Bathymetry and temperature of some glacial lakes in Wyoming

(geomorphology/limnology)

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Geology

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ABSTRACT **On the west flank of the Wind River Mountains, Wyoming, are several large lakes occupying glacially scoured depressions dammed by terminal moraines. Fremont, Willow, and New Fork Lakes, having maximal depths of 185, 85, and 62 m, respectively, are not only deep, but in 1970–1978 they had no measurable coliform. They have exceptionally low values of total dissolved solids; Fremont Lake has only 12.8 mg/liter, probably the second most dilute large lake in coterminus United States. Summer mixing is restricted to the uppermost 10 m, below which the lakes are essentially isothermal at the maximum density temperature, about 3.9°C.**

In the Wind River Mountains, Wyoming, there are hundreds of lakes occupying depressions scoured by glacial ice in the late Pleistocene. Among these, the largest are behind the terminal moraines of the last or Pinedale advance. These include Fremont, Willow, New Fork, Boulder, and Little Half Moon Lakes, the first three of which are discussed here in a preliminary way. These lakes are fed by streams originating at or below the continental divide and drain an area of Precambrian crystalline rocks, mostly gray gneiss extensively cut by quartz, pegmatite, and quartz dikes. The dilute character of the water in these lakes is attributed to the highly insoluble character of these rocks and the virtual absence of deep soil cover. The drainage basins are at elevations varying from 2200 to 4100 m, where both temperature and precipitation are low, acting further to slow chemical and biochemical reactions.

Methods

Bathymetric contours were drawn on the basis of measurements of depth made with an oceanographic echo sounder. Boat location during the survey was determined by angle intersection from two or three shore-located theodolites. The number of located points at which depth readings were obtained averaged 17 per km^2 of lake area.

Temperature profiles taken during the years 1971–1979 were made with Watanabe Keike deep-sea protected reversing thermometers, read to the nearest 0.01 or 0.1°C.

Details of water chemistry, hydrology, and biology, including plankton identification, in Fremont Lake have been reported previously (1).

Hydrology

The geographic positions of Fremont, Willow, and New Fork Lakes and their respective drainage areas are shown on Fig. 1. The basins are contiguous, but only that of Fremont reaches to the continental divide. At the upper end of the lakes the drainage areas are, respectively, 196, 64, and 75 km^2.

The mean annual discharge of streams draining into the lake has been measured in two of the three. Pine Creek, feeding Fremont Lake, has an average annual discharge of 5.1 m^3/sec. New Fork River, feeding New Fork Lake, has an average of 1.40 m^3/sec. These are thus, respectively, 0.026 and 0.019 m^3/sec per km^2. The latter probably is applicable also to Willow Lake whose supplier, Lake Creek, has not been measured.

These figures, expressed in the terms familiar to irrigators in western United States, would be: for Fremont Lake, 130,000 acre feet per year; for Willow Lake, 30,400 acre feet per year; and for New Fork Lake, 35,700 acre feet per year.

The annual precipitation at the nearest rain gauge, Pinedale, Wyoming, is 270 mm; on the lake surfaces, it is probably 350 mm. The annual lake evaporation is estimated as 1000 mm.

