LIARD AND MACKENZIE RIVER ICE BREAK-UP, FORT SIMPSON REGION, N.W.T., 1982

by

J.C. Anderson

Northern Hydrology Section
Surface Water Division
National Hydrology Research Institute
Environment Canada
Ottawa, Ontario
K1A 0E7

for the
Water Resources Division
Department of Indian Affairs and Northern Development
Ottawa, Ontario

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ABSTRACT

Observations of break-up on the Liard and Mackenzie Rivers near Fort Simpson, N.W.T. were made during May 1982. The timing and characteristics of break-up were recorded using 35 mm oblique aerial photography, ice thickness was obtained from pans stranded along the shore, surface water temperatures were monitored, and water levels were observed. The 1982 break-up was relatively late but typical in many respects. Liard River ice broke first, to the ferry crossing near Fort Simpson airport by midday, May 9. The ice jammed there, but released the same evening and break-up progressed to the Mackenzie. Mackenzie ice moved at Fort Simpson at about 1010 MST on May 10 but jammed at the downstream end of the island. The water level rose about four metres and considerable ice thrust occurred at Fort Simpson prior to jam release that same evening, but no flooding of any consequence occurred. Mackenzie ice upstream of the Liard confluence to Jean Marie River broke up and moved out in stages between May 15 and 17. Measured ice thicknesses during break-up ranged between 50 and 130 cm, and above-zero water temperatures on the Liard and Mackenzie were first observed on May 12. On May 17, the Liard was approximately 4°C near its mouth and the Mackenzie above Martin Is. was about three degrees colder.

Surface Water Division
National Hydrology Research Institute
Environment Canada
OTTAWA, Ontario
K1A 0E7

September 30, 1982

Mr. A.R. Waroway
Head
Engineering and Planning Section
Water Resources Division
Indian and Northern Affairs Canada
6th Floor, North Tower
Les Terrasses de la Chaudière
OTTAWA, Ontario
K1A 0H4

Dear Mr. Waroway:

Attached is a copy of a report on the break-up of the Liard and Mackenzie Rivers near Fort Simpson, N.W.T., in May 1982.

I trust that the report meets with your approval.

Yours sincerely,

John C. Anderson

ACKNOWLEDGEMENTS

The author wishes to acknowledge the generous support of the following individuals and organizations: the Water Resources Division (D.I.A.N.D., Hull) for funding this study; Ms. L. Kriwoken (N.H.R.I., Hull) for assistance with the field work; Mr. F. Parkinson (Lasalle Hydraulic Laboratories, Lasalle, Que.) for field support and provision of data; Mr. P. Wood and staff (Water Survey of Canada, Fort Simpson) for provision of data and advice; Mr. P. Shaw (D.P.W., Fort Simpson) for logistic arrangements and advice; Mr. B. Gauthier (D.I.A.N.D., Fort Simpson) for provision of accomodation; and Mr. K. Bjornson (D.P.W., Fort Simpson) for the use of a vehicle.

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CHAPTER I

INTRODUCTION

A. Objectives

For over a decade, personnel of the Northern Hydrology Section, National Hydrology Research Institute have been studying the characteristics and timing of break-up on the Mackenzie River. From 1978 through 1980, the Section also studied break-up of the Fort Nelson and lower Liard Rivers on behalf of the Mackenzie River Basin Committee. The Section planned to investigate break-up on the Mackenzie River below Norman Wells in 1982, and in order to continue observations at Fort Simpson the author agreed to conduct a break-up study in that region under the auspices of the Department of Indian Affairs and Northern Development.

More specifically, this study was undertaken to investigate the timing and characteristics of river ice break-up on the Liard and Mackenzie Rivers within a 30 km radius of Fort Simpson. The progress of break-up was to be monitored by 35 mm oblique aerial photography, river water temperatures and ice thicknesses were to be monitored in the near-shore zone during break-up, and water levels were to be measured where feasible by altimeter. In the event of ice jamming, an attempt was to be made to obtain a water level profile through the jam reach.

B. Study Area

Fort Simpson is situated at the confluence of the Liard and Mackenzie Rivers, in the District of Mackenzie, N.W.T. (Figure 1). The village is on a four-kilometre long alluvial island, the largest in a series of islands and shoals at and below the Liard junction (Figures 2,3).

Fort Simpson has experienced severe flooding as a result of ice jamming, most notably in 1963 when approximately three-quarters of the island was under water. A number of factors combine to make this a jam-prone site, among them the following:

(1) the influx of Liard ice and water at a time when the Mackenzie ice cover is usually still intact and relatively strong;

(2) the presence of shoals at the downstream end of Fort Simpson island which constrict ice movement; and

(3) the presence of a relatively sharp narrow bend near MKP 355 (Mackenzie kilometre-post 355) which also constricts ice passage.

