

VELOCITY AND SURFACE ALTITUDE OF THE LOWER PART OF HUBBARD GLACIER

ALASKA, AUGUST 1978

By Robert M. Krimmel and William G. Sikonia

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## CONVERSION FACTORS

For use of readers who prefer to use inch-pound units, conversion factors for metric (International System) units used in this report are given below:

<u>Multiply metric unit</u>	<u>By</u>	<u>To obtain inch-pound unit</u>
grad	0.9	degree
kilometer	0.6214	mile
meter	3.281	foot

## SYMBOLS AND ABBREVIATIONS

<u>Symbol</u>	<u>Name</u>	<u>Units</u>
ID #	Identification number	--
Km	Kilometer	km
m	Meter	m
UTM	Universal Transverse Mercator	--
V	Velocity	m/day
VX	Velocity in the X direction	m/day
VY	Velocity in the Y direction	m/day
X	Horizontal component, positive to east	m
Y	Horizontal component, positive to north	m
Z	Vertical component above National Geodetic Vertical Datum of 1929 (NGVD of 1929)	m

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ABSTRACT

The terminus position and locations of numerous points on the lower part of Hubbard Glacier were determined from 1:58,000 scale vertical aerial photographs taken July 30, 1978 and August 23, 1978. The same surface features were located on each set of photography, allowing displacement during the time interval to be measured. Velocity of the lower glacier for the 24-day interval was about 7 meters per day. The terminus receded 45 meters between the two dates.

INTRODUCTION

Calving speed of several Alaska tidewater glaciers was measured to provide data for a comprehensive study at Columbia Glacier, Alaska (Brown and others, 1982). One of the glaciers measured was the Hubbard. In the late spring of 1986, Hubbard Glacier advanced sufficiently to close the entrance to Russell Fiord. Proposals were made to begin a comprehensive study of Hubbard Glacier to determine the stability and longevity of the ice dam across the entrance to Russell Fiord. This report contains photogrammetric data that may be of use to proposed Hubbard Glacier research.

Vertical aerial photography of the lower part of Hubbard Glacier was obtained on July 30, 1978 and August 23, 1978. Natural features, such as crevasse intersections, on the surface of the glacier can be followed between the two flight dates; this allows measurement of the surface movement. Data given in this report include the control used for the photogrammetry (table 1), the horizontal (X,Y) coordinates of points along

the terminus on both dates (tables 2 and 3), the horizontal (X,Y) and vertical (Z) coordinates of each of many glacier points for each date (tables 5 and 6), and the change in position of the glacier points between the two dates (table 6).

#### CONTROL AND COORDINATE SYSTEM

Control for the photogrammetry was extended toward the east from existing National Oceanic and Atmospheric Administration (NOAA) horizontal control in Disenchantment Bay. Stations HUBB, BANCAS, LEFTY, HAENKE, and LUFF were established by NOAA; stations START, SCARP, and STRIB (fig. 1, table 1) were established specifically for the Hubbard Glacier velocity measurements. All the stations were marked with temporary photo panels prior to the August 23, 1978 aerial photography. Surveying was done with theodolites reading to 0.0001 grads and estimated to be accurate to 0.0010 grads, and a microwave electronic distance measuring device estimated to be accurate to 0.1 m (meters). The altitude of HAENKE was determined by measuring the vertical distance to the tide level, the level of which was established by using NOAA-predicted tide tables for Yakutat, Alaska. The altitude of the net was thus referenced to NGVD of 1929 and estimated to be accurate to 0.5 m.

Geodetic calculations were made using a three-dimensional survey adjustment (Sikonja, 1977) and are estimated to be internally accurate to 0.3 m in X, Y, and Z, which is well within the limits of the photogrammetry methods used. In addition to latitude, longitude, and altitude, Table 1 gives the station locations in the Universal Transverse Mercator (UTM) system. In Tables 2-6 positions are UTM, but with 580,000 meters subtracted from the easting (X) and 6,650,000 meters subtracted from the northing (Y).

## TERMINUS AND GLACIER POINTS

The UTM coordinates of 232 points were determined photogrammetrically by the U.S. Geological Survey's Western Mapping Center in Menlo Park, California by using methods described by Meier (Meier and others, 1985). The Hubbard Glacier photography was flown at a nominal scale of 1:58,000, whereas the Columbia Glacier photography described by Meier and others (1985) was flown at a scale of 1:46,000. On the basis of results from Meier and others (1985) and the difference in scales, it is concluded that the accuracy of the Hubbard points is about 2.5 meters in both the horizontal and vertical.

