HYDROLOGY OF TSIRKU RIVER ALLUVIAL FAN NEAR HAINES, ALASKA

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ABSTRACT

Ground-water discharge at the toe of Tsirku River alluvial fan, 20 miles north of Haines, Alaska, maintains open reaches in the Chilkat River throughout the winter low-flow period. A late fall-early winter run of chum salmon spawn in these open reaches. The spawned-out salmon attract the largest known concentration of bald eagles (more than 3,000) to the area by providing an easily obtainable food source.

Analysis of hydrologic data from the Tsirku fan area, including seismic refraction, water-level, water-quality, and isotopic data, indicated that:

1. Depth to bedrock at the axis of the Chilkat Valley is at least 850 feet.
2. The principal source of recharge to the ground-water system of the fan is water lost from stream channels crossing the fan surface.
3. Seventy-five percent of the winter flow of the Tsirku River at the head of the fan was derived from ground water discharge.
4. Oxygen and hydrogen isotope data suggest that water at a depth of 260 feet is derived from precipitation deposited at relatively high altitude, continental areas.
5. Although areas of visible ground-water discharge at the toe of the Tsirku Fan appear to be randomly distributed, their locations are probably controlled by differences in hydraulic conductivity in the alluvium.

INTRODUCTION

The Tsirku fan is located west of the village of Klukwan, about 20 mi northwest of the city of Haines, Alaska (fig. 1). The area around the toe of the fan, which is bordered by the Chilkat River, is the site of the largest known concentration of bald eagles in the world (Boeker et al., 1980). More than 3,000 birds are attracted to this area by late fall/early winter runs of chum and coho (silver) salmon. Open leads in the Chilkat River during the winter provide spawning habitat, and the spawned-out salmon are an abundant food source for the eagles.

In 1979, the Alaska Chapter of the National Audubon Society asked the U.S. Geological Survey to become involved in hydrologic investigations of the Tsirku fan area. In 1980, a formal request for such a study was

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made by the Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys (ADNR-DGGS). The objectives of the study were to describe (1) the general hydrology of the Chilkat River basin, and (2) more specifically, the relation between surface water and ground water in the vicinity of the Tsirku River alluvial fan. The study began in May 1981, and field work was completed in July 1983. This paper will deal only with the findings of investigations of hydrology of the Tsirku fan area.

The Chilkat River basin, which has an area of about 1,000 mi^2, is characterized by by rugged, highly dissected mountains with steep-gradient streams; braided rivers in broad, glaciated valleys; and numerous glaciers. Altitudes range from sea level at the mouth of the Chilkat River to 7,434 ft at the summit of Mt. Henry Clay. Areas below timberline (about 2,000 ft) support dense brush and forests of spruce and hemlock.

The Chilkat River basin has moderate summer and winter temperatures, heavy precipitation in late summer/early fall, and heavy snowfall in winter. Local orographic effects cause differences in weather conditions over short distances. It is not uncommon for simultaneous temperatures at Haines and Klukwan to differ by as much as 10°F. Average yearly precipitation ranges from about 55 in. at Haines to 20 in. at Klukwan.

GEOLOGY

The Chilkat River basin is divided into two distinct geologic provinces by the Chilkat River fault (which roughly underlies the Chilkat River), an extension of the Chatham Strait fault system to the south (Brew et al., 1966; Ovenshine and Brew, 1972). East of the fault and Chilkat River, the structural trends are predominately northwest, as in much of southeast Alaska; west of the fault and river the structural trends are complex and include west-trending faults and lineaments.

The rocks east of the Chilkat River consist of intrusives and metavolcanics that range in age from Cretaceous to early Tertiary (100-50 million years). Lithologically diverse, metamorphosed Paleozoic, Cretaceous, and Tertiary rocks (500-50 million years) are present west of the river.

GLACIAL HISTORY

The principal land-shaping process during recent geologic time has been glaciation, and this process continues to modify the landscape. About 25 percent of the Chilkat basin is ice covered. Most types of glacial features can be found in the basin, and ground moraine covers most of the bedrock at lower altitudes. The complex glacial history includes multiple, basin-wide glaciations as well as local fluctuations of individual glaciers. The latest ice advance into the Tsirku fan area may have been as recent as 1,700 years ago or as early as 11,000 years ago (McKenzie and Goldthwait, 1971).

