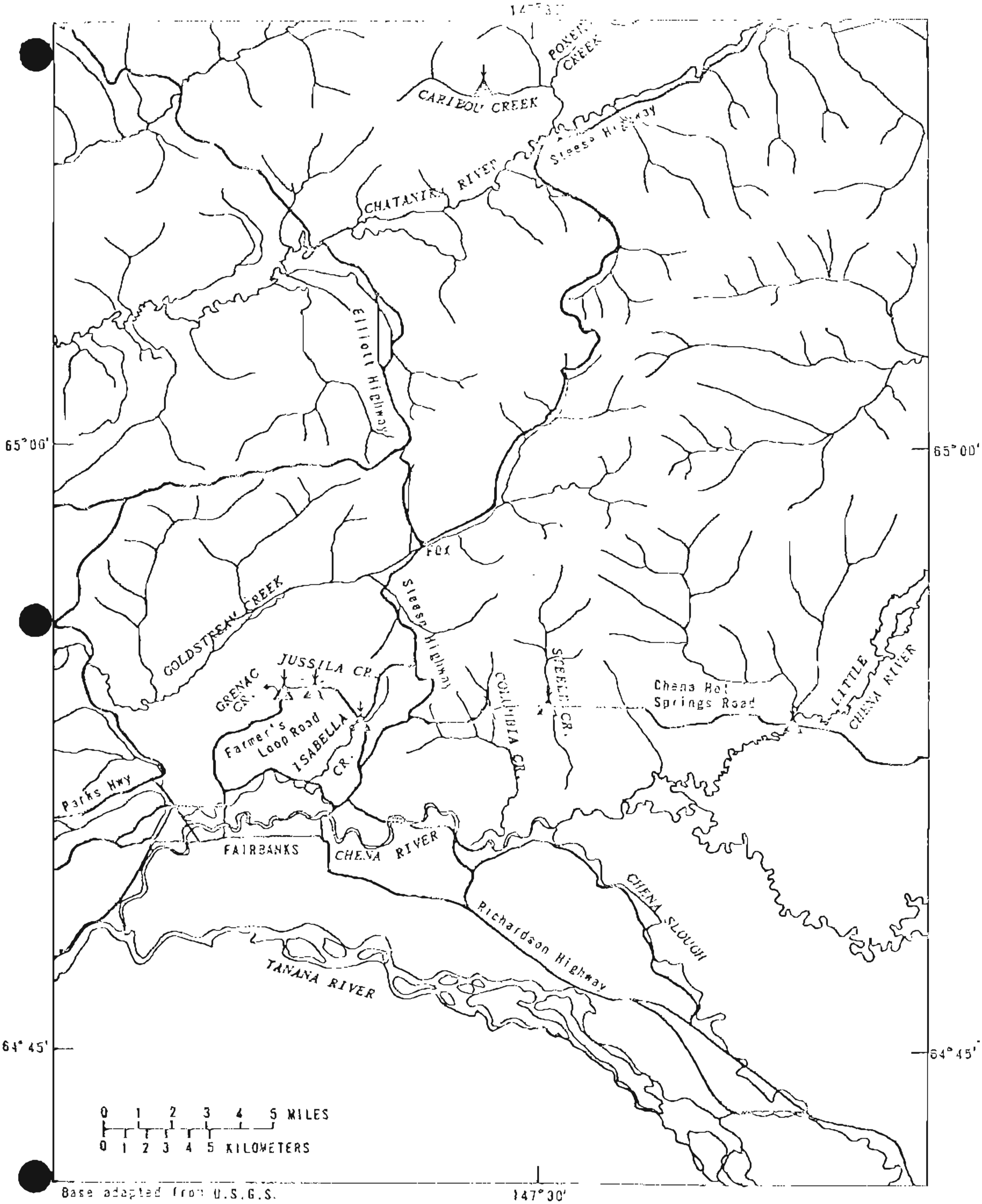
Base flows are lowest in basins near the Tanana River flood plain and increase in the basins at higher altitudes to the north and east. Base flows in the range of 16,000 - 40,000 (gal/acre)/yr may then be typical for such basins as Goldstream Creek, Little Chena River and Engineer Creek, all of which drain hills higher than many of those in the Farmer's Loop - Chena Ridge area.