Tables 2 and 3 show the X and Y coordinates of 51 (July 30, 1978) and 71 (August 23, 1978) points at the ice-water interface, the glacier terminus. These points also are shown on figures 2 and 3 as diamonds. Tables 4 and 5 give the X, Y, and Z for 55 glacier points on both July 30, 1978 and August 23, 1978.

## VELOCITY AND SURFACE ALTITUDE

The change in coordinates of a point between the photo dates gives the displacement vector for the period. Table 6 gives the mid-point of each vector, its X and Y components in meters per day, and the total horizontal displacement in meters per day. Figure 4 shows the same information. It is estimated, based on information from Meier and others (1985, page F7) that the velocities are accurate to 0.2 m/day. Altitude changes are not easy to discern because each point is moving downslope on a surface that has a gentle slope and that is falling in time owing to ablation. Figures 2 and 3 show the altitude of each point and the point's location on the respective date.

The terminus retreated between July 30 and August 23. The area of the polygon formed by a point near the southeast terminus margin (UTM



588343, 6651938), a point near the northwest terminus margin (UTM 582482, 6658502), and the terminus points on July 30 was  $1.22 \times 10^7 \text{ m}^2$ . The area of the polygon with the same end points and the terminus points on August 23 was  $1.18 \times 10^7 \text{ m}^2$ . The change in area between dates divided by the 8,800 m distance between the end points gives terminus recession of 45 m. The average speed of points near the terminus (I.D. 101-105) was 7 m/day. Over the 24-day interval the glacier would have advanced 168 m had there been no calving. The difference between the ice displacement and the terminus position change for the interval was 213 m, thus the calving speed was 9 m/day.

## REFERENCES

- Brown, C.S., Meier, M.F., and Post, Austin, 1982, Calving speed of Alaska tidewater glaciers, with application to Columbia Glacier: U.S. Geological Survey Professional Paper 1258-C, 13 p.
- Meier, M.F., Rasmussen, L.A., Krimmel, R.M., Olsen, R.W., and Frank, David, 1985, Photogrammetric determination of surface altitude, terminus position, and ice velocity of Columbia Glacier, Alaska: U.S. Geological Survey Professional Paper 1258-F, 41 p.
- Sikonia, W.G., 1977, Three-dimensional geodetic survey adjustment: U.S. Geological Survey Computer Contribution, U.S. Department of Commerce, National Technical Information Service, PB-278 600, 189 p.