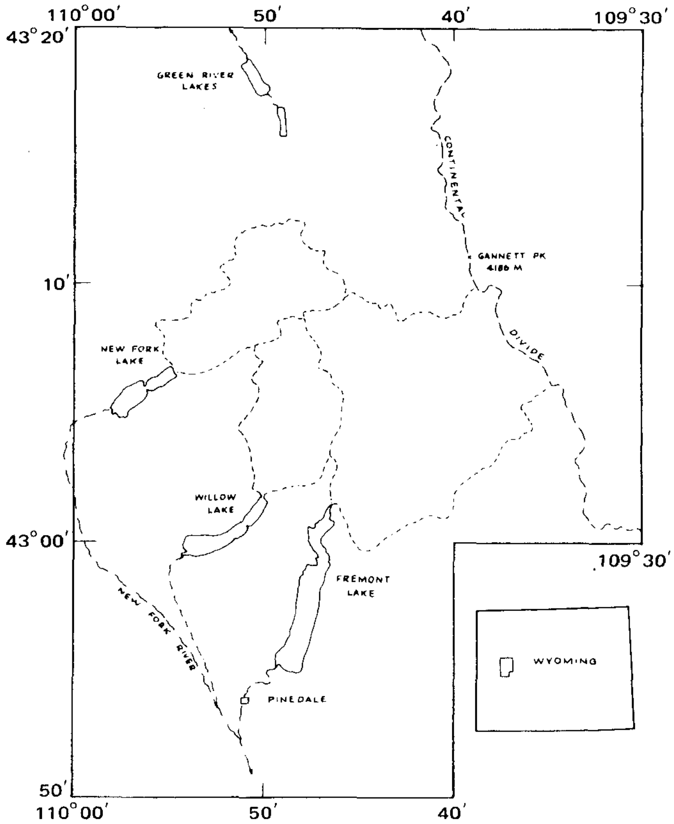

FIG. 1. Location map showing New Fork Lake, Willow Lake, and Fremont Lake and their respective drainage areas, Sublette County, Wyoming. Many smaller lakes in the vicinity are not shown.

Table 1. Lake characteristics and drainage basin area

	Fremont Lake	Willow Lake	New Fork Lake
Drainage area, km^2	196	64	75
Lake area, km^2	20.61	7.26	4.97
Water elevation, m, msl*	2261	2346	2383
Lake volume, km^3	1.69	0.26	0.16
Maximal depth, m	185	85	62
Mean depth, m	82	36	33
Maximal drawdown, m	0.9	2.7	3
Useable storage			
km^3	0.0185	0.0196	0.0149
acre ft.	15,000	15,900	12,100

* msl, Mean sea level.

