GLACIER SURVEYS IN BRITISH COLUMBIA

By

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The collection of streamflow data in Canada is carried out principally by the Water Resources Branch, Department of Northern Affairs and National Resources. Since glaciers play an important part in the pattern of run-off in mountainous areas, the Branch, in 1945, enlarged its activities in Western Canada to include surveys of certain typical glaciers. The ultimate purpose in view is the determination of the effect of glacier variation on run-off, particularly the amount of run-off which may be expected in future from glaciers. A limited number of glaciers were selected for observation purposes, each reasonably accessible and considered to be typical of the general area of location. As far as possible the glaciers selected were those for which records had previously been obtained. The studies are being conducted under the general direction of the Head Office of the Water Resourves Branch in Ottawa, Ontario.

Glacier Phenomena

A glacier is a mass or stream of ice formed from great depths of snow accumulating in mountain basins at high altitude, which advances slowly in manner resembling that of a river. The forward movement is due to the pressure exerted by the snow combined with gravitational effect. As in a river, all portions of the glacier do not move with the same rapidity. The surface moves faster than the bed and the centre faster than the sides. Where a change in direction is met, the concave side lags till the convex side assumes its proper place. When the slowly moving mass of ice reaches lower altitudes, melting takes place during summer months owing to higher temperature, and glacial streams are formed. When rate of ice flow is greater than rate of melt, the glacier advances; while, if melting exceeds the forward movement, the glacier retreats. Many factors are at work in determining the advance or retreat. Some of these are temperature, precipitation, amount of suspended material in the glacier, sunshine, and the topography of the valley. Although changes in the snout of the glacier are closely related to the changes in these factors, changes in the icefield appear to be the result of similar forces acting over longer periods of time, particularly the factors of temperature and precipitation.

Observations by Alpine Club of Canada

Glacier observations in Canada under governmental direction began in 1945. Prior to this date, sporadic observations had been made by members of the Alpine Club of Canada over a long period of years, the first on record being for the year 1887. In addition to photographs, the recorded observations usually have included the distance from a reference point to the nearest ice of the glacier toe; a limited number of observations also were made of the rate of glacier flow.

Purpose of Investigation

The purpose of the surveys is to determine the movement of the glaciers in advance or retreat with respect to a fixed point on the ground, the volumetric shrinkage, the flow of the glacier tongues and the amount of water flow from the glaciers.

Since the glaciers supply a considerable portion of the summer flow of many of our rivers, their size and behavior constitute an important factor in all streamflow investigations. Comparison of British Columbia streams which are glacier-fed with those which derive their supply from other sources shows that the glacier-fed streams usually reach their seasonal peaks at the period of maximum temperatures (that is, about July), while the peak flows of other streams which derive much of their run-off from snow alone usually occur in May. The streams which derive a large portion of their flow from glaciers or perpetual snowfields have a very noticeable diurnal fluctuation.

In a region such as British Columbia, which is, generally speaking, mountainous with steep slopes, it is to be expected that there will not be many large lakes or other natural reservoirs in the headwaters of the streams. Fortunately, however, there are many glaciers and snowfields in the place of these as regulators. On this account it is essential to determine, if possible, what effects glaciers will have on future streamflows.

Method of Observation

When the Branch's survey of glaciers was initiated in 1945, the observations were made annually.

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It was subsequently found that yearly changes in the glacier snout were comparatively small and after 1950 the frequency of surveys was reduced to once every two years. The survey of these glaciers has been made on about the same dates each year.

The surveys used to date by the Branch have included the following:

1. The establishment of fixed reference marks near toe of each glacier, referenced to permanent topographical features.

2. The measurement of the distance from the forefoot to a reference point or base line; or, alternately, the mapping of the forefoot. In the latter case, successive plottings show clearly the average advance or recession across the whole forefoot.

3. The setting up of camera stations from which photographs are taken at each survey to show prominent changes in the glacier.

4. Estimation of amount of water discharge from each glacier.

In 1947, glacier surveys were expanded to include the following:

a. The recording of the rate of glacier forward surface movement by means of plaques or markers set out on the ice along a reference line crossing the glacier some distance above the toe.

b. Determination of ablation (or decrease in depth) by means of surface cross-section and profile lines.

Glaciers under Observation

In the Coast Mountains, which are the most westerly of the several parallel mountains on the mainland of British Columbia, the glaciers selected for observation were Helm, Sentinel and Sphinx, all in Garibaldi Park.

The Rocky Mountain Trench is bounded on the west, in part, by the Selkirk Mountains and on the east by the Rocky Mountains. Two Glaciers were selected in the Selkirk Mountains, the Kokanee in the south and the Illecillewaet in the north.