Effects of ground-water pumping

Most of the ground water being pumped from the bedrock aquifer is for domestic use. All this water is returned to the ground via septic tanks and either seepage pits or drain fields. Most of the water returned to the ground probably infiltrates downward to recharge the aquifer. However, some water may be drawn to the land surface by capillarity or if a seepage pit becomes plugged, water may actually flow to the surface. Water that reaches the land surface is then lost to the atmosphere by evaporation and transpiration. An effective seepage pit or drain field (one which is not plugged and which allows the effluent to percolate downward) is therefore important in maintaining a balance between ground-water supply and ground-water use.

Ground water used for irrigation of lands, gardens and crops is applied directly to the land surface. As it is supplied only to make up soil moisture deficiencies, it is totally lost through evapotranspiration.

The quantity of water returned to the aquifer for reuse is dependent on the construction and condition of the seepage systems, the permeability of the soils, and the use to which the water is being put (irrigation, domestic consumption, or others). Although it has not been possible to accurately quantify the water permanently lost from the aquifer, it is estimated to vary from less than 10 percent of domestically used water returned to a properly functioning seepage pit to 100 percent of both irrigation water and domestically used water returned to a plugged seepage system.



Base adapted from U.S.G.S.
Fairbanks, Alaska, 1:250,000

Figure 12.-- Locations of low-flow stations on streams in the Fairbanks area which have been studied to determine the base flow contributed by leakage from the bedrock aquifer.

If the net consumption of ground water (the pumpage minus the water returned to the aquifer) approaches or exceeds the base flow of a basin, flow of springs in the artesian zone may be reduced or eliminated. Reduction or elimination of springflow might dry up some ponds in the artesian zone and decrease the flow of water to muskeg in, and downslope from, the artesian zone. This would result in significant changes in vegetation and wildlife habitat.

Ground-water consumption will lower the potentiometric surface (or water table). This decline caused by pumping will have the greatest impact on springflow and well yields when it is superimposed on a natural decline caused by variations in annual precipitation. Whether or not such a total decline will significantly reduce the yield of any particular well depends on the construction of the well and the magnitude of the potentiometric-surface decline. If the permeable rocks which supply the well are located in the first few feet below the potentiometric surface, then a small regional decline in the potentiometric surface may dewater the well (fig. 13, well b). However, if the water-bearing zone is far below the potentiometric surface, the loss of a few feet of head is insignificant (fig. 13, well a).

From 1972 to 1977, water-level declines of 3-9 ft/yr have been common in areas on the ridgetops and upper hills (fig. 14). A hydrograph from an unpumped observation well on the ridge above Farmer's Loop Road illustrates the decline from 1975 to 1977 (fig. 15). If such declines are typical of a local long-term trend, the ridgetops and upper slopes are areas where well failures may be common.

In contrast, fluctuations of the potentiometric surface beneath the lower slopes are small. The thick silt cover on the lower slopes also creates an area in which head-loss tolerances are high (fig. 16). Although some wells on the upper slopes may also have high head-loss tolerances, the fact that wells on the lower slopes are consistently tolerant of head losses makes such areas likely to experience fewer incidents of well failure.

If one were to devise a plan of development to produce a minimum number of well failures, the general guidelines for distribution of pumping would then be to concentrate the greatest amount of well-water withdrawal on the lower slopes, where the anticipated rate of well failures is lower than it is on the upper slopes and ridgetops.

Because the net water consumed is the pumpage minus the water returned to the aquifer, it may be possible to substantially reduce net consumption by increasing the rate at which water is recharged to the aquifer. In the study area, this rate could be increased by diverting runoff from roofs and roads into dry wells, or by retaining spring snowmelt in ponds until the ground thaws enough to allow infiltration.

