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THE BURSTING OF A SNOW DAM, TINGMISUT LAKE, MELVILLE ISLAND, NORTHWEST TERRITORIES

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Abstract

In July 1979 snowmelt from the hills surrounding Tingmisut Lake, Melville Island, accumulated in the lake basin, trapped behind a dense snowdrift which blocked the valley of the outlet stream. The water level rose until it overtopped this snow dam, and the flowing water cut down rapidly through the dam, resulting in a major flood event downstream. An estimated 1.6 x 10^6 m^3 of water drained from the lake in 36 hours. The implications of such events are discussed.

Résumé

En juillet 1979, l'eau de fonte des neiges provenant des collines qui entourent le lac Tingmisut, dans l'île de Melville, s'est accumulée dans le bassin lacustre, retenue derrière un barrage de neige dense qui bloquait l'exutoire d'écoulement vers la vallée. Le niveau de l'eau s'est élevé jusqu'à ce qu'il dépasse ce barrage de neige, puis, en s'écoulant, l'eau s'est rapidement frayée un chemin à travers celui-ci, ce qui a provoqué une grave inondation en aval. En 36 heures, le lac a perdu une quantité d'eau estimée à 1,6 x 10^6 m^3. L'auteur se penche ici sur les implications de phénomènes semblables.

Introduction

This report describes the first hand observation of an event which, while it may occur quite commonly, is not often seen. In early July 1979, the small valley which drains Tingmisut Lake, Melville Island, Northwest Territories, was almost completely blocked by a dam formed by a large drift of compact, windblown snow, immediately below the outlet of the lake. As the winter's accumulation of snow in the basin surrounding Tingmisut Lake melted and ran off into the lake, the level rose until it finally overtopped the snow dam. The resulting flood event in the outlet valley can only be described as catastrophic, in relation to the small valley concerned.

The account which follows is a largely qualitative description of the breaching of the snow dam. No instruments suitable for recording hydrological parameters such as discharge or flow velocity were available in camp.

Terminology

Woo (1979, 1980) used the term "snow jam" to describe what is here called a "snow dam" – a large snowdrift which more or less completely blocks the valley of an intermittent stream and which fails by being overtopped by meltwater during the spring (Fig. 20.2A, B). In this report, the term "snow jam" is used to describe a more ephemeral obstruction caused by a pile up of large, loose blocks of snow. As described below, a "snow jam" was formed downstream of the snow dam by the failure and collapse of a snow bridge. As the water level behind the jam rises, in response to the obstruction, the blocks float, allowing some water to escape. The jam then reforms and again partially blocks the stream. This mechanism is regarded as being analogous to ice jamming on perennial rivers, and even log jams.

Flood event of 1979

When first seen on July 20, at 1800 h, the snow dam was all the way across the valley below the outlet of the lake. It extended about 500 m down the valley and ended in an almost vertical snow cliff 3-4 m in height (Fig. 20.2A). Examination of the face of the snow cliff showed that the dam was composed of layers of windblown snow with several narrow bands of dirt or dust. The snow dam formed in a valley with one steep side slope (the left bank) and one relatively gently side slope (the right bank). The snow dam apparently started as a lee-side drift on the gentle slope. This drift grew across the valley until it contacted the steep side. From this, it can be deduced that the dominant wind that built the drift was westerly. Downstream of the snow dam, the valley was walled on the east side by a rock cliff, 5-6 m in height, and on the west side by the vertical face of a large snow drift, continuous with the snow dam, and 4-5 m in height. This "gorge" section extended downstream for some 350 m where the valley opened out. Here a second, much smaller snow dam blocked the valley. Below this, the valley is open down to the sea at Weatherall Bay. The distance between the dam and the sea is about 2.5 km along the stream channel.

