FORTY-TWO YEARS OF RECESSION OF THE NISQUALLY GLACIER ON MOUNT RAINIER

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With 2 Illustrations

Introduction

Mount Rainier is a volcanic peak located on the western slope of the Cascade Mountains in the State of Washington, with its summit at 46°51'.2 north latitude, and 121°45'.6 west longitude (Greenwich). In form it resembles a truncated cone with an elevation of 4,391.6 meters above sea-level and a base diameter of approximately 13 kilometers at timber line, which corresponds closely to the height of the surrounding foothills where the summits vary between 1,500 and 1,800 meters. Thus Mount Rainier stands with nearly two-thirds of its height above the general level of the terrain.

Upon the exposed flanks of the mountain lie 26 named glaciers, the most extensive single-peak glacial system in the United States, with an area totaling approximately 103 square kilometers. This ice mantle has been diminishing since 1850 as a result of the world wide warming trend taken by the climate since that time. Recognition of the fact that Mount Rainier's glaciers were everywhere receding occurred in 1896 and a number of investigations have been undertaken since that time to determine the extent of the recession.

Most of the work has been concerned with the valley-type Nisqually Glacier which extends down the south side of the mountain from the central ice cap and is the most accessible glacier in the system. The first study, concerned with the rate of flow of the ice mass, was followed by a program of measurement of the linear recession of the terminus, and that was later supplemented by work intended to determine the fluctuations in the level of the terminal ice through the measurement of cross-profiles and by periodic topographic mapping. Although the early investigations did lead to estimates of the volume of wastage of the terminal portion of the Nisqually Glacier, they were too limited in scope to adequately represent the total effect of recession.

The investigation reported herein was undertaken with the intention of approximating, from available topographic maps, the volume change represented by the wastage of the Nisqually Glacier during the forty-two year period from 1910 to 1952. The result is a view of the net effect of recession upon that glacier, and a presumption regarding its effect upon the entire glacial system.

Review of Previous Investigations

While the study of the glaciers of Mount Rainier is often considered to begin with the work of *S. F. Emmons* and *A. D. Wilson* in the year 1870[1]), they failed to recognize the recessional trend, so that the credit there belongs to a later party of the United States Geological Survey. In 1896 a reconnaissance group including *Israel Cook Russell*, *George Otis Smith* and *Bailey Willis* made some observations on the recession of the glaciers and pointed out the general character of the process. In his report *Russell* says[2]): "Every glacier about Mount Rainier that was examined by the writer furnished evidence of a recent recession of its terminus and a lowering of its surface. In two instances — the Carbon and the Willis[3]) glaciers — rough measurements of the amount of these changes during the past fifteen years were obtained." He also offered the opinion that the recession was the result of a climatic change accompanied by a decrease in the snowfall and an increase in the annual melting, a process which he thought had been in progress for a score or more of years[4]). *Russell* also took particular notice of the Nisqually Glacier by suggesting that it should be made the subject of more detailed study. He recommended rate-of-flow measurements, photographs from permanent locations and the annual marking of the position of the terminus of the glacier[5]), but nothing was done for a decade.

The first step in *Russell's* suggested program was accomplished by Professor *J. N. LeConte*, of the University of California, in 1905. In July of that year he found that the average rate-of-flow of the Nisqually Glacier varied from 15.5 to 41.2 centimeters at a point approximately 1,160 meters above the present bridge[6]).

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[1]) *S. F. Emmons*, "On the Discovery of Actual Glaciers on the Mountains of the Pacific Slope", Amer. Jour. Sci., Vol. I (3rd ser., 1871), pp. 161—65.

[2]) *I. C. Russell*, "Glaciers of Mount Rainier", 18th Ann. Rept. U. S. Geol. Surv., Part II (1897), p. 407.

[3]) Now known as the North Mowich.

[4]) *Russell*, op. cit., p. 408.

[5]) Ibid., pp. 399—400.