DATA COLLECTION

In the fall of 1982, the Alaska DGGS contracted for 1,000 ft of air rotary drilling. Eleven 6-inch diameter wells were drilled and cased -- eight are 40 ft deep and three others are 100, 220, and 260 ft deep, respectively (fig. 2). Three 2-inch diameter observation wells were also drilled using a vibrating-coring device.

Seismic refraction surveys were made on the Tsirku fan, lower Tsirku River valley, lower Klehini River valley, and an area between the Klehini and Tsirku Rivers within the Little Salmon River drainage (fig.2). The primary purpose of the seismic survey was to delineate the bedrock floor in the respective valleys, and thus determine the possibility of hydrologic connection between the Klehini and Tsirku Valleys. A Nimbus ES1210F[2] multichannel signal-enhancement seismograph was used with 12 geophones. Data were analyzed and plotted by computer.

On April 6, 1981, during low-flow conditions, a seepage run (a series of discharge measurements to determine gaining and losing reaches of a stream) was conducted on streams of the Tsirku fan and adjacent areas (fig. 3).

Water samples were collected from both deep (260 ft) and shallow (40 ft) wells and from the Tsirku, Klehini, and Chilkat Rivers. The samples were analyzed for concentrations of major cations and anions, nutrients, heavy metals, and oxygen and hydrogen isotopes.

DISCUSSION OF RESULTS

Drilling Data

Almost all drill cuttings were glaciofluvial materials derived from rocks in the basin, except for those from well AR-1 at the head of the fan. Well AR-1 encountered lacustrine deposits from depths of 150 to 200 ft, and bedrock from 200 to 220 ft. Grain sizes of material in all wells ranged from silt to 2-inch fragments of broken gravel, cobbles, and boulders. Geophysical well logs indicated distinct layers of fine-grained material between coarser grained sediments, a reflection of the complex depositional environment of glaciated valleys.

Seismic Survey

Seismic traverses were made perpendicular to the axes of the Chilkat, Tsirku, and Klehini Valleys, and also across a remnant outwash terrace between the Klehini and Tsirku Valleys, in the area of the Little Salmon River drainage (fig. 2). Data from the Chilkat Valley correlated well both with observation wells drilled on the Tsirku fan and with a

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[2] Use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

1972 gravimetric survey of the Klukwan fan on the east side of the valley made by the H.J. Kaiser Co. (M.M. Holmes, Klukwan Iron Ore Co., written communication, 1983).

Seismic data indicated a depth to bedrock of about 200 ft at the head of the Tsirku fan. The gravity profile of the bedrock surface beneath the Klukwan fan matched well with the projection of the seismic trace of the bedrock profile beneath the Tsirku fan (fig. 4). The greatest depth to bedrock indicated by the seismic survey was about 750 ft, about 1.25 mi from the west edge of the Chilkat Valley. The gravimetric survey indicated almost 900 ft as the deepest bedrock, at a point about 0.8 mi from the east side of the Chilkat Valley. Average seismic velocities were 7,000 ft/s for the saturated, uncconsolidated glaciofluvial sediments, and 12,000 ft/s for the bedrock, a fractured schist and phyllite.

Seismic data from the Klehini Valley indicated a depth to bedrock of about 100 ft at a point 1,000 ft south of the Haines Highway at mile 25. Data from Little Salmon River drainage area indicated a depth to bedrock of more than 150 ft. These results indicate the presence of a continuous alluvial layer between Klehini, Tsirku, and Chilkat Valleys and thus probable hydraulic connection among them.

TSIRKU FAN AQUIFER

The Tsirku fan aquifer is bounded by the bedrock valley floor and the east and west bedrock walls of the Chilkat Valley, and is continuous with sediments, both up- and downvalley. The potentiometric surface of the aquifer, drawn on the basis of water-level measurements in observation wells on the fan, approximates the shape of the fan, becoming slightly skewed down the Chilkat Valley at about mid-valley (fig. 5). The altitude of the potentiometric surface fluctuates seasonally, declining during winter to about 50 ft below land surface and rising during summer and fall to about 10 ft below land surface at the head of the fan. Water levels at the toe of the fan fluctuate seasonally from about 15 to 5 ft below land surface.