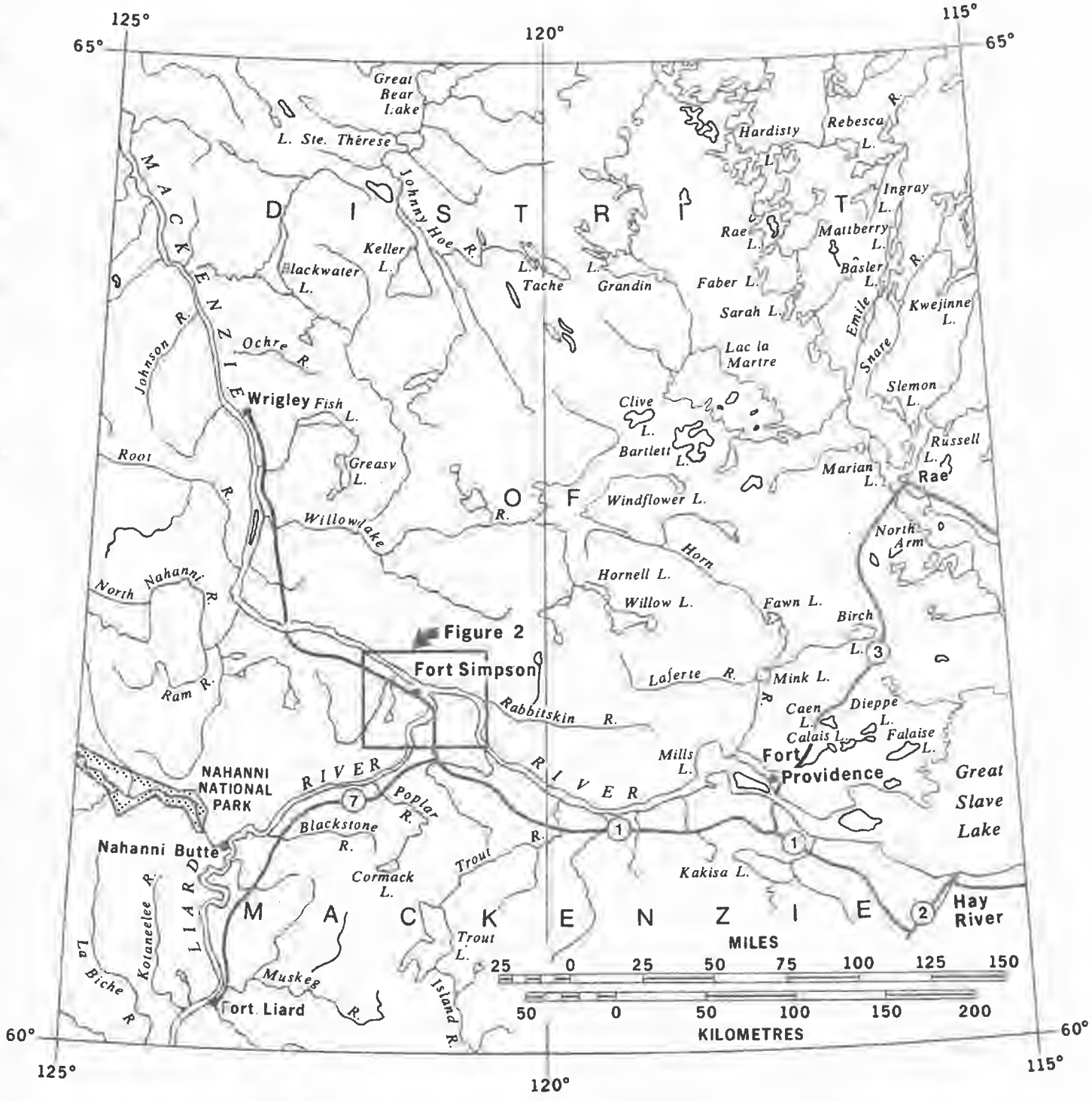


FIGURE 1. Location map, southwest District of Mackenzie, N.W.T.