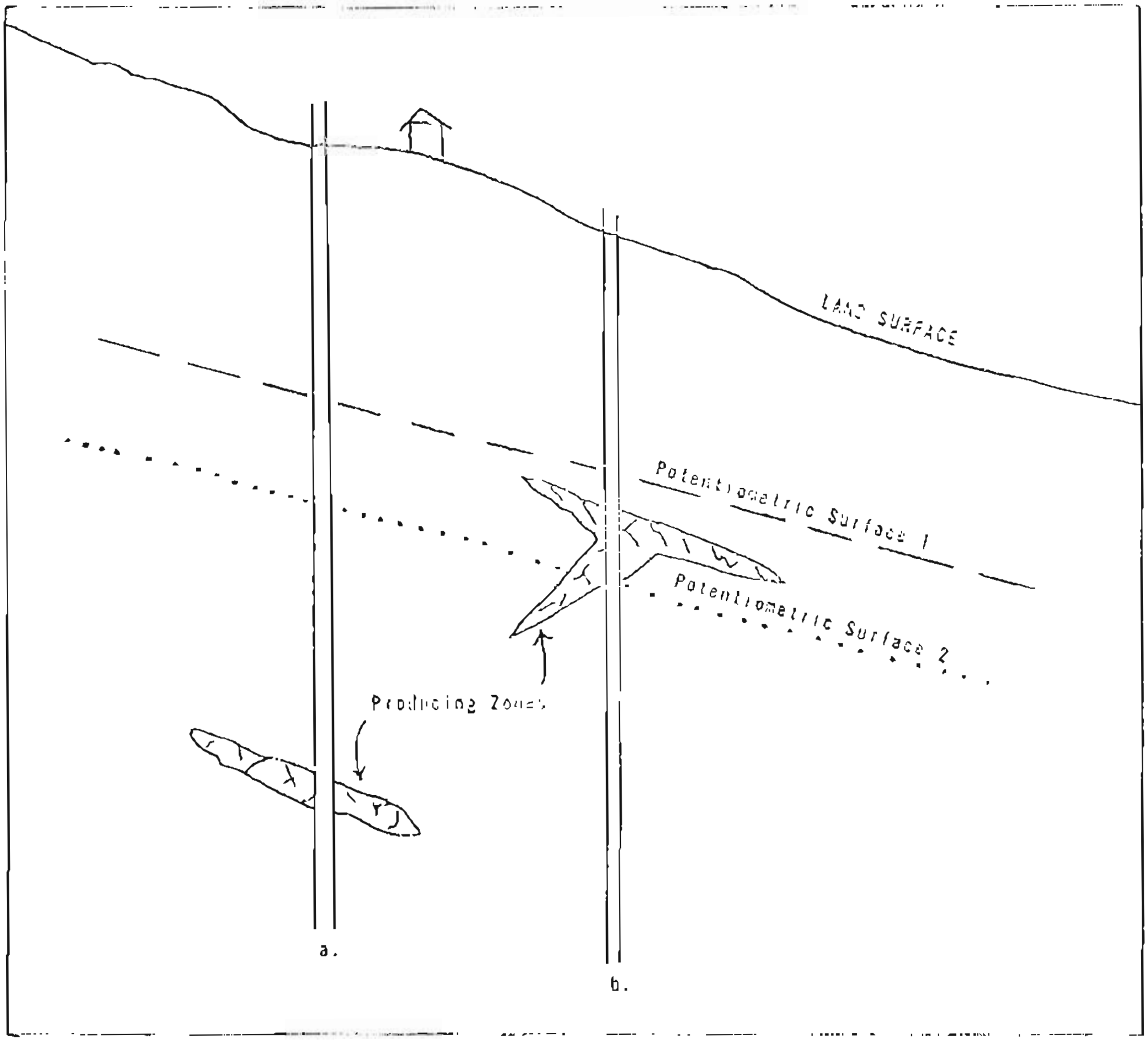