Ground-water flow rates can be estimated using Darcy's law:

$$V = (K/O)(i)$$

where V is average linear velocity, in feet/day;
K is hydraulic conductivity, in feet/day;
i is hydraulic gradient, a dimensionless variable;
O is porosity of the aquifer, expressed as a decimal.

The hydraulic conductivity and porosity have not been directly determined for the Tsirku fan sediments. However, coarse, sandy gravel typically has a hydraulic conductivity ranging from 200 to 2,000 ft/d and the porosity of such material is commonly about 0.25. The gradient of the potentiometric surface is 0.0052. Thus the rate of ground-water movement would range from 4 to 40 ft/d, and travel time from apex to the toe of the fan from 0.5 to 5 years.

Recharge

A seepage run conducted on April 6, 1982 indicated that 63 percent of the water entering the head of the Tsirku fan as streamflow was lost to the aquifer along the channels across the fan--streamflow decreased from 142 to 53 ft^3/s (fig. 3). Of the water in the Tsirku River entering at the head of the fan on April 6, 1982, about 70 percent was from the combined ground-water discharge to the surface in the Little Salmon River drainage, and from the area between Chilkat Lake and the Tsirku River. The remaining 30 percent of Tsirku River flow was outflow from Chilkat Lake.

Analysis of oxygen 18/16 and hydrogen 2/1 isotope data indicates that the water in observation well AR-3 (260 ft deep) was derived from an interior, high altitude source, whereas water from observation well AR-4 (40 ft deep), only 10 ft west of AR-3, was derived from a near-coast, lower altitude source. This suggests that there may be two zones of flow.

Discharge

Ground-water discharge from the Tsirku fan aquifer is concentrated in the Chilkat River at the toe of the Tsirku fan. The discharge zones are easily identified during the winter as ice-free channels where warmer (4-6 °C) water keeps the channels open at the toe of the fan and in a 10-mile reach downstream. Observation wells VC-1, 2, and 3 were drilled 30, 15, and 25 ft deep respectively, in exposed gravel bars in the Chilkat River. Water levels in the wells were higher than in the adjacent river channel during the winter low-flow period, which indicates movement of ground water toward the river. During summer high flows, these ground-water discharge areas are inundated and the discharge zones concealed.

Several possibilities exist for the cause of these ground-water discharge zones. A downstream decrease in hydraulic conductivity due to a general downstream decrease in sediment size could cause a damming effect, inducing the potentiometric surface to rise above the altitude of the land surface at the toe of the fan, resulting in discharge at the surface.

Another reason for the occurrence of discharge zones at the toe of the fan may be the interlayering of sediments from the Tsirku fan, Klukwan fan, and Chilkat River, which could cause local changes in hydraulic conductivity. Depositional modes may have ranged from catastrophic, colluvial/fluvial deposition on the Klukwan fan, to primarily fluvial on the Tsirku fan. The Klukwan fan appears to be built by a series of mud flows and slides with poorly sorted sediments in a fine-grained matrix (H.J. Kaiser Co., written communication, 1983). This mode of deposition is dominant along the flanks of the eastern Chilkat Valley, where there is a series of steep colluvial/fluvial fans.

In contrast, the Tsirku fan is built entirely by fluvial tranport of sediment. Consequently, the sediments are better sorted than on the Klukwan fan, and have a greater hydraulic conductivity. Sediment in the

Chilkat River sampled upvalley from the Tsirku and Klukwan fans is finer grained than Tsirku fan sediments. This condition may add to the variation in sediment size and complex structure of the alluvial aquifer in the Tsirku fan area.

The cause of the discharge zones is most likely a combination of the above factors. No geochemical, isotopic, or physical evidence was found to indicate that the Chilkat River fault has any influence on ground-water flow paths or discharge at the toe of the Tsirku fan.