[6]) *J. N. LeConte*, "The Motion of the Nisqually Glacier", Sierra Club Bull., Vol. VI, No. 2 (1907), pp. 108—14. *LeConte says:* "The motion of the glacier was measured accurately at a point about 3,000 feet from the snout." (which was 800 feet above the bridge in 1905).

In the year 1910 work was begun on a topographic map of Mount Rainier by a United States Geological Survey party under the direction of *Francois E. Matthes*. The work was completed in 1913 and has been published in several editions[7]). This map is valuable because it provides the earliest reliable data on the position and character of the Nisqually Glacier.

The annual marking of the position of the terminus of the glacier, as suggested by *Russell* in 1897, was begun in 1918 by *F. W. Schmoe* of the newly established National Park Service, and Professor *Henry C. Landes* of the University of Washington. The work which *Schmoe* continued until 1928, has been summarized by *C. Frank Brockman*[8]), who succeeded him as Park Naturalist in that year.

In 1930, the interest of the Department of Public Utilities of the City of Tacoma in the hydro-electric potential of the Nisqually River led to its cooperation with the U. S. Geological Survey, the U. S. National Park Service, and the U. S. Bureau of Public Roads in a study of the lower Nisqually Glacier. In the course of this joint investigation two cross-profiles were established for annual measurement of fluctuations in the ice level, and a plan was drawn up which called for the mapping of the terminal portion of the glacier at five-year intervals. Accordingly, a topographic map of the lower 3,050 meters was prepared from a survey made by *Bartlett G. Long* in October, 1931[9]). The map was the basis for an estimate of the volume of the terminal wastage, which was roughly calculated at 24,678,900 cubic meters since 1910, or 370,183,500 cubic meters since 1850[10]). At the same time the rate-of-flow of the glacier at a point 900 meters above *LeConte's* determination was found to average 7.8 centimeters per day over a period of 246 days[11]).

A photographic record of the appearance of the terminus of the Nisqually Glacier was begun by *C. Frank Brockman*[12]) soon after he took up his duties as Park Naturalist. He also continued the measurement of the recession of the terminus[13]). In 1941, Mr. *Brockman* was succeeded by *Howard R. Stagner* who began preparing annual reports of glacial recession — a practice which has been followed to the present[14]).

During the years following 1931, the United States Geological Survey continued to make measurements along the established cross-profiles[15]) and additional cross-profiles were later added[16]). Also, the lower portion of the glacier was remapped in 1936 by *G. W. Crippen*, and in 1940 by *F. F. Lawrence* (these maps, as well as the 1931 map, appear at the scale of 1:12,000 in *Lawrence's* "Studies based on 1940 Survey")[17]). The following year *Arthur Johnson* mapped the lower 4,000 meters of the glacier's surface[18]), but the survey which was scheduled for 1946 does not appear to have been made. The map prepared in 1951 was compiled from aerial photographs[19]), instead of by the plane-table method of ground survey used in the earlier mapping, and it included more of the glacier.

Still another method of mapping was employed in 1952 when Dr.-Ing. *Walther Hofmann* of the Photogrammetric Institute of Munich, Germany, made a survey of the Nisqually Glacier by means of terrestrial photogrammetry[20]). The map, which he later prepared by stereo-autograph plotting of the controlled photographs, includes the entire glacier with its tributaries and snowfields[21]) (see plate added to this symposium).

The Glacier and Factors Affecting It

The Nisqually is the largest glacier on the exposed south side of Mount Rainier. It arises in the summit snowfield, where it can first be distinguished at an elevation of 4,050 meters,

[7]) The Topographic Map of Mount Rainier National Park, (U. S. Geol. Surv., 1938), as reprinted in 1947, is the current edition.

[8]) *C. Frank Brockman*, "The Recession of Glaciers in Mount Rainier National Park, Washington", Jour. Geol., Vol. XLVI, No. 5, (July-August, 1938), p. 771.

[9]) *Llewellyn Evans*, "1931 Progress Report on Nisqually Glacier Study", unpublished M. S., City of Tacoma, Dept. of Public Utilities, March 5, 1932, map in pocket of cover.