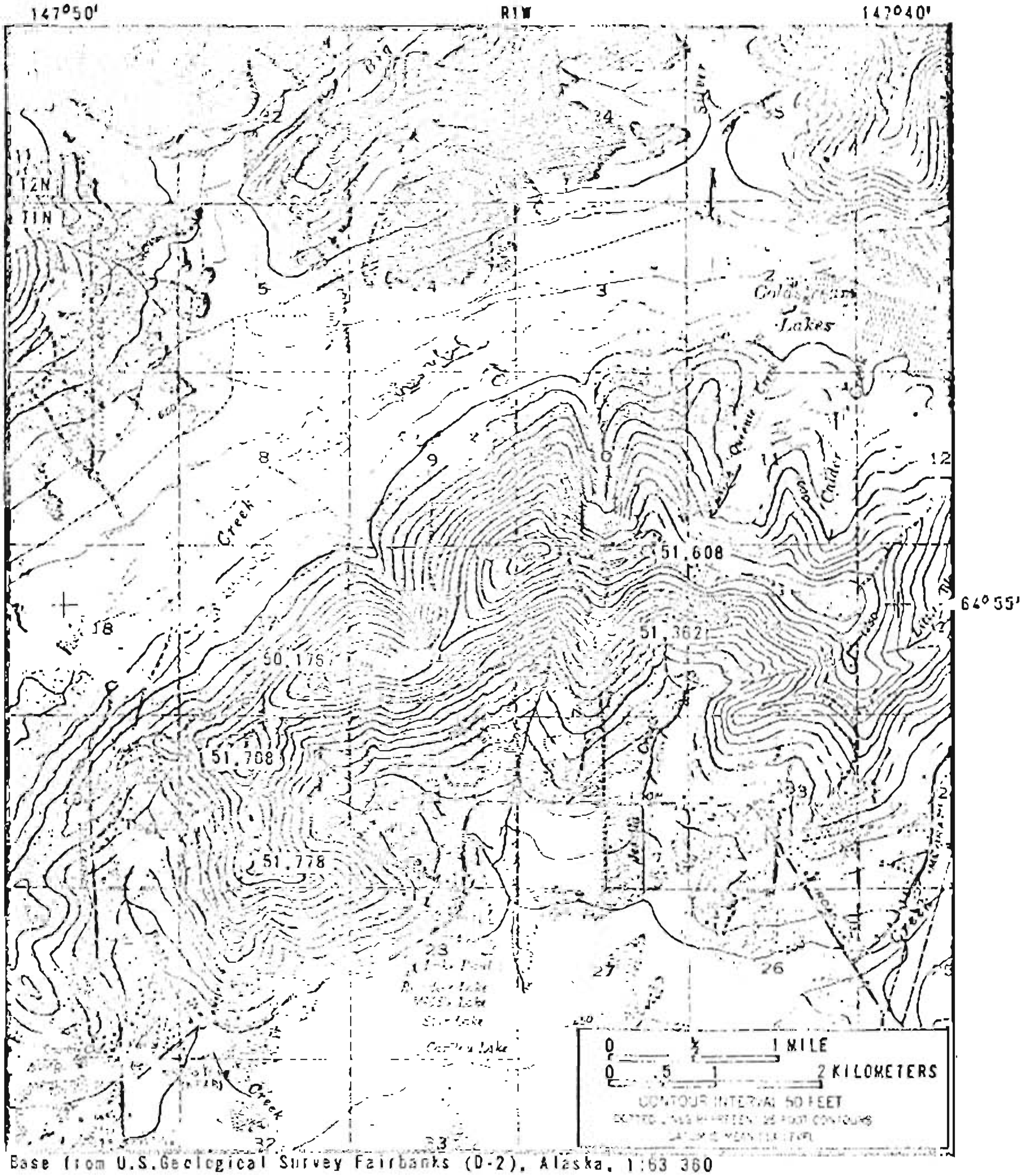