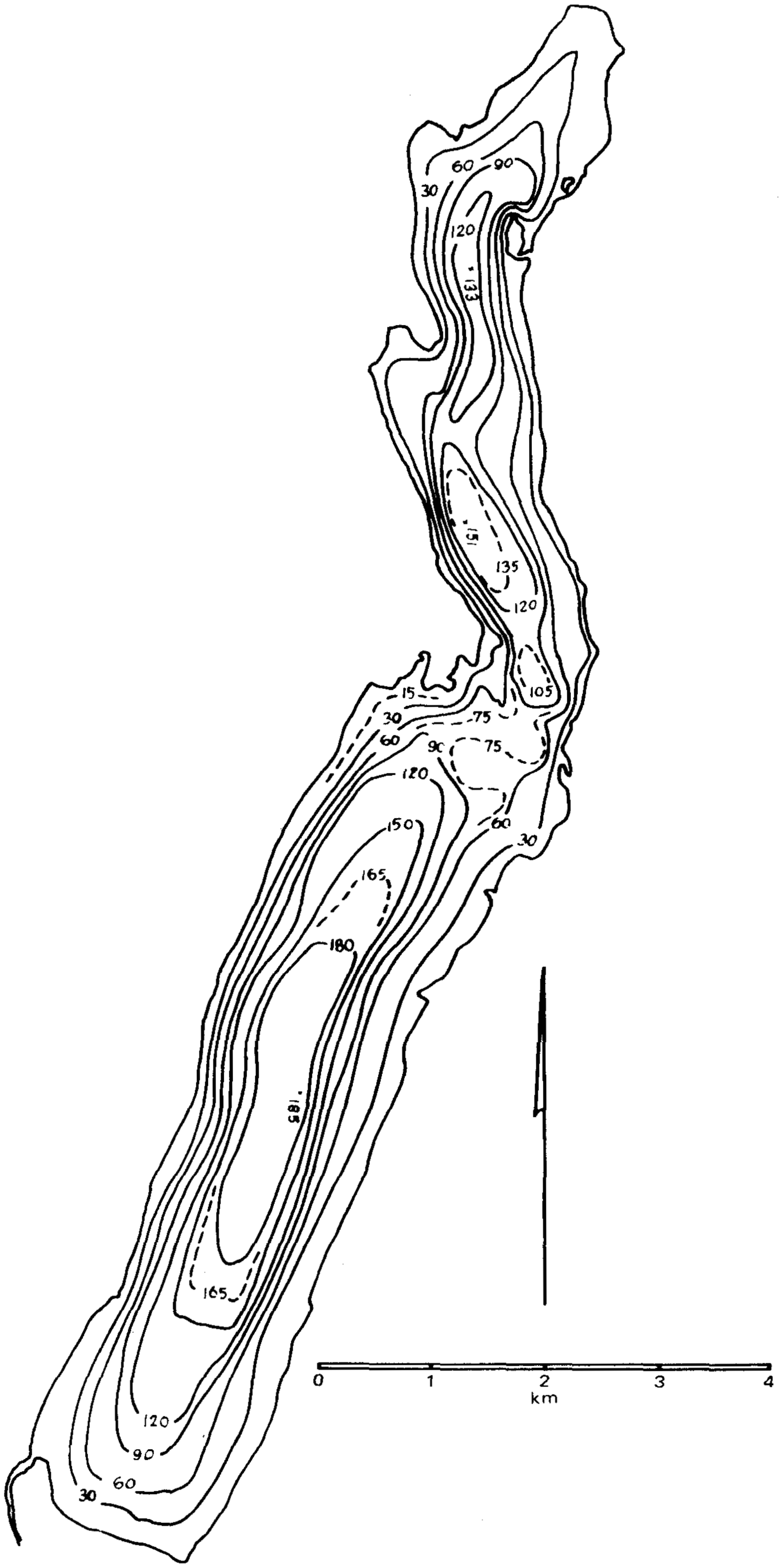

FIG. 2. Bathymetric map of Fremont Lake. Mean water surface elevation and spillway elevation is 2179 m, mean sea level. Depth contour interval is 30 m; intermediate depths are given by broken lines.

Bathymetry

The lake areas and volumes are summarized in Table 1. Bathymetric contours are shown in Figs. 2–4.

Both Willow and New Fork Lakes are dammed at the outlet. The gates are used to store water for irrigation during the spring snowmelt and to release water during the period June 1–July 20. The dam at Willow, built and controlled by a ranch family, is 3.7 m high, was built about 1931, and causes a water surface fluctuation of about 2.5 m. That on New Fork was built by the New Fork Irrigation District comprising several local ranch families with no government subsidy. The dam is 5.2 m high, was built in 1928, and causes a summer drawdown of 2–3 m.