On July 20, the water level in Tingmisut Lake was high, as most of the snow on the surrounding hills had melted. The shores of the lake slope very gently, and the high water level had resulted in shoreline flooding, particularly at the southeast end, near the outlet (Fig. 20.1). When the upstream boundary of the dam was first seen, a little water was leaking into the snow dam and flowing onto the dam surface (Fig. 20.2B). This coalesced into a small, suprasnow stream flowing in a meandering channel, 20 to 30 cm wide and about 30 cm deep, over the surface of the dam. About half-way down the dam this stream disappeared into a "moulin", near the east side of the snow dam, reappearing at the base of the snow cliff which formed the downstream face of the dam (Fig. 20.2A). Some internal erosion may thus have been active within the dam.

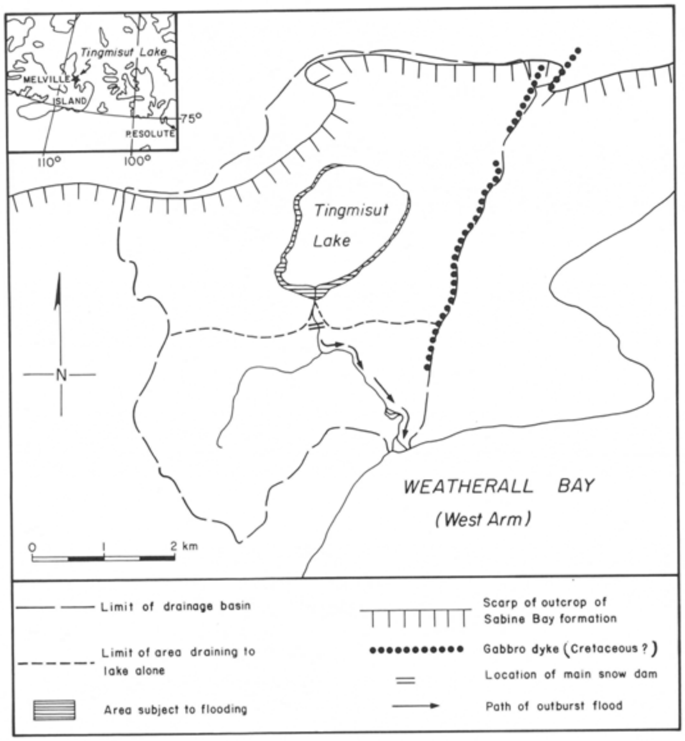


Figure 20.1. *Location map and site map for Tingmisut Lake, Melville Island, Northwest Territories.*

The sequence of events leading up to the overtopping of the snow dam on July 22 are as follows. During the previous two days, the upper edge of the dam had been eroded by wave action. On July 21 small amounts of water had begun to flow onto the dam. Most of this appeared to soak into the snow. After about midday on July 22, the weather, which had been fairly cool until then, warmed. During the afternoon the flow of water onto the dam increased until there was a continuous stream flowing as far as the moulin noted above. At about 1900 h the capacity of the moulin was exceeded and a pond began to develop on the surface of the dam (Fig. 20.3A). The rate of flow onto the upper part of the dam continued to increase as the channel across the upper part was enlarged by thermal erosion. By 2045 h this pond, now quite extensive, began to spread across the downstream part of the snow dam. Throughout this period, there was no appreciable increase in the flow of water discharged from the pipes in the face of the snow dam. The pond on the dam surface gradually spread until, at 2120 h, it spilled over the last barrier on the dam surface and, at 2125 h it began to spill down the face of the dam (Fig. 20.3B, C).