Figure 13.--Generalized section showing two wells with different tolerances to a declining potentiometric surface. Well "a" would be little affected by a decline of the potentiometric surface to position 2, whereas well "b" would be nearly dry.



Base from U.S.Geological Survey Fairbanks (D-2), Alaska, 1:63 360

Figure 14.--Location of wells on ridgetops and upper slopes in which head losses have been recorded. Amount of losses and periods of record for the wells are listed in the table below.

Well number	51,608	51,362	50,176**	51,708	51,778
Head loss	-*	16	8	27	9
Years of record	1973-75	1971-77	1975-77	1972-75	1972-75

*Decline was not measured, but well experienced loss of yield.
**U.S.Geological Survey observation well (see fig.15)

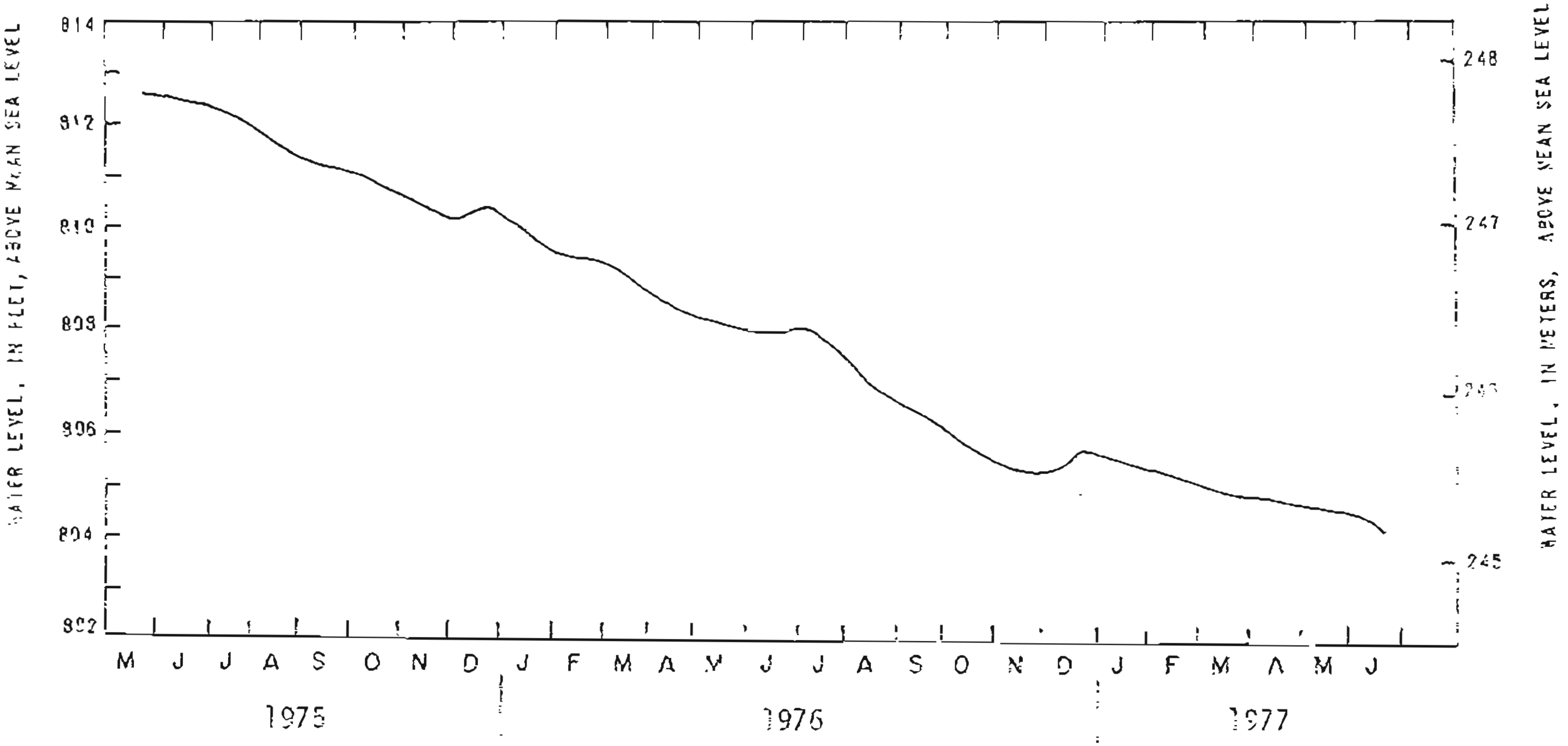


Figure 15.--Hydrograph of well 50,176 situated on ridgetop overlooking Farmer's Loop Road.
(Well location on figure 14)