Glaciers of the Coast Mountain Range - Garibaldi Park

This park, situated about 30 miles north of Vancouver, contains a number of mountains with elevations over 8000 feet and several glaciers which feed the Cheakamus, Pitt and Lillooet Rivers. It is easily accessible by air or by railway and trail. The three glaciers under observation - Helm, Sentinel and Sphinx - constitute part of the drainage basin of the Cheakamus River which flows into Howe Sound.

Helm Glacier

This glacier has a northern exposure and a total area of approximately 1½ square miles, surrounded by mountains which rise to an elevation of over 7000 feet. Its two tongues, which are only about half a mile apart, vary appreciably both in retreat and type of moraine. The difference in the two moraines is of particular interest. At the east tongue the moraine is of typical rocky and irregular formation while at the west tongue it is of a flat delta nature composed of cinder-like material.

From an inspection of the banks and the moraine at both tongues, it is possible to determine the retreat since the end of the last general advance in the Canadian glaciers. This is reported in the Canadian Alpine Journal to have occurred between 1850 and 1870 and for the purposes of this report has been taken as the year 1865.

There are three distinct variations which have been measured in the glaciers:

1. Retreat - backward movement of the tongue forefoot.

2. Forward surface movement — onward motion of the tongue surface.

3. Ablation — The decrease in the depth of the tongue.

Total retreat of the forefoot at the east tongue of the Helm Glacier between 1865 and 1958 was 2,481 feet, or an average of 27 feet per year. From 1865 to 1945 average annual retreat was 22 feet and from 1945 to 1958 it was 56 feet. The average annual forward surface movement of the tongue between 1947 and 1958 was eight feet. The tongue has now receded into the main glacier and surveys therefore were not carried out in 1960.

On the banks of the east tongue of Helm Glacier, well defined marks indicate that the ice level had dropped 190 feet from time of maximum advance to 1947, or an average of two feet per year. The average annual decrease in depth between 1947 and 1958 was eight feet.

Total retreat of the forefoot at the west tongue between 1865 to 1960 was 1,438 feet, or an average of 15 feet per year. From 1865 to 1945 average annual retreat was 13 feet and from 1945 to 1960 it was 28 feet. As this tongue is badly crevassed and rather inaccessible, its ablation and forward surface movement is not being recorded.

Sentinel Glacier

Sentinel Glacier, with an area of approximately 700 acres, is the smallest of the four glaciers near Garibaldi Lake. As is typical with glaciers found in Garibaldi Park, it is composed of several small cirque and cornice glaciers discharging into a short trunk glacier which flattens out considerably on reaching the valley floor at an elevation of about 5000 feet. There is no terminal moraine and it is thus likely that the ice front pushed into the lake at its greatest point of advance.

Total retreat of the forefoot at Sentinel Glacier between 1865 and 1960 was 4,104 feet, or an average of 43 feet per year. From 1865 to 1945 average annual retreat was 39 feet and from 1945 to 1960 it was 65 feet. The average annual forward surface movement of the tongue from 1947 to 1960 was eight feet.

On the banks of this glacier, well defined marks indicate that the ice level had dropped some 165 feet from the time of maximum advance in recent years to 1947, or an average of two feet per year. The average annual decrease in depth between 1947 and 1960 was 15 feet.

Sphinx Glacier

Due to difficulty in approaching the tongue of this glacier, it was not included in the program in 1945. However, interesting comparative photographs have been taken since that year. The moraines of this glacier are well defined and could prove useful for studying the last several hundred years of the glacier's history.

Glaciers of the Selkirk Mountain Range - Kokanee Park

This park is situated in the southern part of the Selkirks in Canada and about midway between Slocan Lake on the west, the North Arm of Kootenay Lake on the east, and the West Arm of Kootenay Lake on the south. The principal mountain in the park, Kokanee Peak, has an elevation of 9400 feet. Access is by car from Kaslo to the abandoned Joker Creek mill site and then by trail to the glaciers under survey.

Kokanee Glacier

Kokanee Glacier, which is the largest of several in Kokanee Park, lies on the north side of a ridge formed by Kokanee Peak, Mount Cond, Esmeralda Peak and the Giant's Kneecap. It is a typical basin type with northern exposure, and the total ice area of approximately 800 acres is drained by two tongues about a mile apart into the headwaters of Coffee and Joker Creeks.

At present the only terminal moraine remaining from Joker Creek tongue is that separating Mansfield and Joker Lakes. Timber growth on this moraine indicates that it was at least 200 years since the glacier was at that point. The Geological Survey of Canada maps, prepared in 1925 from surveys of 1923, show the toe about midway between the terminal moraine and its present position. Total retreat of the forefoot between 1923 and 1960 was 1,977 feet, or an average of 54 feet per year. From 1923 to 1945 the average annual retreat was 60 feet and from 1945 to 1960 it was 45 feet. The average annual forward surface movement was eight feet between 1950 and 1960.