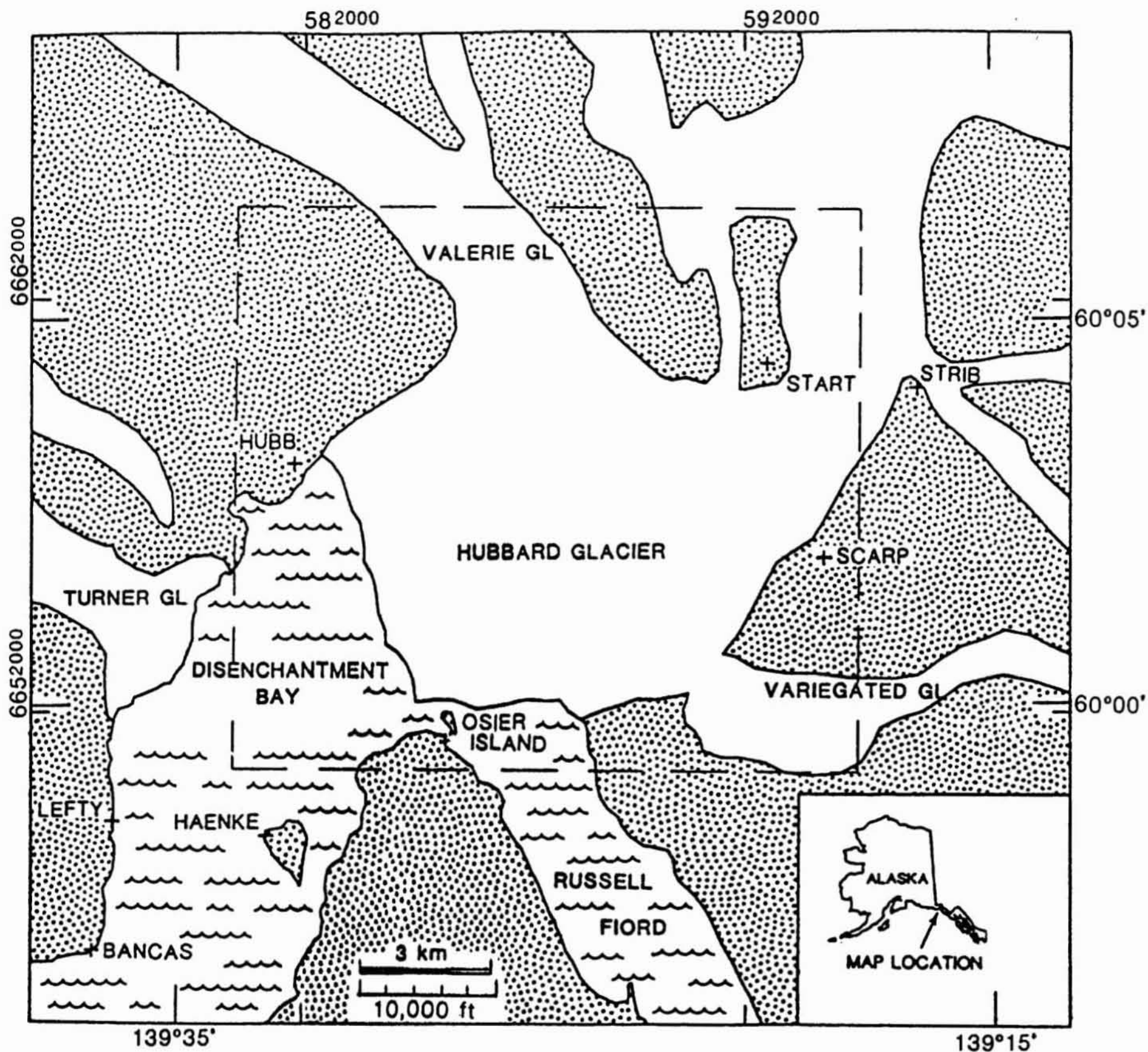


Figure 1 -- The lower Hubbard Glacier, Alaska. Control points used for the photogrammetry are shown as crosses. The dashed box indicates the approximate area shown in figures 2, 3, and 4. The terminus position is for 1974. Station LUFF is out of the map area toward the southwest.