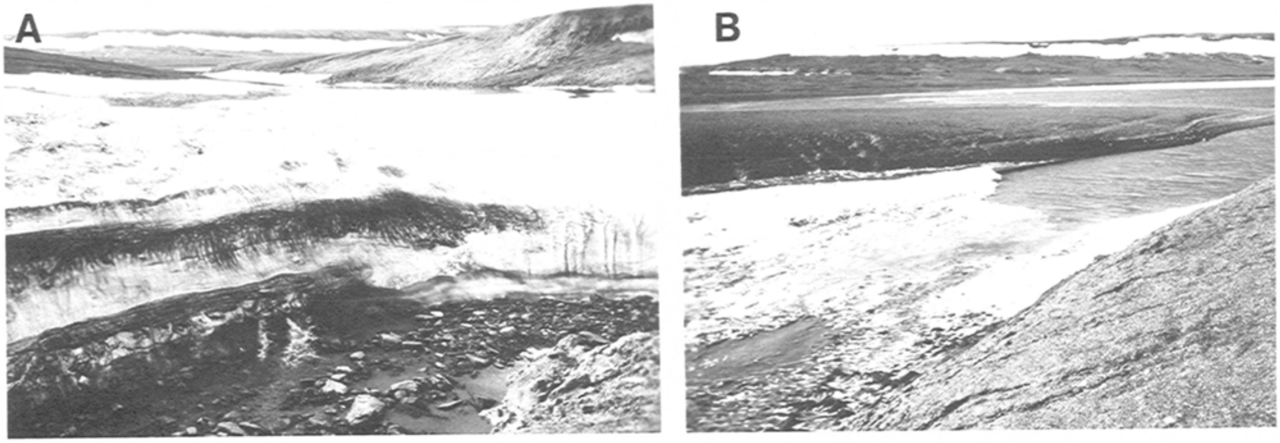
By 2300 h the stream had become a wide, fast-flowing torrent which had carved a deep notch in the face of the snow dam (Fig. 20.3D, E). Downstream of the upper dam, the water ponded behind the second dam until it was some 2 m deep, when it overtopped this dam. Farther downstream the stream continued as a torrent that completely filled the stream bed, flowing between walls of rock and snowbanks. The torrential flow continued throughout the night (Fig. 20.3F).

On the morning of July 23, the stream was still flowing across ice in the area of the upper part of the main snow dam. In the lower part of this dam, the stream had cut down to the boulders and bedrock of its normal bed (Fig. 20.4A). The increased flow of water in this section led to the sides of the "snow gorge" being undercut, by as much as 2 m in places. Periodically large blocks of snow would break away, falling into the stream (Fig. 20.4B). Farther downstream, the second dam had become a snow bridge (Fig. 20.5A). At about 1115 h this bridge collapsed, partially damming the stream again (Fig. 20.5B) and forming a "snow-jam", as discussed above. As the water level behind it rose the blocks floated, the jam failed, and some water escaped. The jam then reformed and blocked the stream again. The result was a period of pulsed flow farther downstream.

By the morning of July 24, 36 hours after the dam was first overtopped, the water level in the lake had dropped to near its normal summer level. At this stage, the level of the lake is controlled by a sill of bedrock and boulders. The flooding around the shore of the lake had retreated, and the flow of water in the stream was considerably reduced.