[10]) Ibid., p. 3.

[11]) Loc. cit.

[12]) *C. Frank Brockman*, "Progressive Summary of Glacial Recession in Mt. Rainier National Park, Washington", unpublished M. S. in the file of the park museum, October, 1940, pp. N—4 to N—8.

[13]) Ibid., pp. 5—6.

[14]) Reports prepared under various titles, as, "Glacier Recession in Mount Rainier National Park", etc., are in the files of the park museum beginning with the report for 1943.

[15]) Cross-profile No. 1, re-measured in 1932, 1933, 1941, 1942, 1943, 1944, 1946, 1948, 1949, 1950, 1951, 1952, 1953 and 1954; and cross-profile No. 2 re-measured in 1932, 1933, 1936, 1940, 1941, 1942, 1943, 1944, 1945, 1946, 1947, 1948, 1949, 1950, 1951, 1952, 1953, and 1954.

[16]) Cross-profile No. 3, established in 1944, and cross-profile No. 2—A, established in 1948.

[17]) *Fred F. Lawrence*, "Nisqually Glacier, Washington: Studies based on 1940 Survey", unpublished M. S. of U. S. Geol. Surv., May, 1941.

[18]) Scale, 1 : 9,600; contour interval, 50 feet.

[19]) *Gordon C. Giles*, "Nisqually Glacier, Washington: Progress Report 1953", unpublished M. S. of U. S. Geol. Surv., February, 1954. Following p. 8 a portion of the 1951 map is presented.

[20]) *Walther Hofmann*, „Gletschermessungen in der Cascade Range des Staates Washington, USA, 1952". Erdkunde, vol. VII, No. 3, Bonn 1953.

[21]) Scale, 1 : 10,000; contour interval, 20 meters.

and extends down the mountain in a river of ice 6.37 kilometers in length and 0.8 kilometer in width at the widest point in its channel.

Following the Nisqually Glacier downward, it is divided by a rocky cleaver at about 3,960 meters. On the east side the nearly vertical drop has formed an ice fall over which huge blocks of névé move, usually by gradual slippage though occasionally they break free and avalanche to the bottom where the shattered fragments are compacted into ice. On the west side of the cleaver the drop is less precipitous, but the surface of the ice is badly crevassed. The two branches come together at 3,200 meters.

Below 2,620 meters the Nisqually is joined from the west by the Wilson Glacier, which originates in a cirque 1,220 meters below the summit of the mountain. It is a small glacier of steep gradient and the only important feeder connected with the Nisqually.

After passing the Wilson, the Nisqually Glacier enters a canyon which it has gouged and where it is confined within the walls of old moraines. At 1,770 meters the course of the glacier is obstructed by a low rock island which has deflected it against the west wall of the canyon. The steep face of exposed ice below this point is the end of the active ice. Remnants of ice, protected by deposits of morainal debris up to 6 meters in depth, remain down to an elevation of 1,398 meters, but there is no motion except settlement of the debris.

The heavy snowfall which provides the nourishment of the Nisqually Glacier results from a combination of climatic and topographic factors. Mount Rainier lies west of the crest line of the Cascade Mountains and thus is exposed to the moisture-laden westerly winds which blow from the Pacific Ocean, distant less than 160 kilometers. These prevailing winds meet no barrier of any consequence until they reach the foothills of the Cascades, where the rising air currents are cooled and rapid condensation results in heavy precipitation, of which more than 86 per cent occurs from October to May and so is mostly available as snow.

Most of the snowfall occurs between the elevations of 2,437 and 3,048 meters — the zone of greatest precipitation[22]) — so that the Nisqually Glacier receives only a small part of its nourishment from the summit ice cap. The Wilson Glacier, which has already been mentioned as a tributary of the Nisqually, is a collecting basin which lies within the optimum limits.