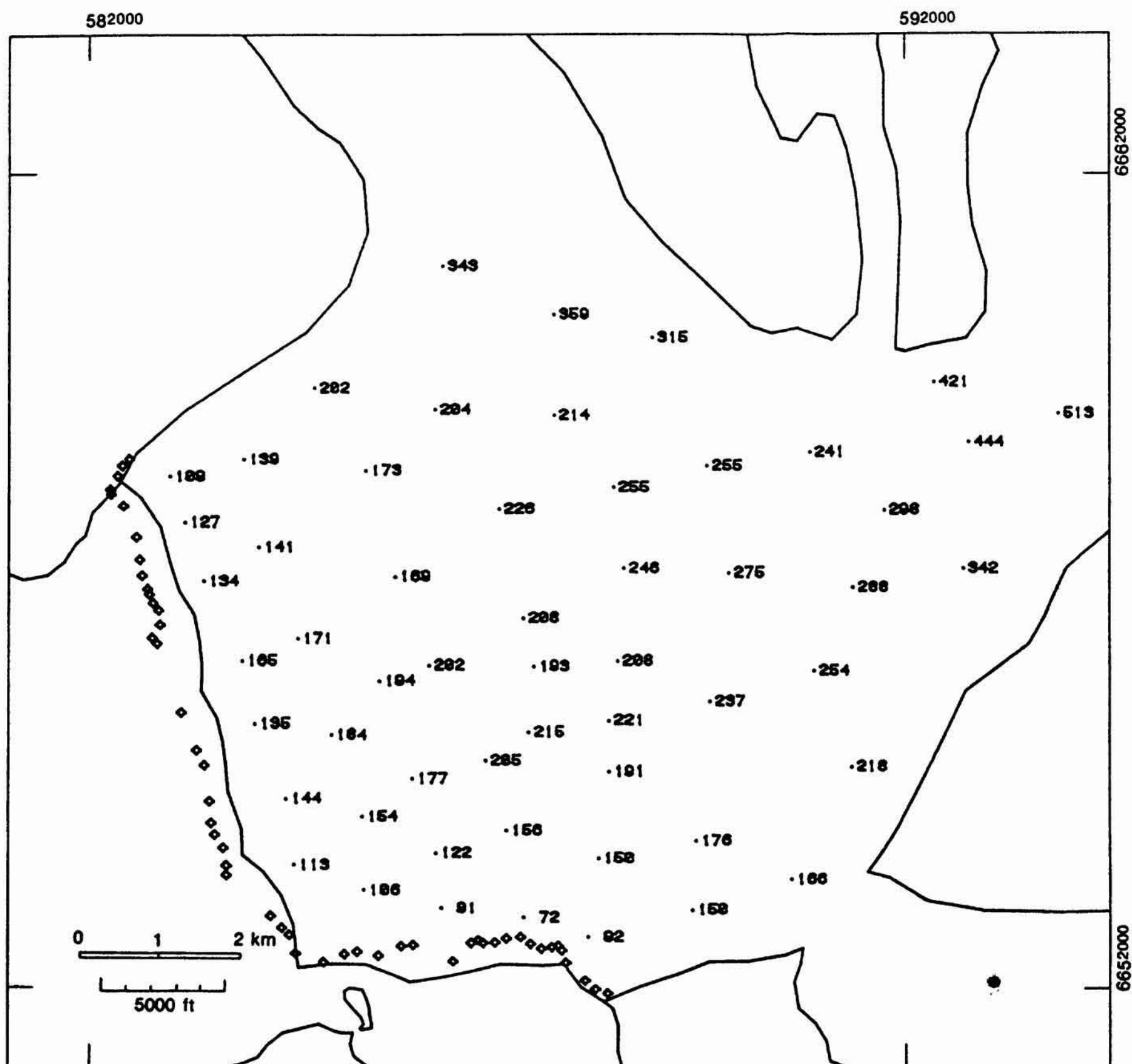


Figure 2 -- Photogrammetrically determined altitudes, in meters above NGVD of 1929, of points on July 30, 1978. The diamonds indicate photogrammetrically determined points along the terminus on the same date. The solid line terminus position is for 1974.