Fremont Lake has a low barrier across its discharge outlet that

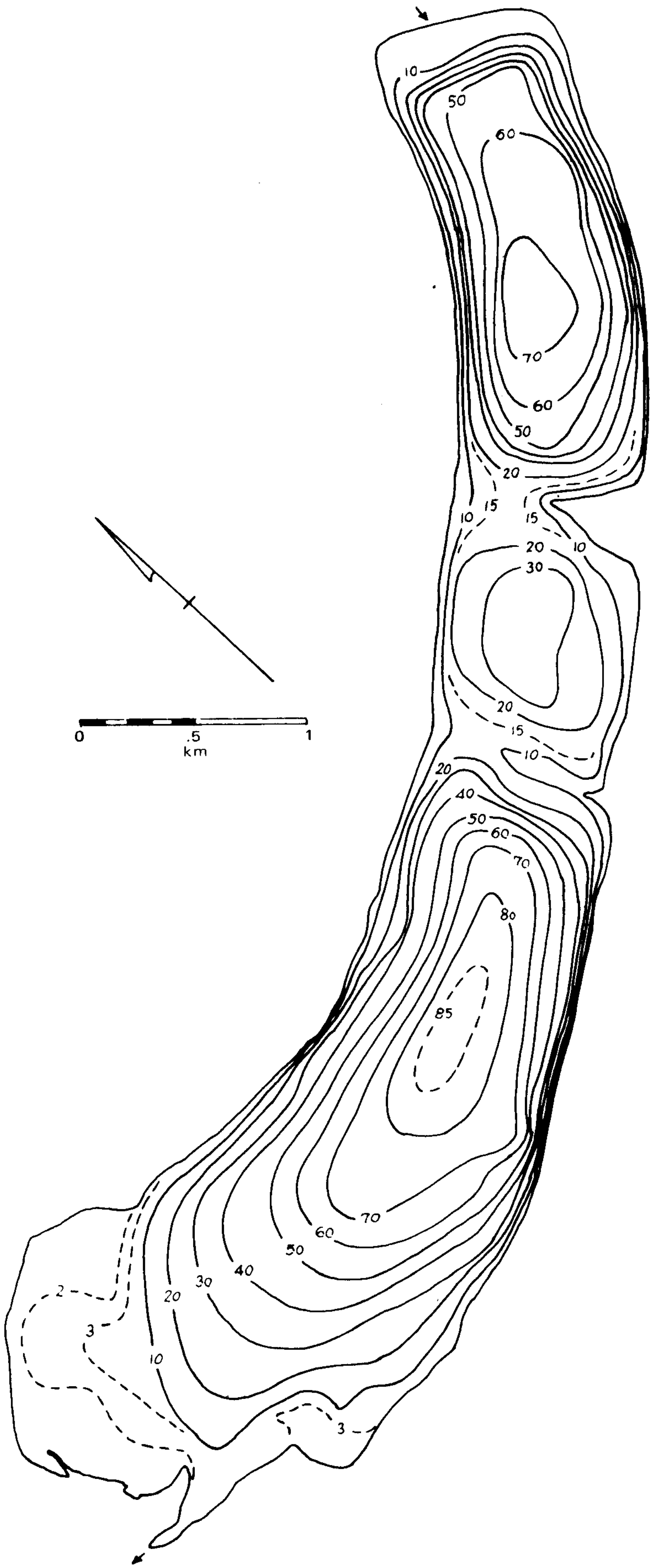

FIG. 3. Bathymetric map of Willow Lake. Mean water surface elevation is 2346 m, mean sea level. Points of inflow and outflow are indicated by arrows. Depth contour interval is 10 m; intermediate depths are given by broken lines.

can, with wood flashboards, raise the water level about 0.6 m. The effect of the artificially fluctuated water surface is shore erosion, resulting in segments of the shoreline standing as vertical banks of morainal gravel 2 m high. Littoral vegetation is periodically submerged so that in places there is an accumulation of logs of dead trees along the shore. The upstream third of Fremont Lake is bounded by steep slopes of bedrock, whereas the lower and larger portion is bounded by lateral moraines with