Table I
Climatological data for Mount Rainier
Average Monthly and Annual

Month	Temperature: Longmire	N	Temperature: Paradise	N	Precipitation: Longmire	N	Precipitation: Paradise	N	Snowfall: Longmire	N	Snowfall: Paradise	N
January	–1.1° C.	41	–3.1° C.	26	29.33 cm	42	38.48 cm	25	122.8 cm	43	305.1 cm	29
February	0.3	41	–2.7	26	21.72	43	27.89	25	88.2	44	213.3	27
March	2.4	41	–1.7	27	19.30	42	25.50	25	78.5	42	230.0	27
April	5.3	41	1.6	29	12.88	42	15.17	28	29.2	42	129.5	28
May	8.9	41	4.8	26	10.14	42	11.99	27	4.3	42	53.6	28
June	12.2	41	7.7	30	7.87	43	10.91	30	0.3	43	13.0	31
July	15.9	41	11.6	34	3.07	42	4.24	33	0	41	0.8	34
August	15.8	41	11.8	33	4.39	42	7.32	32	0	46	0.5	34
September	12.9	41	9.7	31	9.09	43	14.61	32	T	46	17.3	32
October	8.5	41	4.8	25	20.01	44	25.17	31	2.8	43	56.4	27
November	3.1	41	0.5	29	27.15	42	34.00	27	36.6	42	177.0	30
December	0.1	41	–2.6	26	33.57	42	40.00	27	97.1	42	250.3	28
Annual	7.1[1])		3.9[2])		198.52[1])		255.28[3])		459.8[1])		1446.8[3])	

[1]) Based on records of 41 consecutive years, 1914—1954, incl.
[2]) Weighted average of all available records, 1916—1954, incl.
[3]) Based on all available records, 1916—1954, incl.

Compiled by *A. L. Haines* from U.S.W.B. data.

The available climatic data summarized in Table I show that the average annual precipitation at Longmire (elevation, 842 meters) is 199 centimeters, while at Paradise Park (elevation, 1,668 meters) the precipitation is 255 centimeters. The average annual snowfall for the two stations, which are 7.2 kilometers apart in the same drainage basin, increases from 460 centimeters at Longmire, to 1,447 centimeters at Paradise Park. Maximum snow depths up to 7.5 meters are recorded at the higher station.

As great as the nourishment of the Nisqually Glacier is, it is exceeded by the wastage. In addition to the loss from sublimation, which is particularly destructive on the upper reaches of the glacier, the process of melting is constantly at work from June through September, and occasionally into October, reducing that portion of the glacier below 2,400 meters. Warm rains

[22]) *Francis Matthes*, Mount Rainier and Its Glaciers, (U. S. Dept. of Inter., 1922), p. 21.

which often occur during June and September are also effective through their eroding action. But perhaps the most important factor has been the warming trend of the climate which has pushed the elevation of the snow line up from about 1,800 meters in 1910 to nearly 2,300 meters in 1952.

Methods Used in this Investigation

The topographic maps upon which this investigation is based differ both in scale and in contour interval[23]), so that the first step was to bring them to a working equivalence. That was accomplished by interpolating 100-foot contour lines into the *Hofmann* map and plotting the metric grid on the *Matthes* map.

Since the small field-scale of the latter map[24]) gave hope of only moderate accuracy in the determination of the difference in volume between the two map representations of the Nisqually Glacier, an approximate computation based on the method of average end-areas was decided upon. Cross-profiles parallel to the east-west grids were established as the basis for the end-areas, the first cross-profile being at 8,200 meters north, the second at 8,500 meters, and succeeding cross-profiles at 500 meter intervals. This arrangement made the cross-profiles nearly normal to the major axis of the glacier. Along each cross-profile the level of the ice was plotted from both maps at equal horizontal and vertical scales (1:4,800), with enough of the adjacent terrain for correction purposes. Adjustment of each cross-profile was then accomplished by shifting the plot-line from the Matthes map into the position of best fit with regard to the adjacent terrain as mapped by *Hofmann*. The amount of the discrepancy at each cross-profile is shown in Table II, from which the average correction was found to be + 7.6 meters; a figure which is within tolerable limits, as will be shown later in connection with the evaluation of the results.