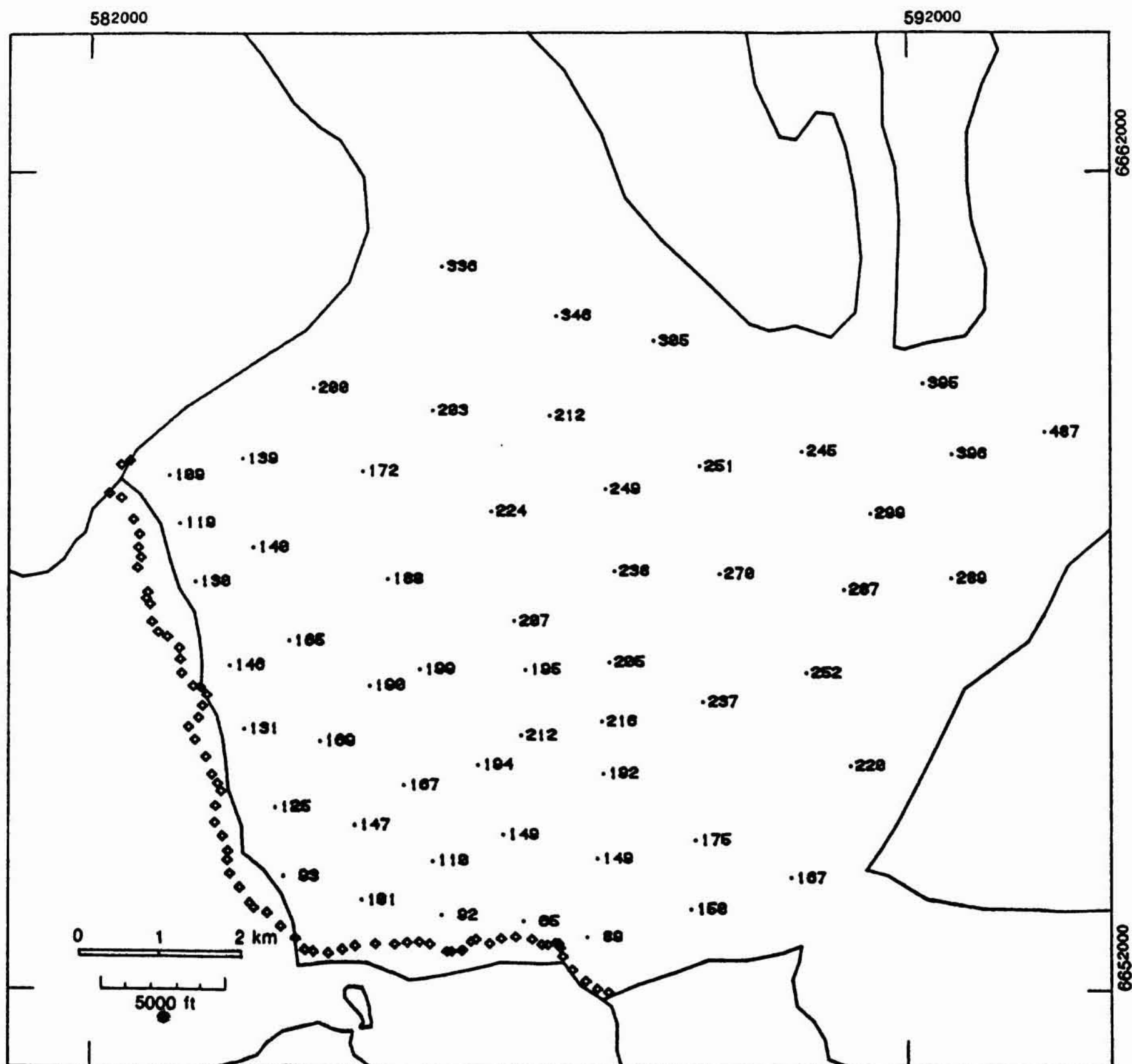


Figure 3 -- Photogrammetrically determined altitudes, in meters above NGVD of 1929, of points on August 23, 1978. The diamonds indicate photogrammetrically determined points along the terminus on the same date. The solid line terminus position is for 1974.