Estimate of 1979 flood magnitude

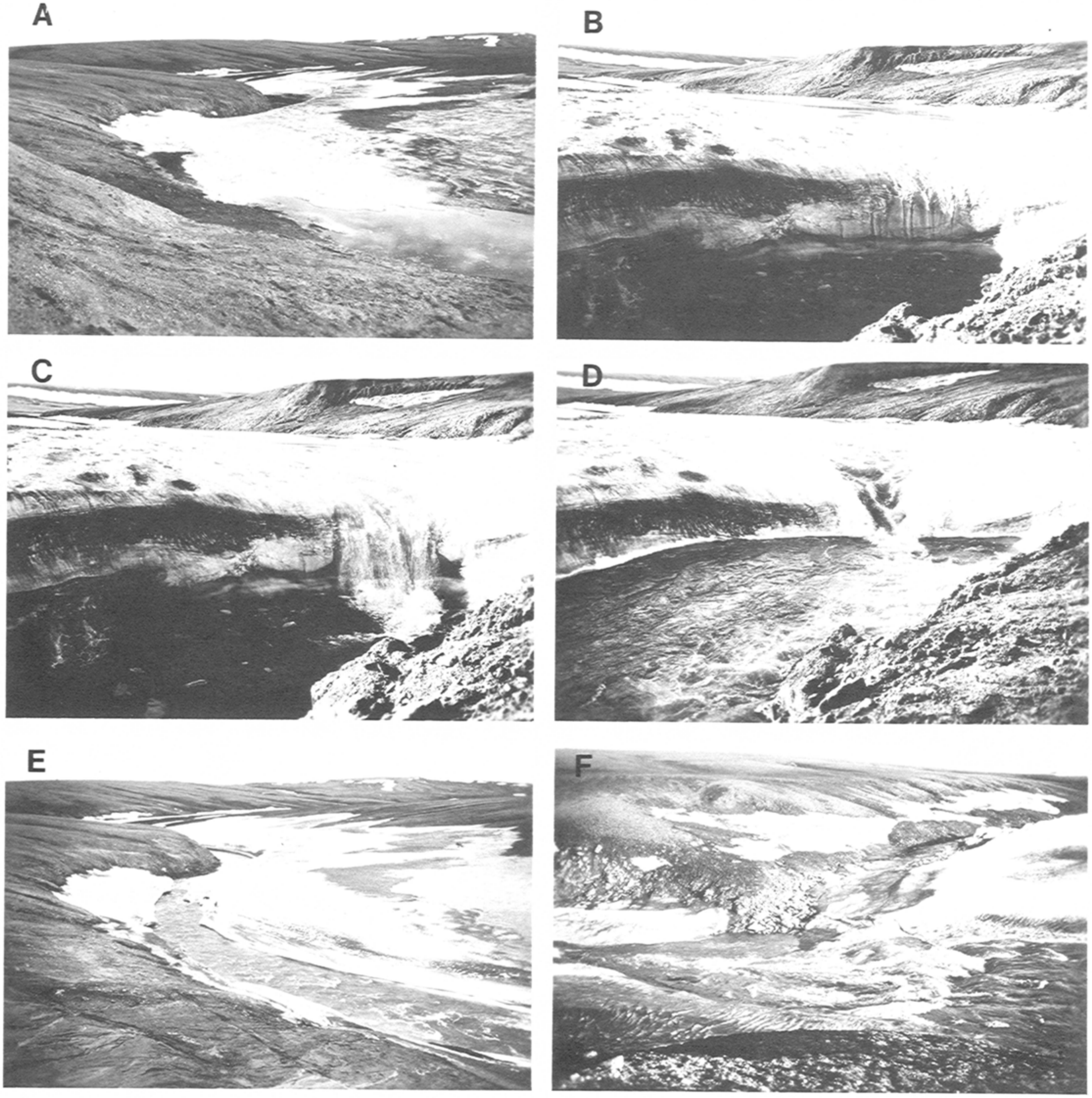
A rough estimate of the volume of water involved was made, based on field observations of the fall in lake level and on the area of the lake as measured on a vertical aerial photograph (Fig. 20.6). In the 36 hour period following the overtopping of the dam at 2125 h, 22 July 1979, the water level in the lake dropped approximately 80 cm.