Table II
Amount of Adjustment of the Cross-profiles from the Matthes Map, in Meters

Profile	Area	West —	West +	East —	East +
8,200 N					
8,500	Nisqually		6.1		1.5
9,000	„		12.2		15.2
9,500	„	6.1		45.7	
10,000	„		6.1	0	
10,500	„		7.3	18.3	
11,000	„	26.2		18.3	
11,500	Wilson	48.8			33.6
	Nisqually-	0		73.2	
12,000	Wilson-Nisqually	35		0	
12,500	Wilson-Nisqually	45.7		0	
	Snowfield	24.4		30.5	
13,000	Wilson	18.3			18.3
	Nisqually	0		12.2	
	Snowfield		30.5	27.4	
13,500	Nisqually-Snowfield	21.4		0	
14,000	Nisqually		6.1	3.0	
14,500	Nisqually (W)	12.2		0	
	Nisqually (E)		12.2		18.3

The next step was to determine the area between the plot-lines at each adjusted cross-profile, which was done with a polar-planimeter. Each area was measured twice and the results were averaged to obtain the values shown in Table III for the difference in end-areas at each cross-profile.

The net differences in the end-areas of the cross-profiles were then averaged by pairs to obtain the average end-area for each section between the cross-profiles, after which an approximate computation of the volume of the section was made from the following formula:

$$Ve = \frac{1}{2}(A_0 + A_1)\,L$$

Where A_0 and A_1 are the end-areas of the section in square meters, and L is the length of the section in meters, Ve is the volume in cubic meters. Since the areas planimetered on each cross-profile were reasonably regular, the error in computation resulting from the use of such an approximate formula is probably less than would be expected in its application to engineering

Table III
Increase or Decrease in End Areas of the Cross-profiles, in Square Meters, from 1910 to 1952

Profile	— Area	+ Area	Net Area
8,200 N	0	0	0
8,500	18,400	0	— 18,400
9,000	33,300	0	— 33,300
9,500	32,200	0	— 32,200
10,000	25,120	0	— 25,120
10,500	4,030	0	— 4,030
11,000	9,050	0	— 9,050
11,500	15,940	0	— 15,940
12,000	22,410	3,670	— 18,740
12,500	32,390	3,220	— 29,170
13,000	27,380	1,940	— 25,440
13,500	29,080	0	— 29,080
14,000	1,350	14,200	+ 12,850
14,500	9,800	2,320	— 7,480

[23]) The *Matthes* map (1910) used was a copy at 1 : 31,680 with a contour interval of 100 feet, while *Hofmann*'s map (1952) was an advance sheet at 1 : 10,000 with a contour interval of 20 meters

[24]) Field scale for the plane-table work was 1 :48,000.

Ill. 1: Photograph of the Nisqually Glacier taken by *Asahel Curtis*, April 14, 1915, from a point about 60 meters east of the present highway bridge (No. 32254, Curtis and Miller Collection, Washington Historical Society). Ill. 2: Photograph of the Nisqually Glacier taken by *V. R. Bender*, August 1954, from the approximate point used by *Asahel Curtis*, The waterfall left of center is Tato Falls.