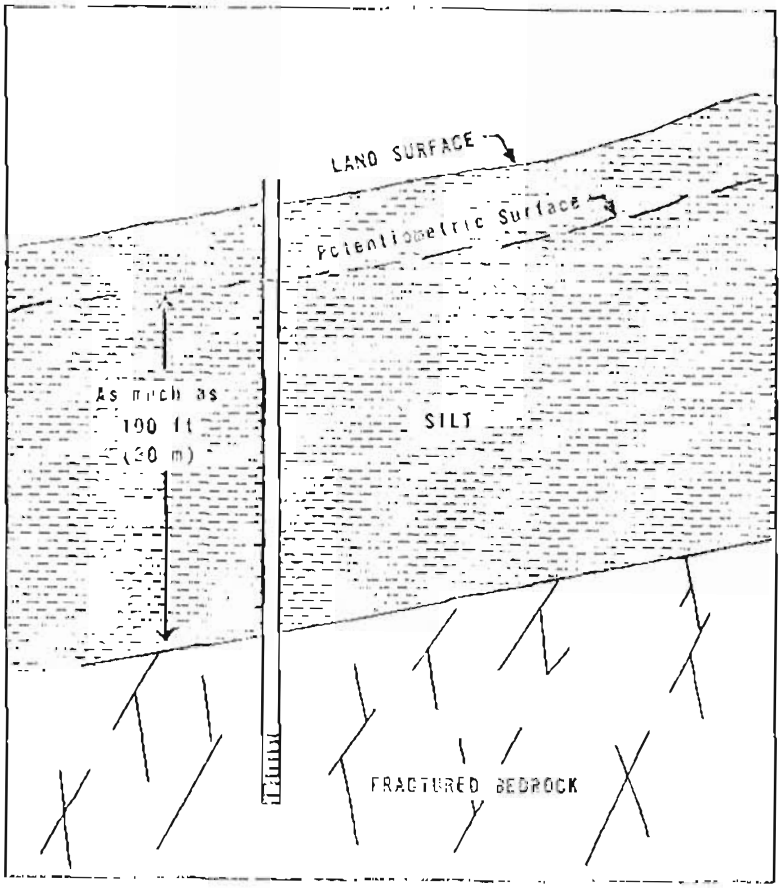


Figure 16.--Generalized hydrogeologic conditions on the lower slopes. A substantial thickness of low-permeability silt overlies water-bearing bedrock. Wells can still yield adequate water for domestic purposes if the potentiometric surface falls several tens of feet.

The net water consumed may be substantially increased by water waste. A seepage pit which is not replaced when it becomes plugged causes water waste. A well in the artesian zone which is allowed to flow unchecked also wastes water. For example, near the intersection of Steese Highway and Farmer's Loop Road (fig. 1), flow continued for more than a year from a well in which a drilling company was unable to control thermal erosion of the frozen materials. During the period of uncontrolled flow (July 1976 to September 1977), the well discharged more than 26 million gal of ground water, and water level declined 8.2 ft in a well located 764 ft upslope. Uncontrolled flow has occurred from several other wells along Farmer's Loop Road and from one in the valley of Goldstream Creek.

Ground-water quality

Ground water throughout the uplands is of calcium bicarbonate or calcium sulfate type. Four chemical properties of concern to most local homeowners are hardness of water and its concentrations of arsenic, nitrate, and iron. Health-related aspects of these properties are discussed, and the distribution of ground water containing objectionable amounts of each are depicted on a map by Johnson and others (approved for publication).