A. *Downstream face of main dam; note water leaking from base of dam. (GSC 203553-V)*

B. *Head of dam with flooded area of Tingmisut Lake beyond. (GSC 203553-A)*

Figure 20.2. *The main snow dam as first seen on 20 July 1979, at 1800 h.*



A. 1900 h: pond forming above moulin and spreading across the lower part of the main dam. (GSC 203554-T)

B. 2120 h: water beginning to spill down face of dam. (GSC 203554-I)

C. 2125 h: water pouring over snow dam. (GSC 203554-L)

D. 2300 h: notch cut in main dam; water backing up due to second snow dam farther downvalley. (GSC 203553-E)

E. 2300 h: channel cut across main snow dam (looking downstream). (GSC 203554-C)

F. 2310 h: torrential flow in stream below the snow dams. (GSC 203553-F)

Figure 20.3. *The failure of the main snow dam on the evening of 22 July 1979.*

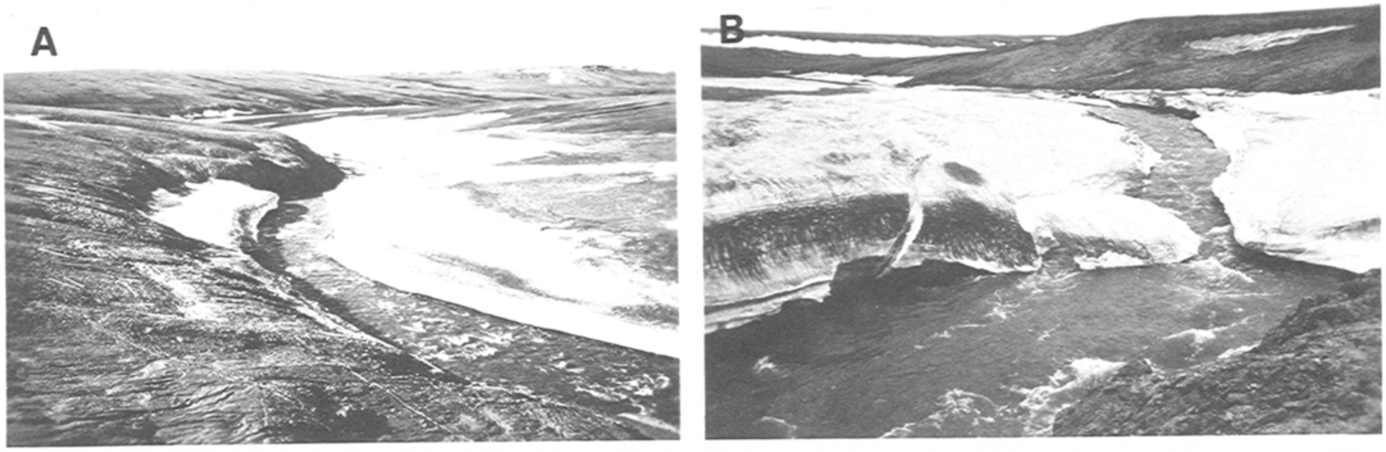
The area of the lake was measured on airphoto A16763-55. By comparison with the 1:250 000 NTS map (78 H, Byam Channel), the actual scale of this photograph was determined to be 1:56 000. The area of the lake was measured at 612 mm^2 on the photograph, which equals 1.92×10^6 m^2.

Tingmusit Lake has a very gently sloping margin and at flood level is considerably more extensive than at low water. Field observations suggested that the area of dark grey, waterlogged soil evident on the airphoto (Fig. 20.6) was representative of the flooded area. The area was determined to be about 250×10^3 m^2, for a total lake area at flood level of 2.17×10^6 m^2. If this parcel of water is regarded as the frustum of a cone, with a height of 80 cm, the volume of water released is approximately 1.60×10^6 m^3.

From this volume, a rough estimate of the peak discharge was made – 102.7 $m^3 \cdot s^{-1}$ – using the empirical formula developed by Clague and Mathews (1973). Woo (1980), in studying a small lake on Cornwallis Island, also subject to flooding by the formation of a snow dam, noted the areally averaged spring flood had a value of 6.5 $m^3 \cdot s^{-1} \cdot km^{-2}$. In this example, with a drainage area of 12.9 km^2 (also measured on airphoto A16763-55) and a discharge of 102.7 $m^3 \cdot s^{-1}$, the areally averaged spring flood of Tingmisut Lake equals 6.8 $m^3 \cdot s^{-1} \cdot km^{-2}$, a very comparable value.