SUMMARY

Ground-water discharging to the Chilkat River at the toe of the Tsirku fan is derived from the Tsirku fan aquifer. The major source of recharge to the aquifer is stream loss on the fan. During winter low-flow periods, most of the water in the Tsirku River at the head of the fan is from ground-water discharge to the surface in both the Little Salmon River drainage and in the area between Chilkat Lake and the Tsirku River.

The potentiometric surface in the Tsirku fan is deltaic in plan view, and is skewed slightly downvalley as it flows toward the center of the Chilkat River valley. Ground-water levels in the Tsirku fan fluctuate seasonally, rising in the summer and fall and declining in the winter and early spring. The greatest seasonal fluctuations in water level occur at the head of the fan.

The depth to bedrock in the Chilkat Valley in the vicinity of the Tsirku fan is more than 850 ft. Ground water sampled at 260 ft in the Tsirku fan aquifer is probably derived from high altitude, interior precipitation. Shallower ground water is probably derived from precipitation originating in lower altitude, coastal areas.

The locations of ground-water discharge areas at the toe of the Tsirku fan are probably controlled by the distribution of zones of varying hydraulic conductivity in the alluvium.

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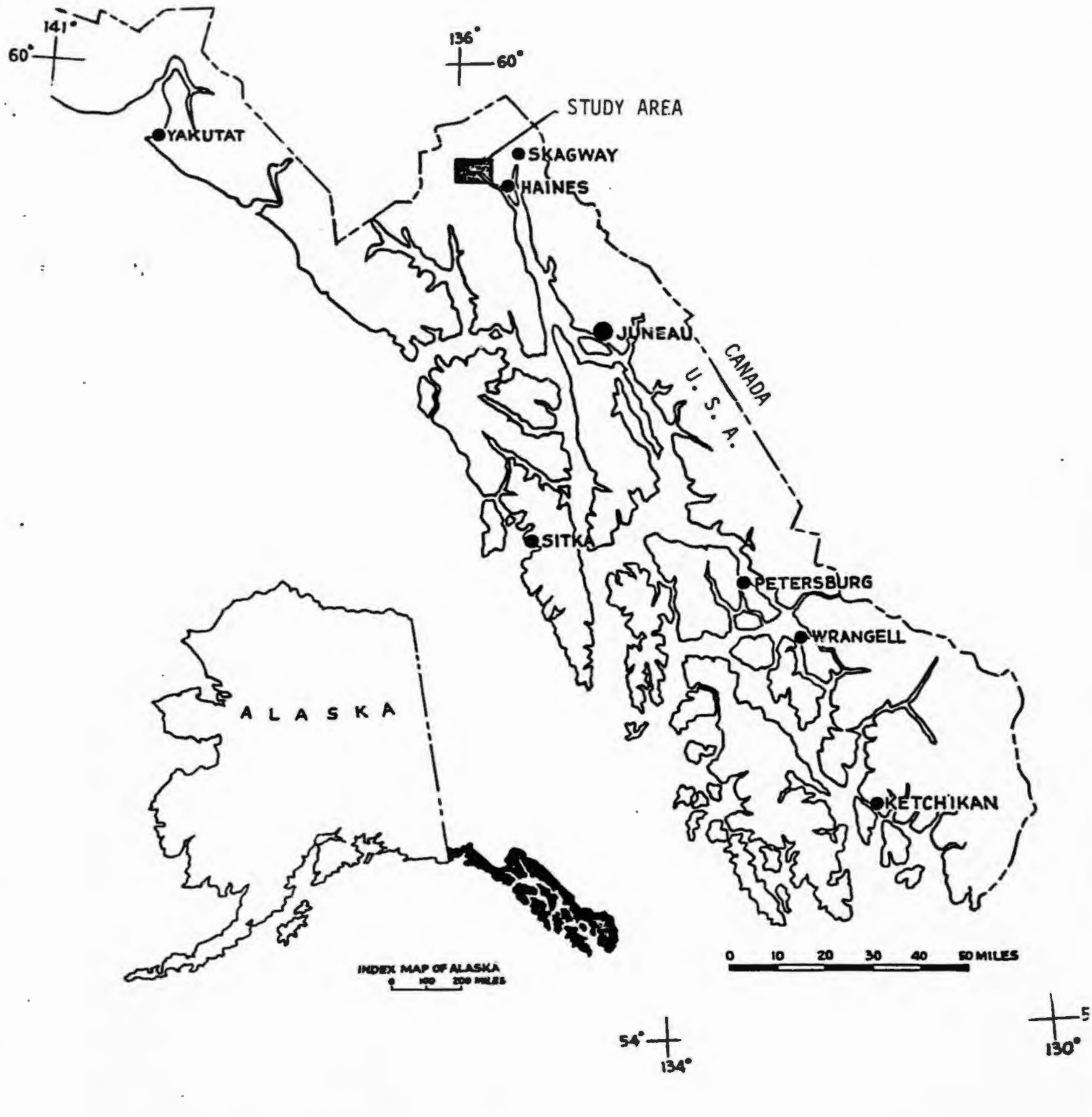

