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ICE JAMS RELATED TO CLIMATOLOGICAL AND HYDRAULIC PARAMETERS - YUKON RIVER AT DAWSON CITY

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BREAK-UP MECHANISM OF THE YUKON RIVER AT DAWSON CITY

Break-ups of the Yukon River at Dawson have been recorded since 1896, just after the founding of the settlement. The Water Survey of Canada has been measuring the river discharge and gauge height since 1945 and the winter ice thickness since 1957.

Records of break-up on the Klondike River started in 1956 and complete flow measurement in 1965.

Each year break-up follows the same general pattern: First, the small creeks on the hill around Dawson start to flow. This triggers the break-up of the Klondike River, usually a day or two after. Then, an average of 5 days later, the Yukon starts to break up. This time lag between both break-ups is crucial. It can allow the formation of an ice jam at the mouth of the Klondike because the ice sheet on the Yukon prevents the downstream movement of the heavy flow of ice and water of the Klondike. Several times in the past, this situation did result in the flooding of the southern part of Dawson and in the washout and flooding of the highway along the Klondike.

ICE JAMS IN DAWSON

By analyzing the past record of gauge height and discharge measured and computed by the Water Survey of Canada, and by comparing the result with the rating curves, it has been possible to determine the time and length of ice jams on the Yukon River at Dawson. This was complemented by information from the Water Survey data books, by material from the archives, and by personal recollections of Dawson residents. It shows that the ice jams on the Yukon are very frequent at break-up time. Analysis of past records show that out of 27 years of records there was 17 years of ice conditions and ice jams during break-up (Table 1). These ice jams last from a few hours up to 10 days, but only a small number of the jams reach flood level.

ANALYSIS OF ICE JAMS

All the parameters that can be measured and that are possibly related to ice jamming have been computed and analyzed. These parameters are:

(a) River ice thickness prior to break-up.

(b) Water elevation at time of freeze-up.

(c) Froude number at break-up time and evolution of the Froude number during ice jamming (Table 1). A winter Froude number has been computed corresponding to winter water depth and velocity.

(d) Total number of degree days above 32°F up to the time of break-up and up to the last day of ice jamming.

The results show that the hydraulic considerations are the governing factor for ice break-up starting and jamming formation. Break-up occurs for a Froude number between 0.04 and 0.09 (Fig. 1).

An increase in the Froude number will either help to evacuate the ice or start ice jam conditions. Ice jams are found to happen for Froude number between 0.08 and 0.13. It shows that it takes a higher Froude number to break a jam than it takes to start the river break-up. No ice is found for Froude number above 0.13. Ice jam equilibrium seems to be independent of the ice thickness. As previously stated by Kivisild (Ref. 1) the Froude number of the flow in front of an ice cover is a valid criterion of ice cover stability.

Degree days, as computed, did not show any significant relation to break-up and ice jamming formation. However indirectly, hydraulic conditions and degree days are related: an increase of the degree days start the snowmelt which in turn change the hydraulic conditions.

Water elevation at the time of freeze-up has been plotted (Figure 2) for the years 1946 to 1973. Results show that this has very little influence on spring ice jamming, although there seems to be a slightly higher frequency of ice jam when water level was low at freeze-up time. In this case ice will freeze solid to the bottom in the shallow reaches of the river and increase the danger of ice jams during spring break-up, although this type of jam is the mildest one and causes least danger of flooding.

CONCLUSIONS

With 80 years of break-up records and 30 years of flow and ice thickness measurement Dawson City is a unique case in the Canadian North. Results show that the hydraulic considerations are the governing factor for ice break-up starting and jamming formation.

From the flow charts it was relatively easy to determine for each year the length of time of the ice conditions and jams but it was not possible to assess the type and the importance of each jam. Distinction between "ice conditions" and "ice jams" was in some cases difficult to establish (in general the distinction was based on the shape of the recession part of gauge height versus time curve). Thus jams are known mainly indirectly by their consequences (change in the gauge reading, floodings etc.). There is no recorded description of the ice jam behaviour itself.