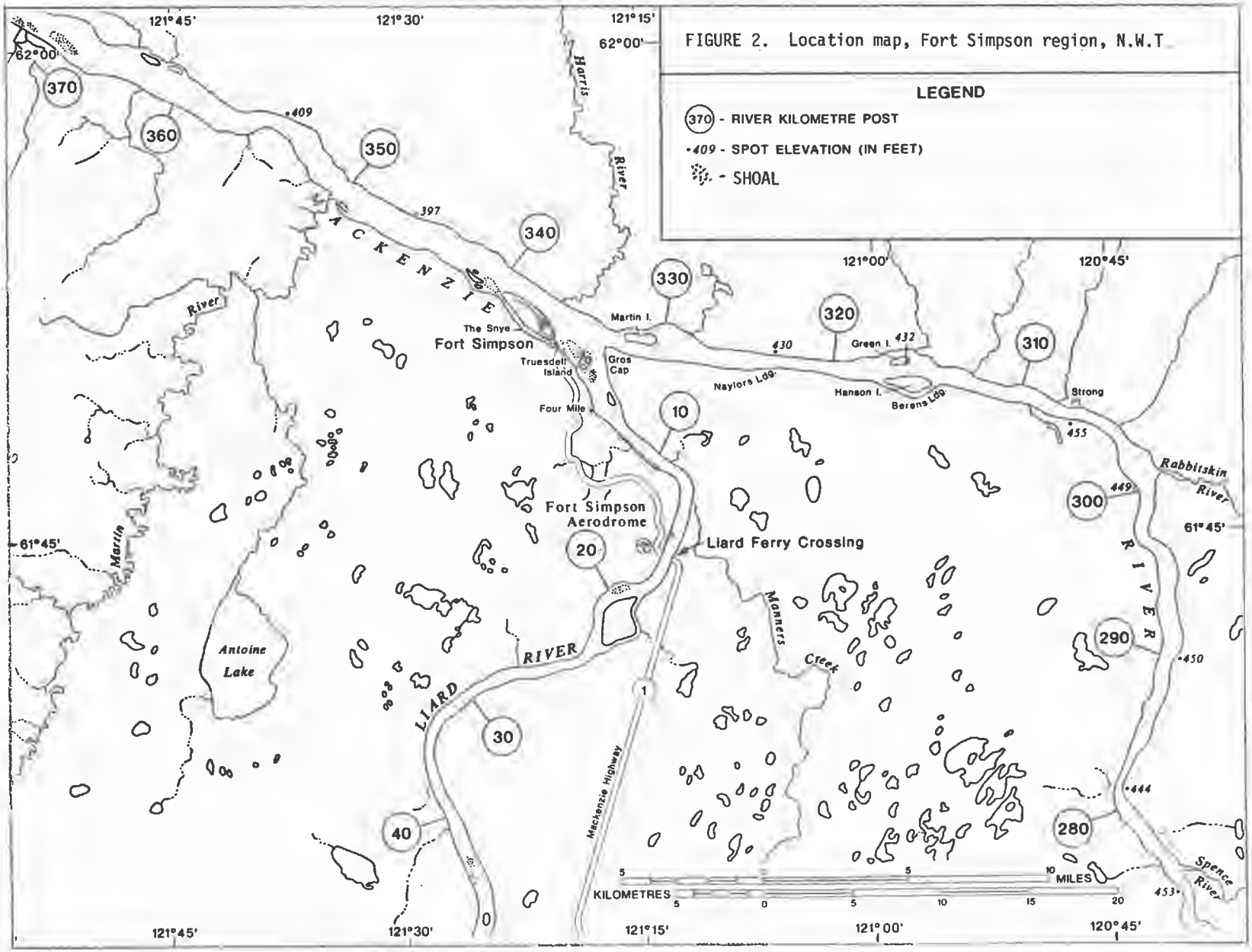


FIGURE 2. Location map, Fort Simpson region, N.W.T.