Figure 1.--Location map of Southeast Alaska and field area.

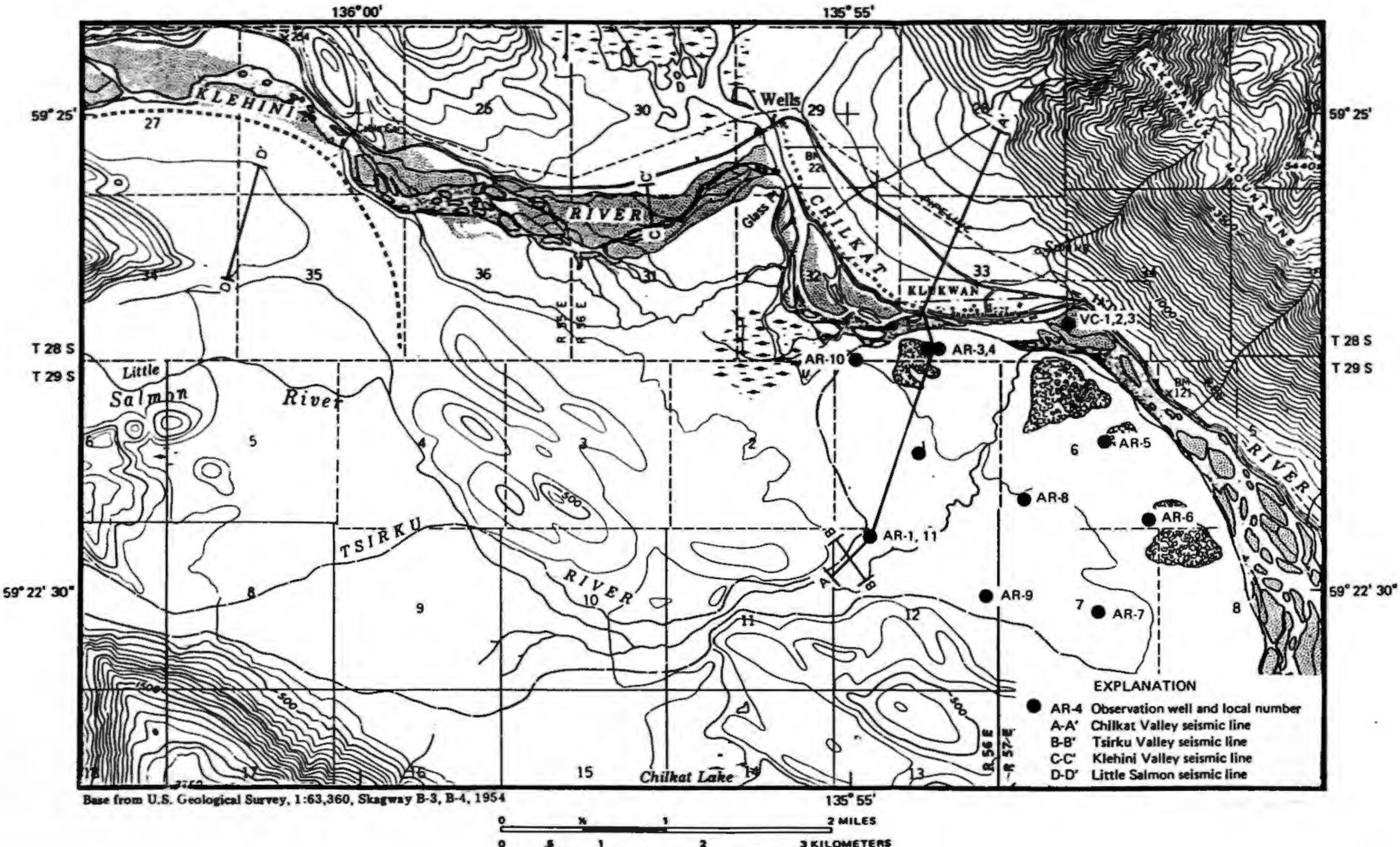

Figure 2.–Tsirku Fan, Klukwan Fan and vicinity, showing locations of observation wells and seismic survey lines for the Chilkat, Tsirku, Klehini, and Little Salmon valleys (for cross section of Chilkat Valley see figure 4).