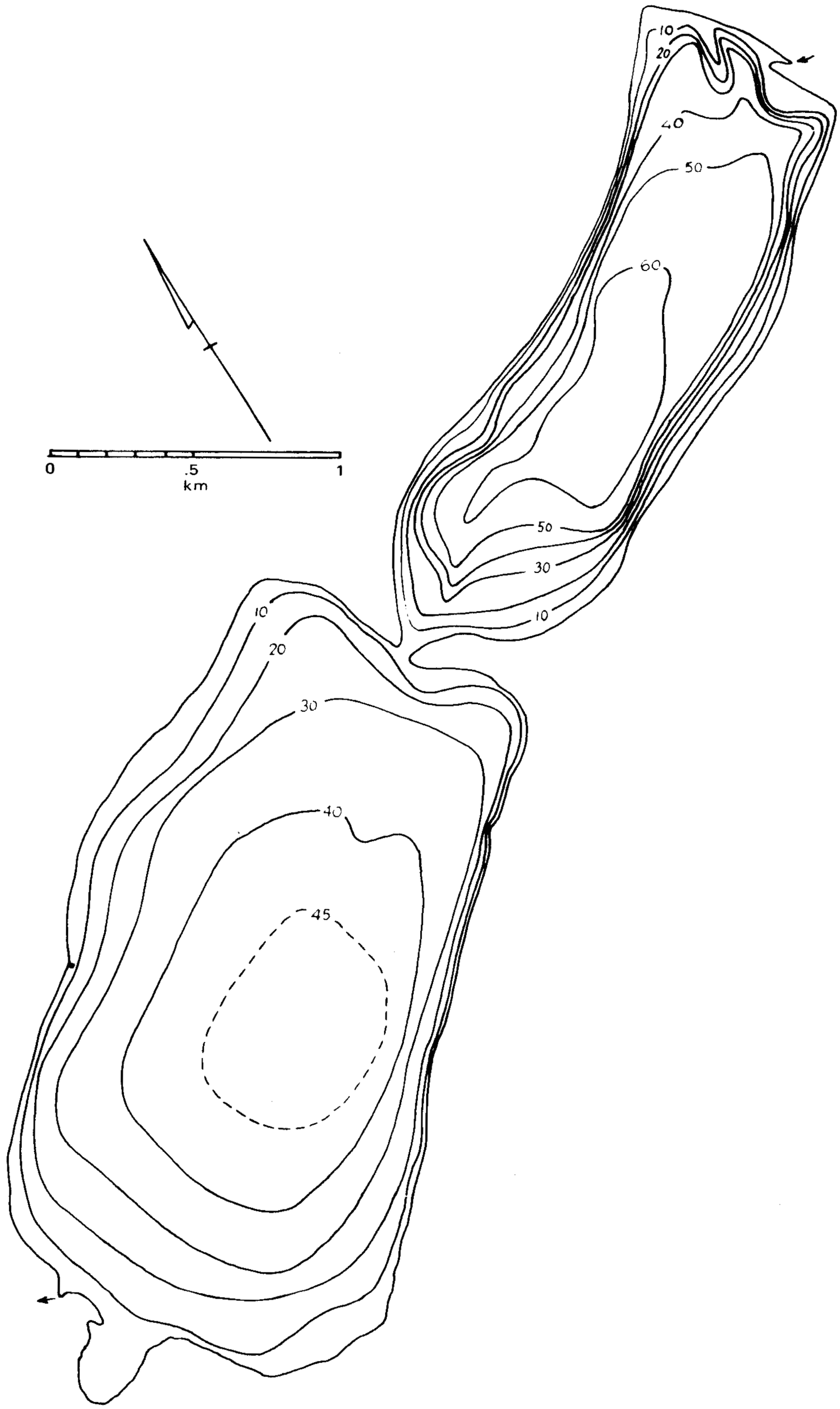

FIG. 4. Bathymetric map of New Fork Lake. Spillway elevation at outlet is 2383 m, mean sea level. Points of inflow and outflow are shown by arrows. Depth contour interval is 10 m; intermediate depths are given by broken lines.

Table 2. Surface water temperature (°C) of lakes near Pinedale, Wyoming

Date	Fremont Lake	Willow Lake	New Fork Lake
May 9, 1971	3.88		
May 12, 1971	4.17		
May 17, 1971	4.01		
June 16, 1971	10.80		
July 21, 1970	17.6		
July 31, 1979			20.04
Aug. 16, 1979			17.8
Aug. 23, 1979			15.88
Aug. 25, 1973			16.78
Aug. 26, 1973		15.96	
Sept. 19, 1971	15.30		

no outcrops of bedrock. Willow and New Fork Lakes are bounded by lateral moraines for their full length. Fremont Lake is not segmented by any moraine. Both Willow and New Fork Lakes are partly cut by moraines extending as submerged barriers across the lake. In Willow there are two such constrictions and in New Fork only one. The Narrows of New Fork Lake is formed by a moraine nearly cutting the lake in two, and the water depth over the connecting shoal is a mere 1 m.

The fact that three adjacent lakes nearly identical in location relative to the mountains exhibit quite different expressions of glacial advance and halt should give pause to geologic interpretation of the glacial history of a mountain range on the basis of the moraines in any single valley.

The lower end of Fremont Lake is characterized by a nearly flat lake bed over an area 3 × 0.75 km. This can be ascribed tentatively to sedimentation of colloidal-size material deposited from density currents in the deep body of water. It may be surmised that a similar deposit of fine-grained sediment fills the lower basins of both Willow and New Fork Lakes, but the area of flat bed is not as large as in Fremont Lake.

Temperature

Summer mixing achieves a depth of about 10 m in each lake. Below that, all the lakes tend to maintain a nearly constant temperature close to that of maximum density, t_{md}. The t_{md} changes from 3.94°C at the surface to 3.73°C at a depth of 180 m (2). Table 2 shows the change of surface water temperature during the summer season.