REFERENCE

1. H.R. Kivisild (1959) Hanging ice dams. Proc. 8th Congress I.A.H.R.

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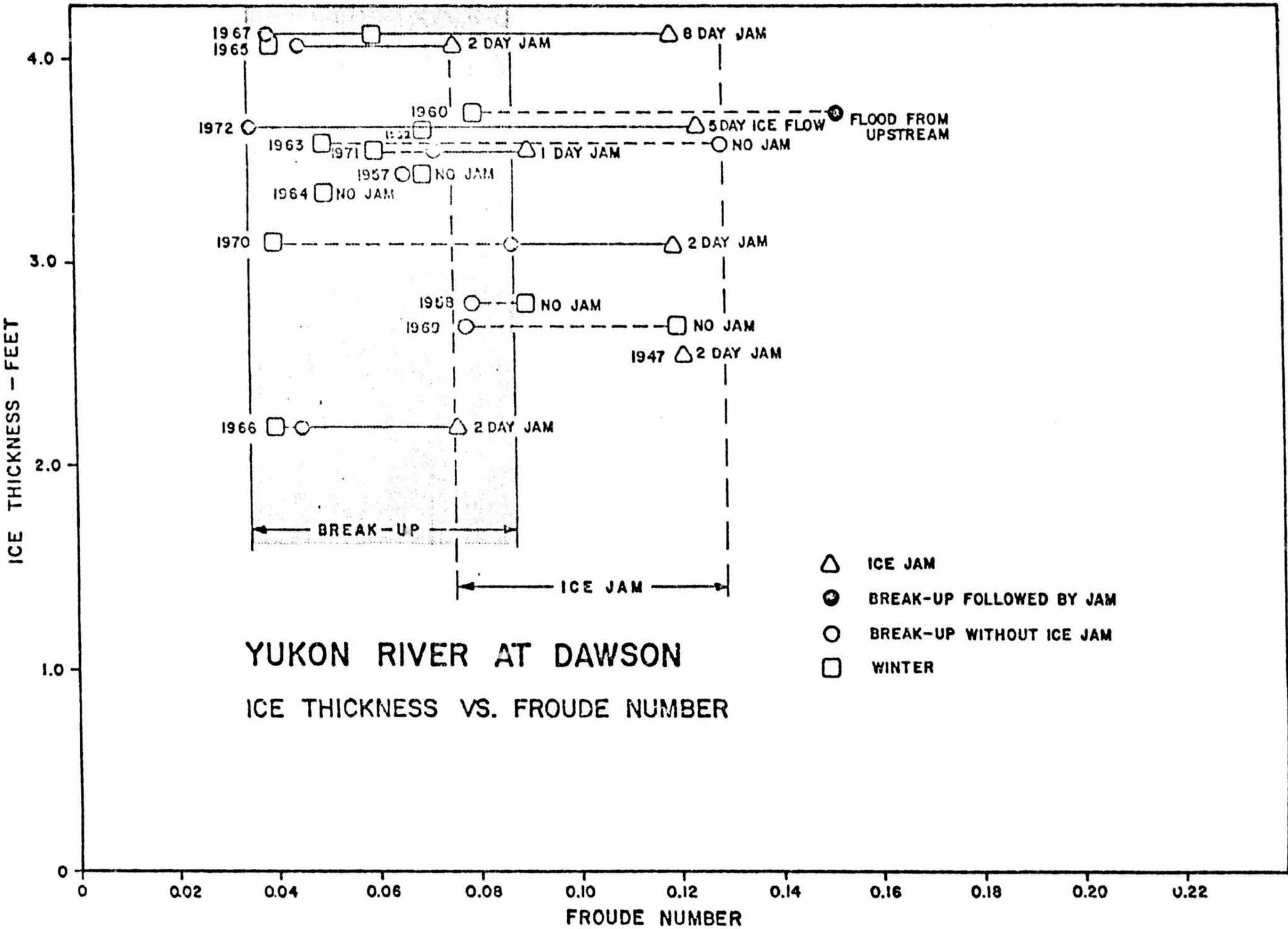

YUKON RIVER AT DAWSON
ICE THICKNESS VS. FROUDE NUMBER
ICE THICKNESS – FEET
FROUDE NUMBER
BREAK-UP
ICE JAM
ICE JAM
BREAK-UP FOLLOWED BY JAM
BREAK-UP WITHOUT ICE JAM
WINTER
1967
1965
8 DAY JAM
2 DAY JAM
1960
FLOOD FROM UPSTREAM
1972
5 DAY ICE FLOW
1963
1971
NO JAM
1 DAY JAM
1957
NO JAM
1964
NO JAM
1970
2 DAY JAM
NO JAM
NO JAM
1947
2 DAY JAM
1966
2 DAY JAM