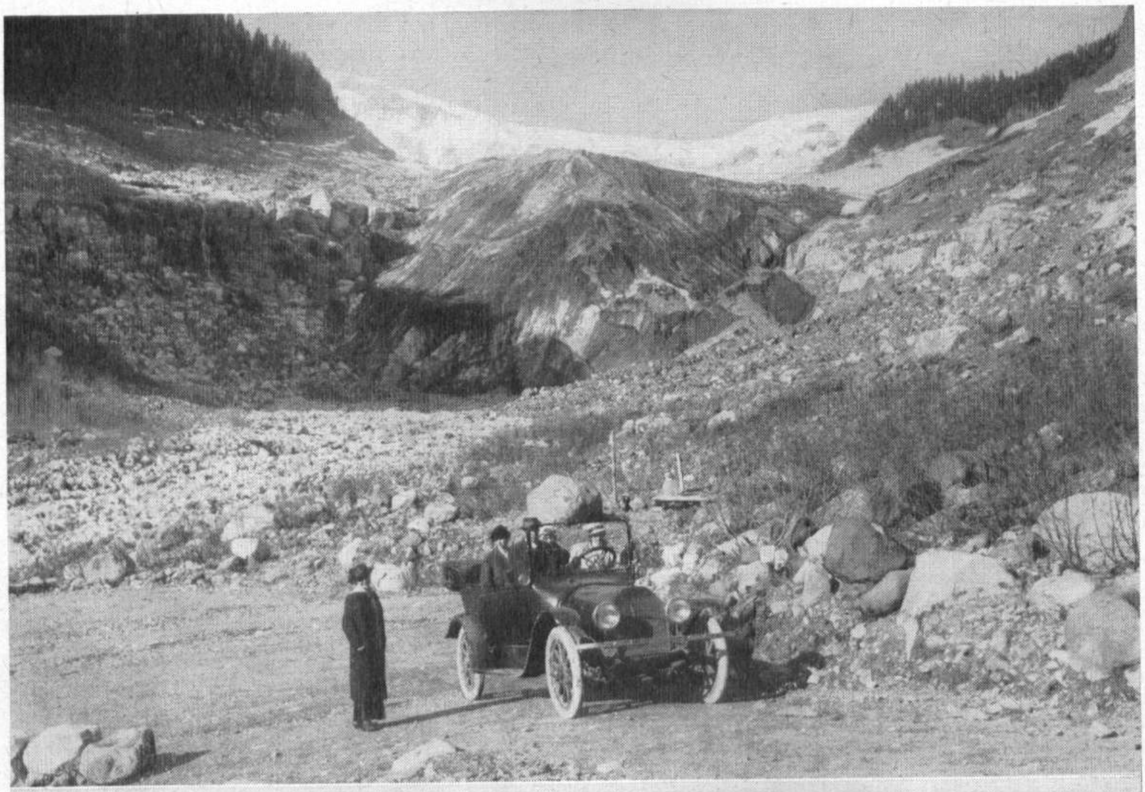

Table IV
Net Change in the Volume of the Sections in Cubic Meters, from 1910 to 1952

Section	$1/2 (V_0+V_1)$	L	Volume
8,200— 8,500 N	— 9,200	300	— 2,760,000
8,500— 9,000	— 25,850	500	— 12,925,000
9,000— 9,500	— 32,750	500	— 16,375,000
9,500—10,000	— 28,660	500	— 14,330,000
10,000—10,500	— 14,575	500	— 7,287,500
10,500—11,000	— 6,540	500	— 3,270,000
11,000—11,500	— 12,495	500	— 6,247,500
11,500—12,000	— 17,340	500	— 8,670,000
12,000—12,500	— 23,955	500	— 11,977,500
12,500—13,000	— 27,305	500	— 13,652,500
13,000—13,500	— 27,260	500	— 13,630,000
13,500—14,000	— 8,115	500	— 4,058,000
14,000—14,500	+ 2,685	500	+ 1,342,500

Table V
Comparison of the Area of the Nisqually Glacier In 1910 with the Area in 1952

Elevation	Square Kilometers 1910	Square Kilometers 1952	Percent Remaining
Below 1,524 meters	0.399	0.150	37.6
Between 1,524 and 1,829	0.850	0.274	32.2
Between 1,829 and 2,134	0.964	0.917	95.1
Between 2,134 and 2,438	1.159	1.048	90.4
Between 2,438 and 2,743	1.058	1.151	108.8
Between 2,743 and 3,048	1.533	1.533	100.0
Between 3,048 and 3,353	0.477	0.588	123.5
Between 3,353 and 3,658	0.181	0.194	107.2
Between 3,658 and 4,054	0.373	0.365	97.9
Total	6.994	6.220	88.9

earthworks[25]). The average end-areas and the volumes computed for the sections are given in Table IV.