Previous flood events

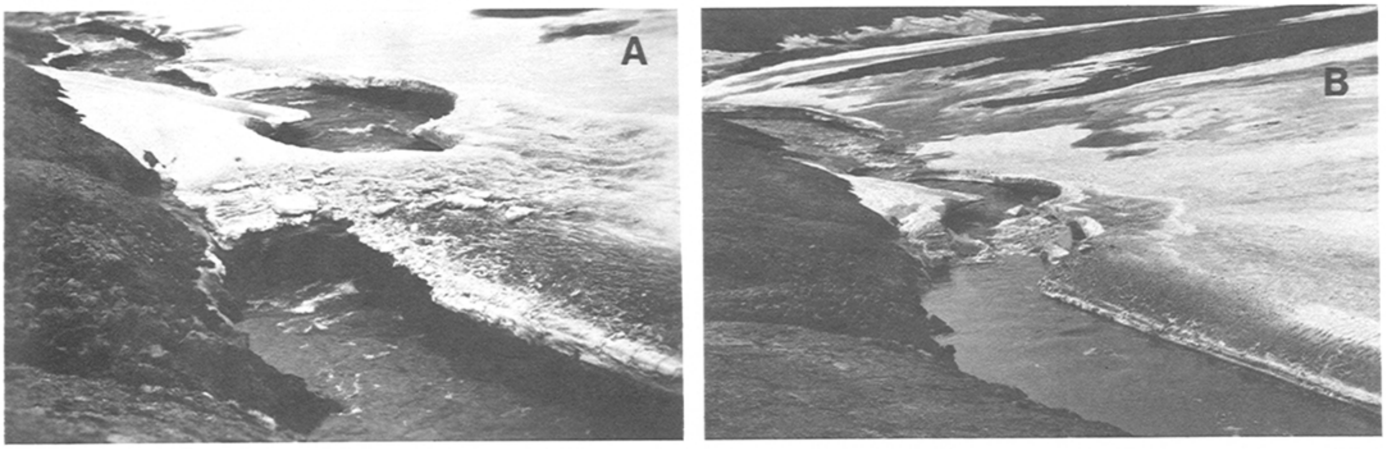
An attempt was made to determine whether similar flood events had occurred in this valley in previous years. All available aerial photographs of the area were examined, and an attempt was made to contact all people who had visited the Tingmisut Lake area in the last few decades. In both cases the results were inconclusive. There is some evidence to suggest that floods probably occurred in 1973 and 1977, and may have occurred in 1962, 1971, and 1972. No flood occurred in 1981. Generally low snowfalls in the winter of 1981-82 resulted in a very shallow snowpack and low runoff. The dam was seen between July 5 and July 10, by which time it had not failed.



A. 0800 h: channel across main snow dam cut down to natural, rocky stream bed (compare with Fig. 20.3A and 20.3E). (GSC 203553-U)

B. 0800 h: collapsing walls of gorge, following undercutting. (GSC 203553-H)

Figure 20.4. *The remains of the snow dam on the morning of 23 July 1979.*



A. 1100 h: snow bridge at site of the lower snow dam. (GSC 203554-D)

B. 1115 h: collapse of the snow bridge and formation of the snow jam. (GSC 204018-H)

Figure 20.5. *Formation of the snow jam at the site of the lower snow dam on the morning of 23 July 1979.*

Figure 20.6

Vertical airphoto of Tingmisut Lake, taken in August 1950 (NAPL A16763-54). Arrow marks site of main snow dam.

Discussion

Previous report of snow dams in Arctic and Alpine environments

Similar flood events have seldom been reported in the literature. Some occurrences on eastern Bathurst Island in early July 1976 are reported by Wedel et al. (1978, p. 28), and others have been seen in central Bathurst Island by the author. An extensive description of snow dams and associated floods is presented by Woo (1979) for the period 1976 to 1978 for rivers in the vicinity of Resolute, Cornwallis Island. In a discussion of the conditions required for the development of a snow dam, Woo (1979) suggested that they are formed by compact, wind-drifted snow that has accumulated in stream valleys throughout the long arctic winter. Incised stream valleys, bordered by steep slopes are usually infilled with larger amounts of snow than more open, non-incised valleys.

A related phenomenon, the damming of an ice-marginal meltwater stream by falling glacier ice is described from Ellesmere Island by Ballantyne and McCann (1980). Burkimsher (1983) reported the damming of a subglacial steam by collapse of a tunnel within the Pasterzengletscher, Austria, in 1980. Floods due to both ice jams and snow dams have been reported from Baffin Island by Church (1972).