The forefoot of the Coffee Creek tongue retreated a total of 3,923 feet between 1923 and 1958, or an average of 112 feet per year. From 1923 to 1945 average annual retreat was 118 feet and from 1945 to 1958 it was 102 feet. The average annual forward surface movement from 1952 to 1954 was two feet. The Coffee Creek tongue has now receded into the main glacier and surveys were therefore not carried out in 1960.

The 1925 Geological Survey of Canada maps, photographs by Mr. Arthur Fleming of Nelson, B. C., and marginal moraines indicate a lowering of the ice surface of both tongues of approximately 500 feet between about 1920 and 1945. This is an average of about 19 feet per year. The average annual decrease in depth was six feet at the Joker Creek Tongue between 1948 and 1958 and 13 feet at the Coffee Creek tongue between 1948 and 1954.

Glacier National Park Region

There are a number of glaciers in this park situated at the northern end of the Selkirk Range about midway in the bend formed by the Columbia River about 35 miles northeast of Revelstoke on the Canadian Pacific Railway.

Illecillewaet Glacier

The Illecillawaet icefield lies between 8,000 and 10,000 feet elevation on the west side of and against the main divide of the Selkirk Mountains, a ridge formed by Mount Sir Donald, Terminal Peak and Mount Macoun. About nine square miles in area, it is drained by three valley glaciers, the Illecillewaet at the north, which is the source of the Illecillewaet River, and the Geikie and Asulkan at the south end, the source of the Incomappleux River. Both of these rivers are important tributaries of the Columbia River.

Records on the Illecillewaet Glacier date back to 1887 and have been kept more or less continuously since that date by members of the Alpine Club of Canada. Large alders growing near the toe in 1887 indicated that the glacier had been in this maximum position for many years. Since then the recession has been rapid although decrease in retreat has been noticeable since 1931. The total retreat of the forefoot from 1898 to 1960 was measured as 4,271 feet, or an average of 69 feet per year. From 1898 to 1945, the average annual retreat was 79 feet and from 1945 to 1960 it was 37 feet. The average annual forward surface movement frm 1950 to 1960 was 66 feet, and the average decrease in depth for the same period was three feet.

General Summary

The surveys made in British Columbia so far by the Water Resources Branch and others indicate that there has been a general recession in the glaciers surveyed over the past few decades. It is generally agreed that this recession has been caused by a long-term change in climatic conditions resulting in a slight increase in annual mean temperature and possibly lower precipitation and longer periods of sunshine. Since annual district variations in temperature, precipitation and sunshine determine to a large extent the advance or retreat of a glacier over a short period of years, it is to be expected that these same forces acting over a long period will determine the long-range trend. However, although weather conditions are the largest factor in governing the rate of recession of the glaciers, results obtained to date show that other factors, such as the slope and roughness of the bed, exposure to sun and prevailing winds, and the configuration of the area in which the glacier is situated also play a part.

The influence of these factors is illustrated by lack of a uniform pattern in retreat among glaciers observed. This is illustrated below by results for period 1945 to 1958. This period was chosen because surveys were first initiated by the Water Resources Branch in 1945, and 1958 is the latest year for which figures of retreat are available for all tongues.

Glacier	Average Annual Retreat (feet)
Helm	
East Tongue	56
West Tongue	27
Sentinel	68
Kokanee	
Joker Creek Tongue	46
Coffee Creek Tongue	102
Illecillewaet	39

The collection of data relating to glacier variations is of particular importance in computing estimates of streamflow in B. C. It also permits the correlation of such data with other information relating to weather and climate.

The recording of the discharge of glacial streams on a continuous basis in close proximity to the glaciers is usually not practicable owing to poor channel conditions in moraine material. On the lower reaches of the streams, more satisfactory records can be secured and these may be compared with those obtained on non-glacial streams.

TABLE I.

Summary of Observations

Glacier	Period of Record	Average Annual Change (feet) Retreat	Advance	Decrease in Depth*
Coast Range				
Helm				
East Tongue	1865-1958	27		
	1865-1935	17		
	1935-1945	56		
	1945-1958	56	6 (1947-58)	8 (1947-58)
West Tongue	1865-1960	15		
	1865-1935	9		
	1935-1945	36		
	1945-1960	28		
Sentinel	1865-1960	43		
	1865-1935	30		
	1935-1945	101		
	1945-1960	66	8 (1947-60)	15 (1947-60)
Selkirk Range				
Kokanee				
Joker Creek	1923-1960	54		
	1923-1945	60		
	1945-1960	45	8 (1950-60)	6 (1948-58)
Coffee Creek	1923-1958	112		
	1923-1945	118		
	1945-1958	102	2 (1950-54)	13 (1948-54)
Illecillewaet	1898-1960	69		
	1898-1945	79		
	1945-1960	37	66 (1950-60)	3 (1950-60)

* Average of observations at profile and cross-section lines.

Sources: Alpine Club of Canada
Water Resources Branch