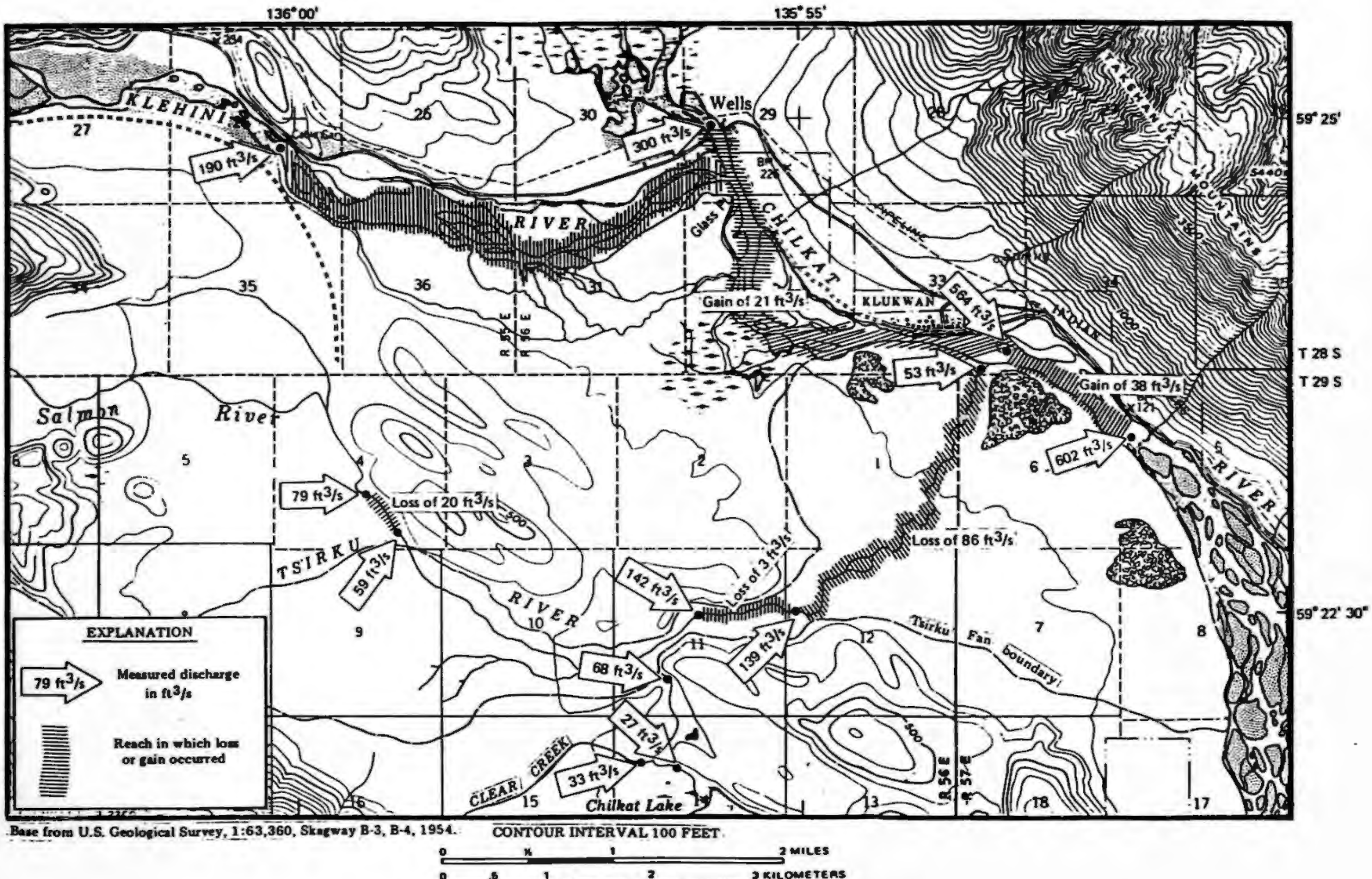

Figure 3.--Losses and gains in streamflow in the Tsirku River Fan area, April 6, 1982.

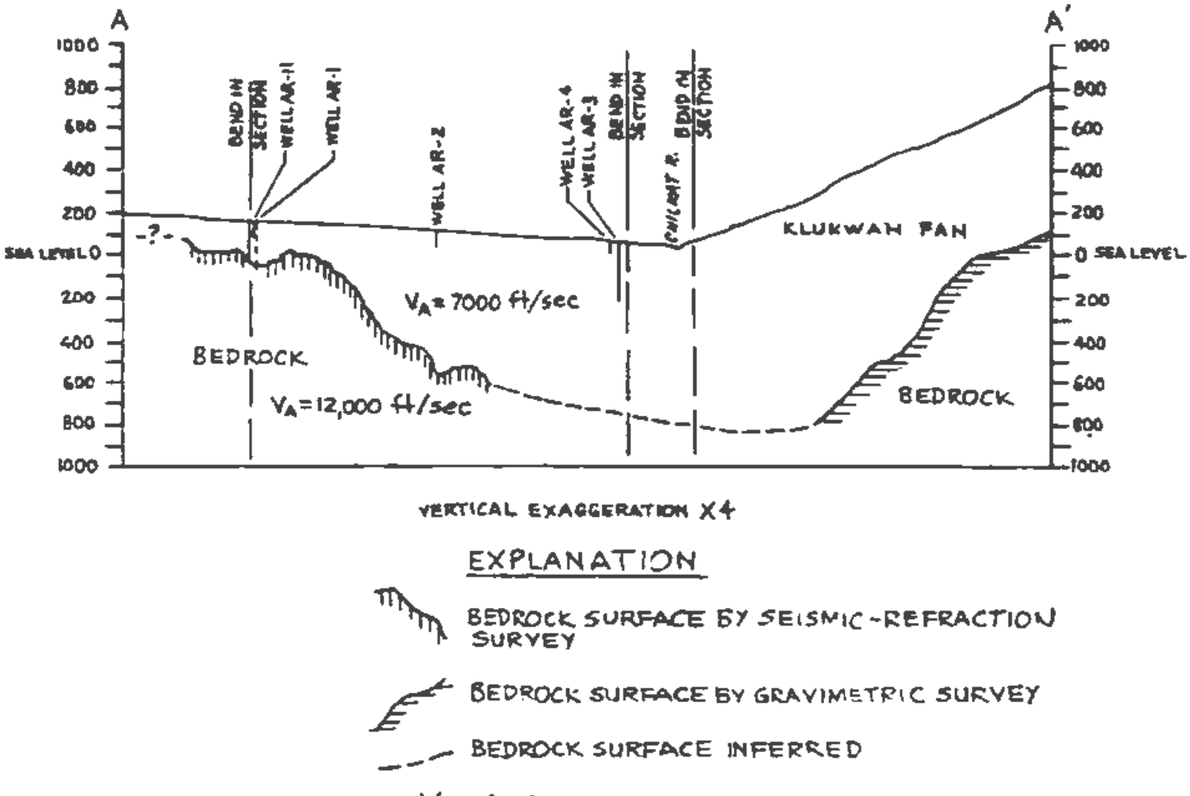

Figure 4.--Section across Chilkat Valley and Tsirku Fan showing bedrock depth from seismic refraction and gravimetric data. See figure 2 for location of line A-A'. (Gravimetric data from M.M. Holmes, Klukwan Iron Ore Co., 1972, written permission.)