Because of irreconcilable differences between the two maps, it was found impossible to extend the computations to the 15,000 N. grid-line, which corresponds closely to the natural differentiation between the summit ice-cap and the Nisqually Glacier. Thus, the computations of wastage do not apply to the entire glacier.

In addition to the computations already described, the change in the area of the glacier during the period from 1910 to 1952 was also determined. Table V shows the area of the glacier by 305 meter levels as measured on each map, with the per cent remaining. The areas were determined with a polar-planimeter and are the average of two trials in each case.

Results of this Investigation

The results of this study indicate that the overall effect of climatic conditions on the Nisqually Glacier during the forty-two years from 1910 to 1952 has been one of recession. During that period the ice mass has shortened, the area covered by it has decreased and there has been a considerable wastage of its bulk.

Comparing the map prepared by *Hofmann* from his survey in 1952 with the one prepared by the United States Geological Survey from the work directed by *Francois Matthes* in 1910, the Nisqually Glacier is 6.37 kilometers in length from its terminus to the 4,054 meter elevation, where it can be identified from the summit ice-cap; while in 1910 its length was 7.10 kilometers. Thus, there has been a total linear recession of 0.73 kilometers, or an average of 17.4 meters annually.

On the basis of area, as determined from the same maps, the Nisqually Glacier and its tributaries has decreased 0.774 square kilometers, or 11.1 per cent, from its former area of 6.994 kilometers. However, it is the distribution of the shrinkage that is most important. Reference to Table V shows that the decrease in area has occurred mainly below 1,829 meters; above that elevation the area of the ice mass is essentially the same, as there is reason to believe the variations at the higher levels are mainly representative of map inconsistencies.

But the most important result of the comparison is the estimate of the volume of the net wastage. Table IV gives the total computed loss in bulk for forty-two years as 116,525,500 cubic meters of ice, which is an average annual decrease of 2,774,400 cubic meters. It should be noted that those figures apply to only 93.7 per cent of the glacial surface, and that they were computed by a formula which gives an over-run which will be considered as 2 per cent. Correcting for both factors increases the total loss to 121,389,300 cubic meters, and the annual to 2,890,200 cubic meters. The greatest decrease in volume occurred in the narrow canyon between the 1910 terminus and the 10,000 N. grid-line, a channel which is now nearly evacuated.

While some local increases are apparent at all the cross-profiles above 11,500 N., except one, they probably are not significant. The corrections which were applied to the *Matthes* map (Table II) average +7.6 meters, so that the terrain appears to be represented too low throughout the length of the Nisqually Glacier. The effect of such an error is to lessen the apparent recession in terms of the shrinkage in area and the wastage in volume. While a correction has been attempted, there is no assurance that it has accomplished the desired purpose, particularly in view of the wide range of the correction values (from 0 to 73.2 meters). In view of the possibility that errors remain in the basic data, no particular significance should be

[25]) *Harry Bouchard*, Surveying, 3rd ed. (International Textbook Company: Scranton, Pennsylvania), 1947, pp. 355—6. An over-run of approximately 2 per cent is given for the end-area formula in comparison with the prismoidal formula.

attached to volume increases of less than 4,000,000 cubic meters, and it is quite probable that the wastage is considerably greater than the volume computations indicate.

Conclusion

The recession data presented here for the Nisqually Glacier are believed to be sufficiently typical of the glacial system of Mount Rainier to warrant an expansion of the estimates to a larger viewpoint. The assumption that the recession of the Nisqually Glacier is typical of the entire system finds some support in recent measurements of the Paradise-Stevens, the Emmons and the Carbon Glaciers. In each case the level of the ice as determined by a traverse survey was compared with the level mapped in 1910. The average annual drop in the surface of the ice between the 1910 terminus and the point of approximate equilibrium was found to be 1.48, 2.82 and 1.50 meters respectively, while the equivalent figure for the Nisqually Glacier was determined as 2.71 meters. Therefore, the estimates of the effect of recession upon the glacial system of Mount Rainier are offered with the hope that their approximate nature will be kept in mind.