Fig. 1

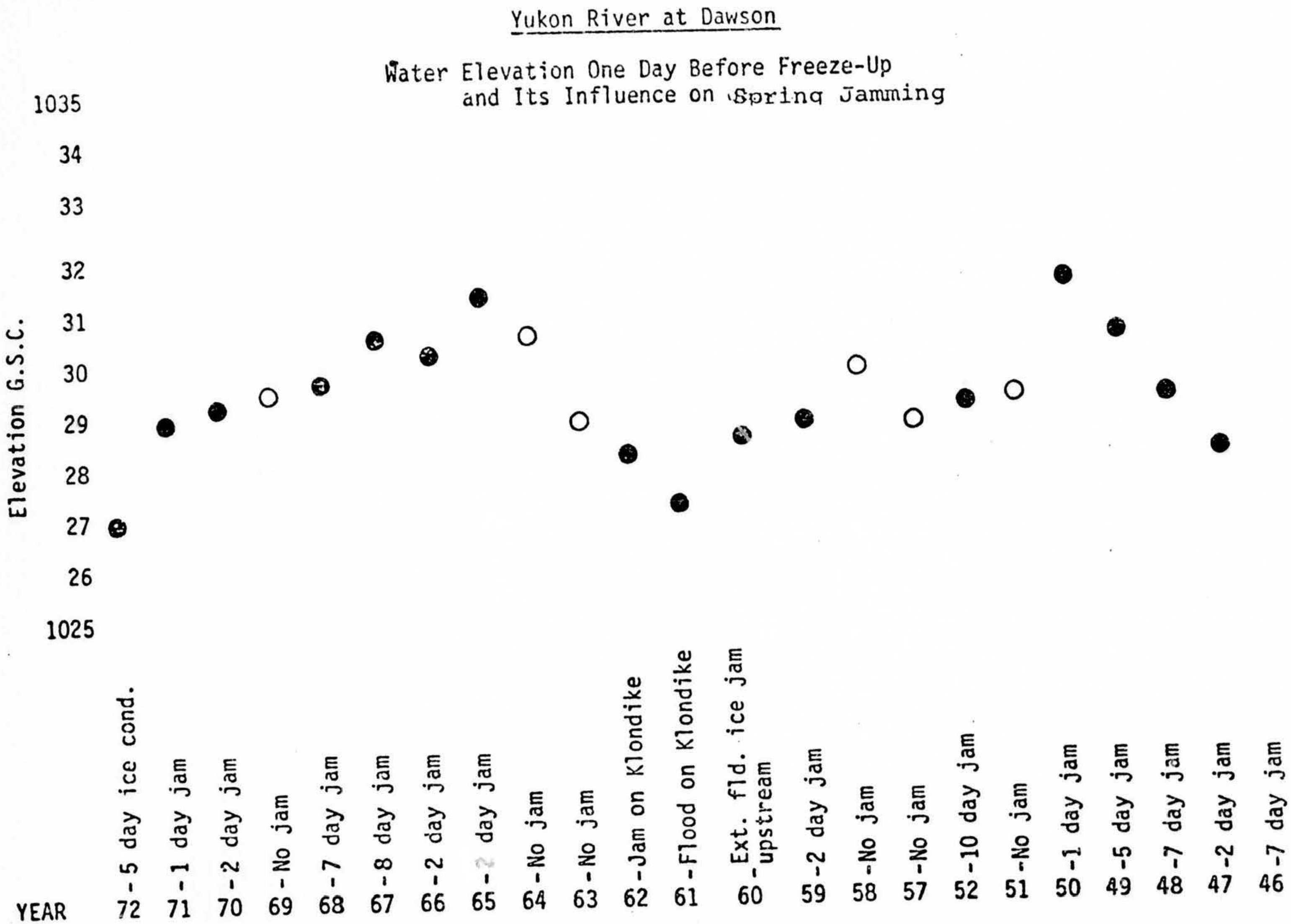
Yukon River at Dawson
Water Elevation One Day Before Freeze-Up
and Its Influence on Spring Jamming
Elevation G.S.C.
1035
34
33
32
31
30
29
28
27
26
1025
YEAR
72 - 5 day ice cond.
71 - 1 day jam
70 - 2 day jam
69 - No jam
68 - 7 day jam
67 - 8 day jam
66 - 2 day jam
65 - day jam
64 - No jam
63 - No jam
62 - Jam on Klondike
61 - Flood on Klondike
60 - Ext. fld. ice jam upstream
59 - 2 day jam
58 - No jam
57 - No jam
52 - 10 day jam
51 - No jam
50 - 1 day jam
49 - 5 day jam
48 - 7 day jam
47 - 2 day jam
46 - 7 day jam