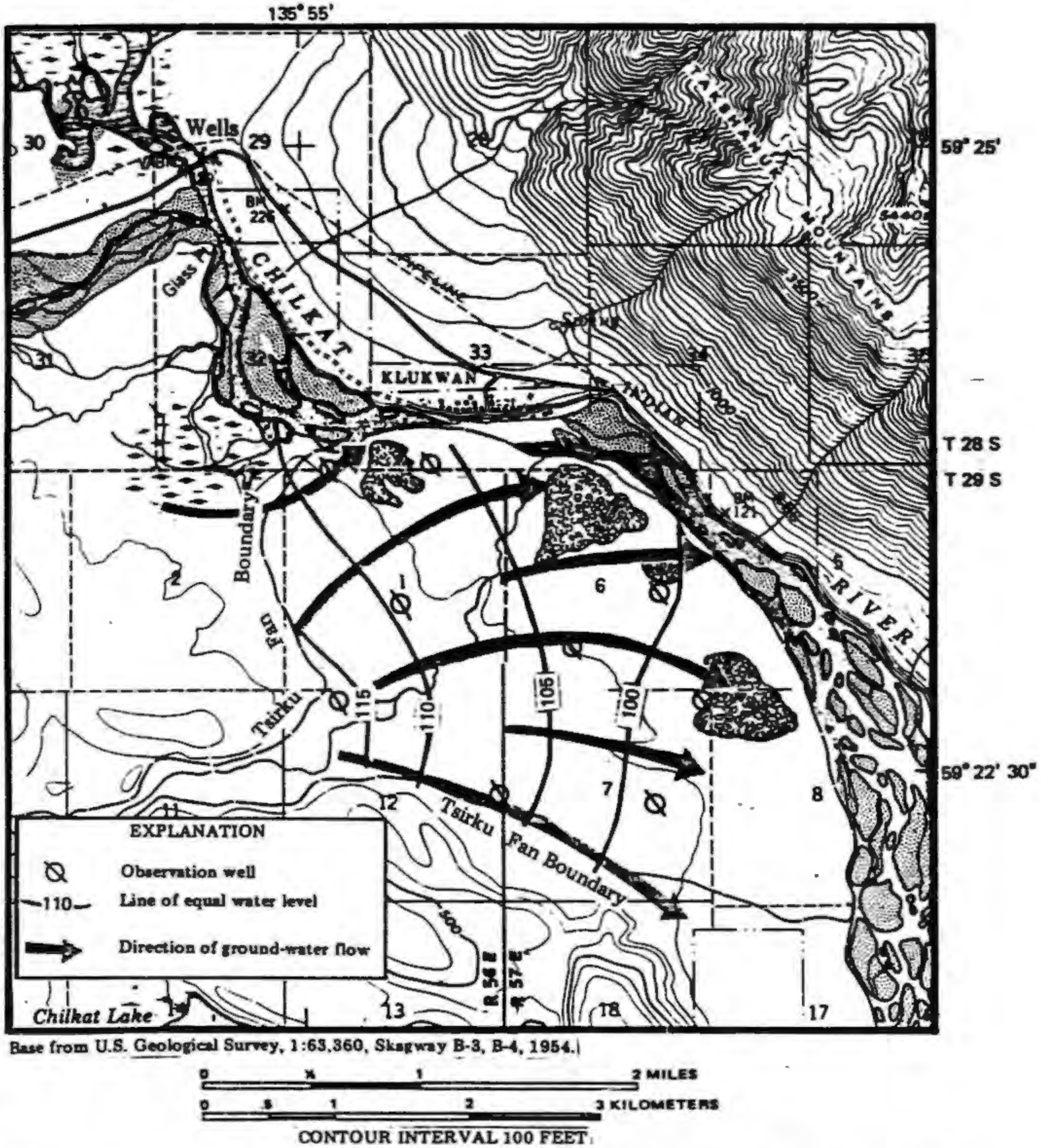

Figure 5.--Potentiometric surface map of Tsirku Fan shallow ground-water system, March 11-16, 1983.