The average date of ice breakup, well documented for Fremont Lake, is May 15. It freezes in mid-January. As shown on Fig. 5, the temperature of Fremont Lake was practically isothermal at 3.88°C on May 9, a few days before breakup in that year. Surface temperature increases progressively to the end of July, but depth of mixing continues to increase until late August. In 1971, temperatures below 90 m remained virtually unchanged between May 9 and 17; ice breakup occurred on May 13. On the basis of these temperature observations, Rickert and Leopold (1) concluded that vernal mixing is incomplete, but the lake must turn over in late fall. The dissolved oxygen concentration was 80% of saturation at the bottom (180 m) on July 21, 1970, one indication of complete circulation at some season. The temperature profiles of the several lakes suggest that they follow nearly identical patterns regardless of maximal depth (Fig. 5).

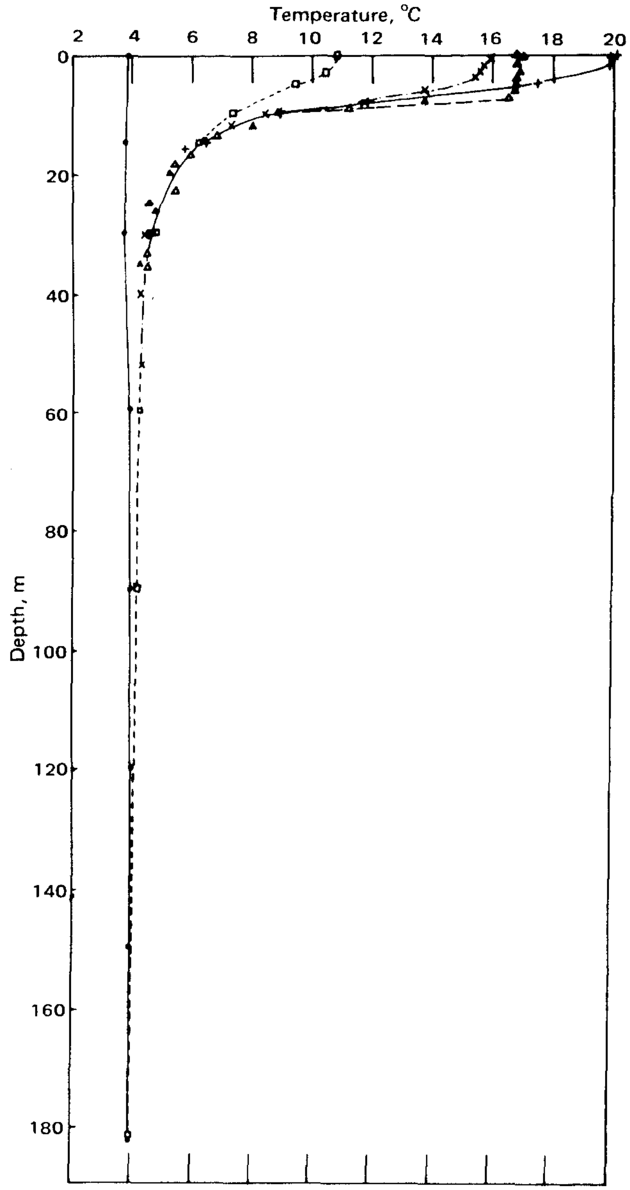

FIG. 5. Profiles of temperature as a function of depth. Fremont Lake: ●—●, May 9, 1971, where depth was 183 m; □---□, June 16, 1971, depth 183 m. New Fork Lake: +—+, July 31, 1979, where depth was 16 m; ▲—▲, Aug. 16, 1979, depth 38 m; X--X, Aug. 23, 1979, depth 56 m; △---△, Aug. 25–28, 1973, depth 38 m.

Conclusion

Glacial lakes in the Wind River Mountains are of exceptional scientific and aesthetic interest owing to their low content of dissolved solids, their depth, and absence of coliform contamination. These lakes are being subjected to rapidly increasing use by recreationists. I hope that a recognition of their unique character, based on physical and biological measurements, will help to protect them from abuse.

1. Rickert, D. A. & Leopold, L. B. (1972) *U.S. Geol. Survey Prof. Paper* **800D**, 173–188.
2. Strøm, K. M. (1945) *Geofysiske Publikasjoner* **16** (8), 14 p.