Fig. 2

Yukon River at Dawson

Break-Up and Ice Jamming

Year	Date of Break-Up	Date of Jamming	Maximum Recorded Ht. of Ice	Min. Q at Time of Jam Max. Q	Corresponding Depths	Corresponding Froude No.	Winter Froude No.	Description
1973	May 8							
1972	May 13	May 13-18	1,035.60	24,000 to 78,000	23.11 21.65	0.035 0.124	--	5 days of ice condition, highway flooding, ice jam upriver.
1971	May 11-12	May 12	1,035.51	44,000 to 62,000	21.19 23.02	0.072 0.090	0.06	One day jam, level from 1,033.68 to 1,035.51.
1970	May 11	May 12-13	1,035.49	56,000 to 82,000	22.05 23.00	0.087 0.119	0.04	Two days jam, level from 1,034.70 to 1,035.49.
1969	May 5	--	1,034.17	49,500	21.68	0.079	0.12	No jam, level dropped, mild run-off.
1968	May 9	May 11-17	1,033.18	22,500 to 68,500	20.60 20.42	0.039 0.119	0.10	Ice jam on Klondike on May 4, 7 days ice jam, level from 1,032.99 to 1,033.18.
1967	May 12	May 13-21	1,037.48	43,000 to 110,000	24.20 21.41	0.058 0.178	0.06	8 days ice condition & jam, level from 1,036.69 to 1,037.48
1966	May 11	May 11-12	1,051.87	40,000 to 100,000	27.24 35.28	0.045 0.076	0.04	One day jam, level from 1,037.14 to 1,051.87, flood, jam on Klondike too.
1965	May 18	May 19-20	1,041.00	68,000 to 90,000	24.05 28.51	0.092 0.095	0.04	Two days jam, level from 1,034.50 to 1,041.00.
1964	May 28	--	1,035.80	160,000	--	--	0.05	No jam, flood in June due to heavy run-off.
1963	May 5	--	1,033.28	76,000	20.70	0.129	0.05	No jam, jam on Klondike April 30.
1962	May 12	--	--	49,600	--	--	0.07	Gauge Height missing, some jamming in Klondike.
1961	May 9	--	--	31,000	--	--	0.04	Gauge Height missing, flooding near end of April on Klondike with road wash-out.
1960	May 4	May 7	1,050.70	134,000	27.17	0.152	0.08	Extensive flood due probably to ice jam coming from upstream
1959	May 15	May 15	1,037.64	118,000 to 132,000	20.63 20.15	0.202 0.168	0.05	Two days jam, Klondike jammed on May 11-12, water level from 1,033.12 to 1,037.64.
1958	May 4	May 3	1,033.75	39,000 to 45,800	20.52	0.079	0.09	One day jam before break-up.
1957	May 7	May 10	1,041.00	52,000 to 44,000	22.57	0.066	0.07	Heavy volume of water coming from Klondike, level from 1,039.06 to 1,045.00.
1956	May 7	--	--	--	--	--	--	NO RECORD
1955-1953	--	--	--	--	--	--	--	NO RECORD
1952	May 12	till May 22	1,032.64	11,800 to 80,000	16.75 20.79	0.028 0.135	--	Ten days of ice conditions and jam.
1951	May 8	--	1,032.84	112,000	20.35	0.193	--	No jam.
1950	May 10	May 13	1,039.37	NOT AVAILABLE	--	--	--	One day jam 3 days after break-up, level from 1,037.77 to 1,039.37.
1949	May 13	May 17	1,041.74	NOT AVAILABLE	--	--	--	5 days ice condition & jam, level from 1,035.24 to 1,041.74.
1948	May 12	May 19	1,040.97	NOT AVAILABLE	--	--	--	7 days ice condition & jam, level from 1,033.54 to 1,040.94.
1947	May 9	May 11	1,042.14	120,000 to 122,000	29.65 22.55	0.121 0.180	--	Ice jam after break-up, level from 1,035.04 to 1,042.14.
1946	May 9	till May 16	1,035.94	--	--	--	0.06	Ice condition & jam for 7 days, level from 1,034.69 to 1,035.94.
1945	May 16	--	1,040.24	50,000 161,000	--	--	--	Jam 8 days after break-up, level from 1,030.54 to 1,040.24.
1944	May 5	May 6-10	1,052.37	--	--	--	--	15 mile long ice jam lasting four days, considerable flooding.

Table 1

DISCUSSION

J.P. Jolly

Two questions: (1) What was the overall objective of the study? (2) You have related ice break-up and ice jam at one location on the River to Froude number for the flow at another location on the River, how can one know the flow regime at an ice jam location from flow parameters measured a few miles away?

J. Penel

Since there is a distance of several miles between the hydraulic measurements (in front of Dawson City) and the actual location of the ice jam, Froude number values of 0.08 and 0.13 for jamming cannot be used as a design criteria for maximum water level forecasting. The results of the study merely show that break-up and ice jamming are related to the Froude number. The actual value of the Froude number could be different at another location. In the past, attempts have been made to improve the relation by including the ice porosity;* unfortunately it adds a new parameter on which we do not have data.

In an indirect way the hydraulic conditions are partially controlled by the meteorological conditions. Increased degree days accelerate the snowmelt which in turn changes the hydraulic conditions.

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*B. Michel (1968) Ice covers in Rivers, Proceedings of the Conference on Ice Pressure. NRC Technical Memorandum 92, pp. 231-247.