Ground water containing arsenic in excess of the recommended maximum for drinking water (Environmental Protection Agency, 1975) is sporadically distributed throughout the uplands. Arsenic poisoning has been reported in Nova Scotia in a man who was drinking water containing 5 mg/L of arsenic (Grantham and Jones, 1977). Concentrations above 0.3 mg/L of drinking water have been correlated with increased incidences of some forms of cancer (Environmental Protection Agency, 1972). The maximum arsenic concentration detected in more than 300 ground-water samples from the Fairbanks uplands is 10 mg/L. Arsenic is colorless, odorless, and undetectable in water except by a properly equipped laboratory. It is not removed by domestic water-treatment systems such as water softeners or reverse-osmosis units.

Nitrate concentrations in excess of the EPA recommended maximum for drinking water are also sporadically distributed throughout the uplands. Nitrate is colorless and odorless and is a health hazard primarily to infants under 3 months of age. Although a simple field test can be made for nitrate, analysis by a qualified laboratory is more precise. Nitrate, like arsenic, is not removed by most water-treatment systems.

Although iron in water is not a health hazard, it is a nuisance to consumers and causes staining of clothing and plumbing fixtures. Much of the ground water in the uplands contains more than 1 mg/L of iron; ground water containing less than 1 mg/L has been detected only in samples collected from wells on the upper slopes and ridgetops. Iron can be removed by individual water-treatment systems installed in homes.

High hardness of water is primarily a nuisance rather than a health hazard. Hard water consumes soap and deposits scale on plumbing fixtures, water heaters, and cookware. Although desirable levels of hardness are a matter of individual consumer preference, 100 mg/L is an approximate boundary between what many people consider hard and soft water (Hem, 1970). Using this criterion, soft water has been found only in wells located on and near the ridgetops above an elevation of 950 ft (Johnson and others, approved for publication).

Other nuisance characteristics of ground water are taste and odor. These are attributable to decomposing organic material in the sediments and are usually accompanied by iron concentrations in excess of several milligrams per liter. The combination of bad taste, bad odor, and rusty water has caused some upland homeowners to discontinue using their wells for drinking water.

Environmental considerations of septic systems

The environmental factors of principal interest in defining pollution susceptibility of the uplands are the capacity of the soil to filter bacteria and sorb chemical pollutants, and the depth to the water table.

Septic systems in the uplands are emplaced either in silt or bedrock. Where the effluent is able to percolate through silt, the small grain size should provide good filtration of bacteria. Where the permeability of the silt is too low to permit the effluent to percolate downward, much or all the effluent moves to the land surface where it either runs off or is lost by evapotranspiration. Whether it infiltrates or flows to the surface, the threat of bacterial contamination to the aquifer is slight. However, health hazards may be posed by effluent that reaches the land surface. Septic systems placed in bedrock may discharge effluent to a variety of materials. If the bedrock is decomposed mica schist, the filtration and sorptive capacities may provide good treatment of effluent. If the bedrock is fractured brittle rock, such as quartzite and marble, the joints and fractures may serve as open conduits which provide negligible filtration.

Most of the seepage systems in the uplands discharge effluent many tens of feet above the water table. Effluent percolates downward through a variety of rocks and minerals and is aerated over a significant distance. Where the seepage pit is emplaced in rocks with poor filtration and sorptive characteristics, the effluent may have to seep through finer and more reactive material at depth before it reaches the saturated zone. Aeration also helps to oxidize bacteria and some other pollutants.

The potential for bacterial pollution of the bedrock aquifer is greatest in areas lacking silt to filter the effluent and where the water table is close to the land surface. Such conditions are unlikely to be found south of Goldstream Creek because the silt cover there is thick on the middle and lower slopes. However, the silt cover thins northward, and, north of Goldstream Creek, the probability of finding such conditions increases.

As of the spring of 1978, there were no known instances of bacterial contamination in the many hundreds of wells completed in the bedrock aquifer. The area therefore appears to have a low potential for contamination.

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