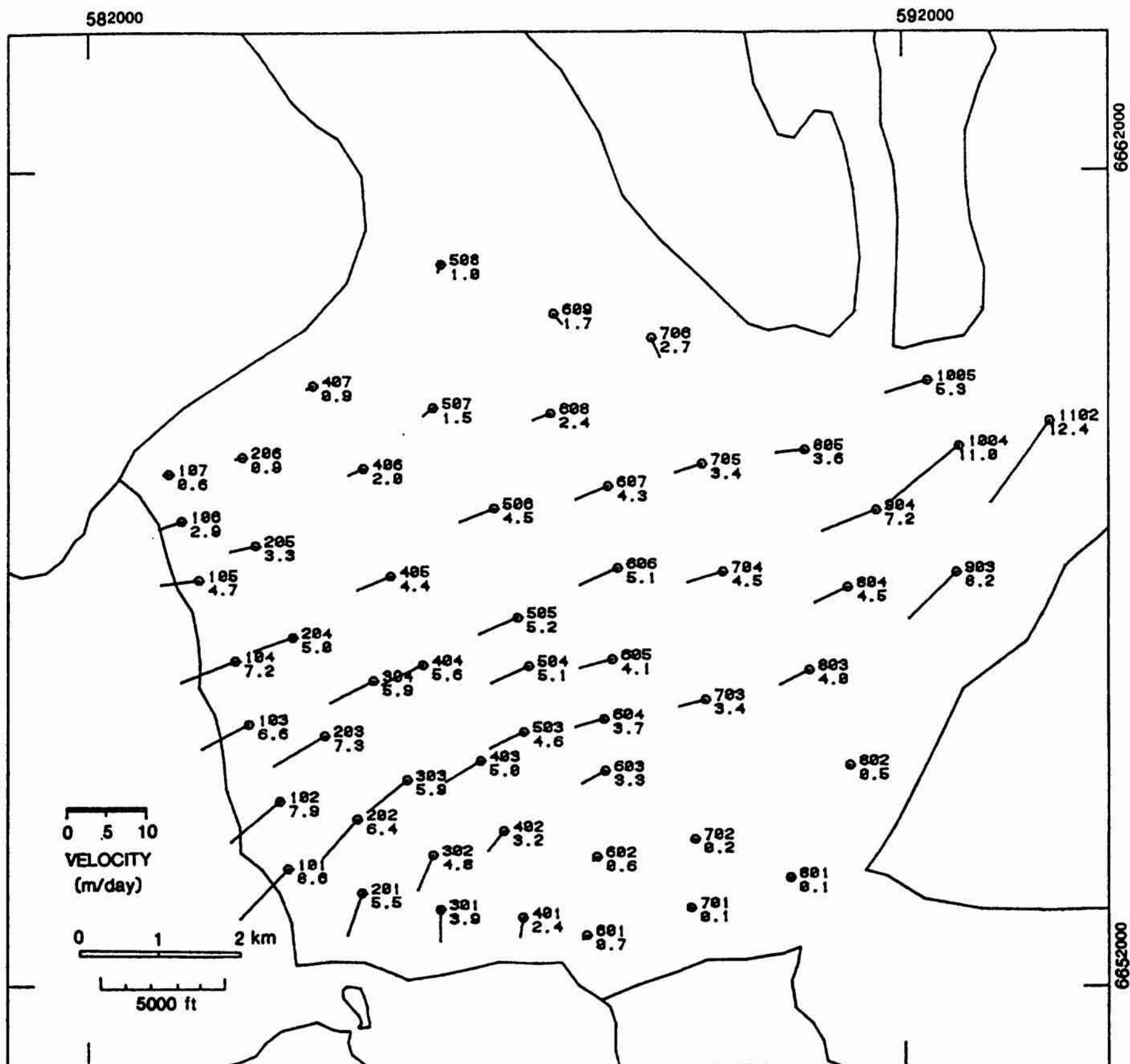


Figure 4 -- The midpoints of trajectories of Hubbard Glacier flow between July 30, 1978 and August 23, 1978 are shown as a circle. The upper number beside each circle is the point ID #, the lower number is the velocity in m/day. Radiating from the circle, is the direction of flow. The magnitude of the vector is also indicated by the scale on the figure.

Table 1 -- The control stations used in the photogrammetry. West Latitude and north Longitude are in degrees, minutes, and decimal seconds. Altitude (Z) is in meters referenced to NGVD of 1929. Universal Transverse Mercator (UTM), zone 7 positions in meters.

NAME	LONGITUDE	LATITUDE	Z	UTM EASTING	UTM NORTHING
LEFTY	-139.363295	59.582805	16.0	577637.2	6649176.0
BANCAS	-139.370622	59.564709	12.6	577186.5	6646042.6
HAENKE	-139.324788	59.581899	14.9	581132.8	6648970.8
LUFF	-139.373925	59.541070	10.2	576774.4	6641194.6
HUBB	-139.320386	60.030741	16.4	581617.7	6657907.1
START	-139.202692	60.042508	741.7	592337.0	6660564.3
STRIB	-139.164410	60.040563	828.2	595796.7	6660050.7
SCARP	-139.190649	60.015238	571.6	593700.4	6655872.5



Table 2 -- Hubbard Glacier terminus position, July 30, 1978. X = UTM easting - 580,000 m, Y = UTM northing - 6,550,000 m. These points are shown in figure 2 as diamonds in the order of ID # from southeast to northwest.

ID #	X	Y	ID #	X	Y	ID #	X	Y
91001	8343	1938	91002	8195	1988	91003	8068	2096
91004	7834	2315	91005	7781	2469	91006	7736	2523
91007	7660	2503	91008	7533	2488	91009	7399	2547
91010	7280	2633	91011	7111	2610	91012	6970	2562
91013	6823	2554	91014	6767	2591	91015	6678	2554
91016	6453	2330	91017	5970	2532	91018	5827	2518
91019	5546	2402	91020	5292	2452	91021	5137	2414
91022	4880	2323	91024	4536	2426	91025	4459	2658
91026	4369	2748	91027	4232	2891	91033	3687	3395
91034	3685	3510	91036	3649	3730	91037	3540	3892
91038	3496	4041	91039	3477	4306	91042	3410	4755
91043	3319	4937	91046	3129	5400	91050	2826	6238
91051	2763	6307	91052	2864	6471	91053	2845	6644
91054	2775	6732	91055	2728	6840	91056	2707	6907
91057	2639	7075	91058	2610	7268	91060	2569	7549
91062	2409	7931	91064	2260	8072	91065	2250	8130
91066	2343	8298	91067	2396	8423	91068	2482	8504

Table 3 -- Hubbard Glacier terminus position, August 23, 1978. X = UTM easting - 580,000 m, Y = UTM northing - 6,550,000 m. These points are shown in figure 3 as diamonds in the order of ID # from southeast to northwest.