Distribution of snow dams

Consideration of the general conditions required for the development of snow dams suggests that they will largely be confined to Arctic regions. An open, windy landscape appears to be necessary for the redistribution of snow into drifts filling gullies and small valleys. Furthermore, wind plays a key role in the formation of dense, compact snow, such as would seem to be essential for a drift that will effectively dam a stream.

The density of newly fallen snow can vary from as low as 0.1 g/cm^3 in cold, wind-free conditions, to over 0.4 g/cm^3 for windblown snow (Mellor, 1964, p. 49). Maxwell (1980, Table 3.22) has estimated mean monthly snow cover densities for 15 stations in the Arctic Islands. His estimates range from 0.23 to 0.38 g/cm^3. Longley (1960) reported snow densities of 0.25 to 0.38, with a mean of 0.30 g/cm^3 from a site at Resolute, Cornwallis Island. Cowan (1966), working at Schefferville, Quebec, examined the differences in snow density in three different vegetation and terrain situations. He found that in well sheltered areas (closed cover forest) snow densities were less than 2.0 g/cm^3 and in some cases ran close to 0.1 g/cm^3. Within the forest edge zone densities were generally between 0.2 and 0.3 g/cm^3, but in open areas (on frozen lakes in this case) densities were as high as 0.3 to 0.4 g/cm^3. These data support the commonly held idea that arctic snow is denser and more compact than snow in other areas.

It is common to find snowbanks in Arctic regions occupying the same locations year after year. Thus it should be expected that snow dams will tend to recur in approximately the same locations in the same stream valleys; however, they may not fully block the valley each and every year. Also, a catastrophic, dam-burst flood may not always occur. The actual occurrence of a dam or a flood will depend on the amount of snow fall, the amount of snow drift, and the pattern of snowmelt. All of these factors will vary from year to year.

Although it is concluded above that snow dams and associated floods are probably confined to Arctic regions, there are circumstances when analogous phenomena could be expected in sub-Arctic or temperate latitudes. Snow dams and floods identical to those already discussed could occur in mountainous regions, above upper timberline. They are less likely here, as snowmelt tends to progress up the mountain, and so the dam may partially melt before any significant amount of water can develop behind it.

At lower elevations, avalanche deposits could possibly block a stream, particularly early in the melt period. The ice or remoulded snow of an avalanche deposit could well be dense and compact enough to be impervious to water and so act as a dam (Haeberli, 1983). Elsewhere, in temperate and sub-Arctic regions the snow is generally too porous to dam up any significant quantity of water. Slush avalanches are a more likely result than water floods from snow dam failures (Washburn, 1980).

Implications of snow dam bursts

Snow dams and the flood events that can occur when a snow dam fails catastrophically are of more than just intrinsic interest. They have serious implications for the location and design of various forms of structures in northern regions. The greatest concern is for the design of structures, the details of sizing of which are in some manner related to the discharge of a stream or river. Chief among these are buried pipeline crossings and road crossings of streams.

In either case, if the hydrologist responsible for determining the design discharge for the stream in question visits the area in the latter part of the summer season, he may see no evidence of flooding. The snow dam remnants will have melted and the stream may look small, insignificant, and harmless. The hydrologist will probably use some form of rational formula to estimate his design discharge. If there are lakes in the system, he may well conclude that lake storage effects will give a reduced peak discharge, and design structures accordingly.

In the case of the stream draining Tingmisut Lake, this approach would yield an underestimate of the peak discharge. Here, the presence of the lake seriously aggravates the situation by providing storage space for much water before the snow dam is overtopped and destroyed. The resulting flood event is considerably larger than if the lake did not exist.

Thus in determining the design discharge for a culvert, a buried pipeline crossing, or any other structure for which stream discharge is significant, the possibility of such flood events of some considerable magnitude must be taken into consideration. In addition, the possibility of such floods must be considered in the siting of facilities beside streams which may be subject to snow damming.

Acknowledgments

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