The total area of ice, as given by *Matthes*, was 116.6 square kilometers in 1910, but the rate of recession found on the Nisqually Glacier (0.018 square kilometers per year) would indicate that the total area was about 102.6 square kilometers in 1952, an average annual loss of 0.335 square kilometers. Similarly, the loss in volume of the entire system, on the basis of the 121,389,300 cubic meters estimated for the Nisqually Glacier, was about 2,198,000,000 cubic meters from 1910 to 1952. That would be an average annual wastage of 52,333,000 cubic meters of ice.

KARTOGRAPHIE UND GLETSCHERKUNDE AM NISQUALLY-GLETSCHER

Walther Hofmann

Mit 1 Abbildung, 3 Bildern und 1 Karte

Vor zwei Jahren konnte ich in dieser Zeitschrift über photogrammetrische Aufnahmearbeiten an Gletschern der Cascade Range berichten[1]). Die Aufnahmen erstreckten sich auf zwei typische Vulkan-Gletscher: den Nisqually-Gletscher am Mt. Rainier und den Coleman-Gletscher am Mt. Baker. Ihre sorgfältige Auswertung erschien aus zwei Gründen bedeutungsvoll. Einmal sollte der Rückgang dieser beiden Gletscher in den letzten Jahrzehnten untersucht und damit der Anschluß an gleichartige Arbeiten in den Alpen gewonnen werden. Für den Nisqually-Gletscher wurde eine solche Untersuchung inzwischen durch *A. L. Haines* an Hand des bisher vorliegenden amerikanischen Kartenmaterials durchgeführt. Das Ergebnis ist in dem vorstehenden Artikel mitgeteilt. — Zum anderen aber sollte eine zuverlässige Grundlage für zukünftige Beobachtungen geschaffen werden: waren doch an beiden Gletschern in neuester Zeit ausgesprochene Vorstoßerscheinungen beobachtet worden, die beim Nisqually zu beträchtlichen Aufhöhungen, beim Coleman sogar zu einem Vorrücken der Zunge geführt hatten.

Die Auswertung konnte mit Unterstützung der Deutschen Forschungsgemeinschaft am Orel-Zeiss'schen Stereoautographen des Institutes für Photogrammetrie an der Technischen Hochschule München durchgeführt werden. Vom Nisqually-Gletscher wurde ein Plan 1:10000 mit einem Höhenlinien-Intervall von 20 m hergestellt. Als Grundlage für die Auswertung der 10 Bildpaare von 6 Standlinien, die das Gesamtgebiet des Gletschers lückenlos erfaßten, dienten die trigonometrisch bestimmten Stand- und Paßpunkte. Sie waren mit einer Genauigkeit von 10 cm in der Lage und 5 cm in der Höhe berechnet worden. Noch in den von den Aufnahmeorten weit entfernten, höheren Partien des Gletschers kann mit einer Höhenlinien-Genauigkeit von 50 cm gerechnet werden, so daß die Auswertung eine sichere Grundlage für spätere Untersuchungen des Gletschers abgibt.

Die bestehenden Karten des Mt. Rainier sind im Maßstab zu klein (größter Maßstab 1:62500) und — da sie mit dem Meßtisch von teilweise weit entfernten Standpunkten aufgenommen sind — zu ungenau, als daß die morphologischen Einzelheiten des Gebietes und die Struktur seiner Gletscher klar genug zum Ausdruck kommen könnten. Es war daher von Anfang an die Entwicklung einer topographischen Karte 1:25000 auf der Grundlage der Autographen-Auswertung vorgesehen. Der weiteren Unterstützung durch die Deutsche Forschungsgemeinschaft und dem Entgegenkommen des Bayerischen Landesvermessungsamtes ist es zu danken, daß die kartogra-

[1]) *W. Hofmann,* Gletschermessungen in der Cascade Range des Staates Washington, USA, 1952. — Erdkunde VII/3, 1953, S. 217—220.