ID #	X	Y	ID #	X	Y	ID #	X	Y
92001	8353	1939	92002	8216	1985	92003	8073	2080
92004	7911	2217	92005	7789	2386	92006	7756	2493
92007	7741	2542	92008	7700	2550	92009	7604	2527
92010	7534	2529	92011	7413	2601	92012	7218	2627
92013	7040	2603	92014	6896	2544	92015	6729	2593
92016	6667	2565	92017	6566	2464	92018	6547	2455
92019	6431	2445	92020	6373	2444	92021	6163	2536
92022	6036	2561	92023	5887	2558	92024	5736	2534
92025	5499	2536	92026	5255	2511	92027	5099	2469
92028	4924	2431	92029	4743	2446	92030	4638	2465
92031	4526	2606	92032	4348	2760	92033	4182	2925
92034	4014	2986	92035	3963	3047	92036	3838	3234
92037	3719	3404	92038	3686	3573	92039	3694	3682
92040	3625	3862	92041	3530	4034	92042	3538	4243
92043	3612	4424	92044	3565	4517	92045	3496	4631
92046	3420	4845	92047	3289	5058	92048	3208	5216
92049	3330	5323	92050	3381	5471	92051	3434	5605
92052	3355	5696	92053	3265	5710	92054	3128	5870
92055	3110	6038	92056	3095	6175	92057	2949	6315
92058	2833	6369	92059	2757	6500	92060	2733	6711
92061	2690	6778	92062	2710	6855	92063	2581	7156
92064	2623	7280	92065	2591	7403	92066	2606	7565
92067	2533	7752	92068	2385	8015	92069	2239	8073
92070	2384	8425	92071	2496	8472			



Table 4 -- Points on Hubbard Glacier, July 30, 1978. X = UTM easting - 580,000 m, Y = UTM northing - 6,650,000 m, Z in meters above NGVD of 1929. The ID # of each point corresponds to the ID # in table 5. These points can be identified on figure 2 by the altitude.

ID #	X	Y	Z	ID #	X	Y	Z	ID #	X	Y	Z
101	4518	3519	113	102	4419	4343	144	103	4038	5262	135
104	3880	6030	165	105	3404	7004	134	106	3171	7732	127
107	2986	8296	109	201	5376	3207	106	202	5347	4118	154
203	4972	5129	184	204	4562	6301	171	205	4088	7425	141
206	3899	8503	139	301	6312	2987	91	302	6245	3667	122
303	5958	4587	177	304	5558	5784	194	401	7320	2872	72
402	7110	3945	156	403	6855	4810	205	404	6162	5973	202
405	5751	7061	169	406	5394	8369	173	407	4765	9373	202
503	7383	5156	215	504	7448	5962	193	505	7319	6553	208
506	7024	7894	226	507	6238	9113	204	508	6332	10870	343
601	8103	2634	92	602	8231	3601	150	603	8362	4678	191
604	8359	5302	221	605	8466	6030	208	606	8545	7164	246
607	8421	8163	255	608	7697	9045	214	609	7699	10272	359
701	9373	2965	150	702	9423	3817	176	703	9594	5533	237
704	9826	7110	275	705	9560	8428	255	706	8901	9991	315
801	10590	3337	166	802	11332	4730	218	803	10869	5907	254
804	11352	6930	288	805	10821	8595	241	903	12708	7160	342
904	11736	7884	298	1004	12782	8719	444	1005	12351	9452	421
1102	13890	9065	513								

Table 5 -- Points on Hubbard Glacier, August 23, 1978. X = UTM easting - 580,000 m, Y = UTM northing - 6,650,000 m, Z in meters above NGVD of 1929. The ID # of each point corresponds to the ID # in table 4. These points can be identified on figure 3 by the altitude.

ID #	X	Y	Z	ID #	X	Y	Z	ID #	X	Y	Z
101	4376	3370	93	102	4274	4222	125	103	3897	5190	131
104	3719	5967	146	105	3292	6990	130	106	3105	7708	119
107	2972	8294	109	201	5334	3082	101	202	5246	4002	147
203	4822	5040	169	204	4448	6262	165	205	4011	7408	140
206	3878	8498	139	301	6311	2893	82	302	6200	3562	110
303	5848	4498	167	304	5431	5720	190	401	7311	2814	65
402	7064	3085	149	403	6752	4747	194	404	6041	5916	199
405	5654	7020	180	406	5351	8349	172	407	4746	9364	200
503	7284	5108	212	504	7337	5911	195	505	7204	6503	207
506	6923	7853	224	507	6210	9089	203	508	6323	10848	336
601	8093	2622	89	602	8220	3591	149	603	8293	4639	192
604	8274	5278	216	605	8370	6004	205	606	8433	7114	238
607	8325	8123	249	608	7644	9025	212	609	7725	10242	346
701	9371	2964	150	702	9419	3814	175	703	9516	5513	237
704	9722	7079	270	705	9482	8403	251	706	8926	9932	305
801	10589	3335	167	802	11322	4725	220	803	10783	5864	252
804	11254	6882	287	805	10736	8585	245	903	12570	7021	289
904	11576	7821	299	1004	12577	8553	396	1005	12229	9415	395
1102	13716	8825	487								

Table 6 -- Velocities of points on Hubbard Glacier, averaged over interval July 30, 1978 to August 23, 1978. X, Y, and Z is the midpoint between the positions on the two dates. VX is the X component of velocity, VY is the Y component of velocity, and V is the total horizontal velocity, all in meters per day.

ID #	X	Y	Z	VX	VY	V
101	4447.0	3444.5	103.0	-5.9	-6.2	8.6
102	4346.5	4282.5	134.5	-6.0	-5.0	7.9
103	3967.5	5226.0	133.0	-5.9	-3.0	6.6
104	3799.5	5998.5	155.5	-6.7	-2.6	7.2
105	3348.0	6997.0	132.0	-4.7	-0.6	4.7
106	3138.0	7720.0	123.0	-2.8	-1.0	2.9
107	2979.0	8295.0	109.0	-0.6	-0.1	0.6
201	5355.0	3144.5	103.5	-1.8	-5.2	5.5
202	5296.5	4060.0	150.5	-4.2	-4.8	6.4
203	4897.0	5084.5	176.5	-6.3	-3.7	7.3
204	4505.0	6281.5	168.0	-4.8	-1.6	5.0
205	4049.5	7416.5	140.5	-3.2	-0.7	3.3
206	3888.5	8500.5	139.0	-0.9	-0.2	0.9
301	6311.5	2940.0	86.5	0.0	-3.9	3.9
302	6222.5	3614.5	116.0	-1.9	-4.4	4.8
303	5903.0	4542.5	172.0	-4.6	-3.7	5.9
304	5494.5	5752.0	192.0	-5.3	-2.7	5.9
401	7315.5	2843.0	68.5	-0.4	-2.4	2.4
402	7087.0	3915.0	152.5	-1.9	-2.5	3.2
403	6803.5	4778.5	199.5	-4.3	-2.6	5.0
404	6101.5	5944.5	200.5	-5.0	-2.4	5.6
405	5702.5	7040.5	174.5	-4.0	-1.7	4.4
406	5372.5	8359.0	172.5	-1.8	-0.8	2.0
407	4755.5	9368.5	201.0	-0.8	-0.4	0.9
503	7333.5	5132.0	213.5	-4.1	-2.0	4.6
504	7392.5	5936.5	194.0	-4.6	-2.1	5.1
505	7261.5	6528.0	207.5	-4.8	-2.1	5.2
506	6973.5	7873.5	225.0	-4.2	-1.7	4.5
507	6224.0	9101.0	203.5	-1.2	-1.0	1.5
508	6327.5	10059.0	339.5	-0.4	-0.9	1.0
601	8098.0	2628.0	90.5	-0.4	-0.5	0.7
602	8225.5	3596.0	149.5	-0.5	-0.4	0.6
603	8327.5	4658.5	191.5	-2.9	-1.6	3.3
604	8316.5	5290.0	218.5	-3.5	-1.0	3.7
605	8418.0	6017.0	206.5	-4.0	-1.1	4.1
606	8489.0	7139.0	242.0	-4.7	-2.1	5.1
607	8373.0	8143.0	252.0	-4.0	-1.7	4.3
608	7670.5	9035.0	213.0	-2.2	-0.8	2.4
609	7712.0	10257.0	352.5	1.1	-1.3	1.7
701	9372.0	2964.5	150.0	-0.1	0.0	0.1
702	9421.0	3815.5	175.5	-0.2	-0.1	0.2
703	9555.0	5523.0	237.0	-3.3	-0.8	3.4
704	9774.0	7094.5	272.5	-4.3	-1.3	4.5
705	9521.0	8415.5	253.0	-3.3	-1.0	3.4
706	8913.5	9961.5	310.0	1.0	-2.5	2.7
801	10589.5	3336.0	166.5	0.0	-0.1	0.1
802	11327.0	4727.5	219.0	-0.4	-0.2	0.5
803	10826.0	5885.5	253.0	-3.6	-1.8	4.0
804	11303.0	6906.0	287.5	-4.1	-2.0	4.5
805	10778.5	8590.0	243.0	-3.5	-0.4	3.6
903	12639.0	7090.5	315.5	-5.8	-5.8	8.2
904	11656.0	7852.5	298.5	-6.7	-2.6	7.2
1004	12679.5	8636.0	420.0	-8.5	-6.9	11.0
1005	12290.0	9433.5	408.0	-5.1	-1.5	5.3
1102	13803.0	8945.0	500.0	-7.3	-10.0	12.4