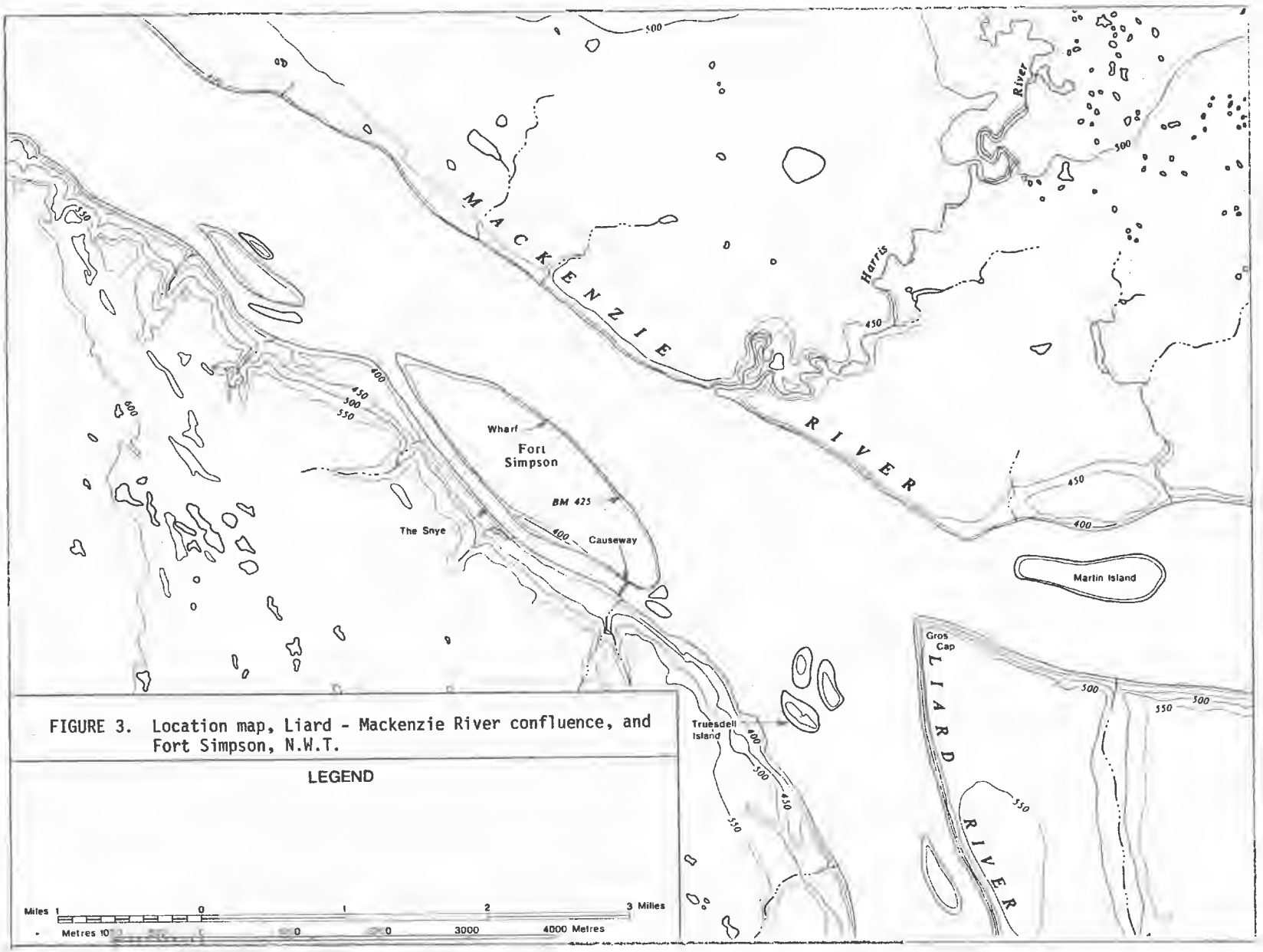


FIGURE 3. Location map, Liard - Mackenzie River confluence, and Fort Simpson, N.W.T.

The causeway shown in Figure 3 which links Fort Simpson to the mainland was completed in 1970. It replaced an earlier, lower causeway which employed the two small islands at the southeastern tip of Fort Simpson island. This former causeway was low enough to be overtopped on occasion by the spring flood, and under those circumstances the Liard was able to break into the Mackenzie via the Snye. Under present conditions, the Liard is forced to enter the Mackenzie at the upstream end of Fort Simpson island.

CHAPTER II

BREAK-UP OBSERVATIONS

A. Break-up Characteristics

In the Simpson region, break-up on the Liard and Mackenzie Rivers normally occurs in early May. The Liard River almost always breaks before the Mackenzie (1980 was a notable exception) owing to a more rapid rise in water level on the former river. The process of break-up could be described as follows:

(1) development of hinge cracks and shore leads as rising water levels fracture and separate the floating from the bottomfast shore ice; as time passes, bottomfast ice lifts and floats in the shore leads;

(2) formation of transverse cracks in the ice cover at points of weakness or due to pulses in discharge caused by upstream jam release, snowmelt and/or precipitation;

(3) the "ice run" which begins with the movement of large floes, and is usually intermittant because of jamming; considerable ice thrust can occur during the initial stages with large quantities of ice being stranded on

shore and in shallows; jamming may result in backwater flooding and subsequent downstream water level surges;

(4) ice clearance, during which stranded ice disappears by "in situ" melt, or by flotation and transport because of rising water levels.

B. Climatic Conditions

Precipitation and air temperature summaries for the October 1981 to May 1982 period for Fort Simpson, Fort Nelson and Watson Lake are provided in Tables 1, 2, and 3 respectively. The October - April period was colder than normal at all three localities, and wetter than normal at two of the three. The Fort Nelson River typically instigates break-up on the Liard below Nelson Forks, and the colder than normal weather in the Fort Nelson and Watson Lake regions in April caused delayed snowmelt and break-up in those areas. In 1982 the Liard did not break at Nelson Forks until the night of May 5-6 (Parkinson, 1982). The ice broke and moved at Fort Liard late on May 8 (Parkinson, 1982), compared with April 30, 1978, May 2, 1979 and April 27, 1980 (Sherstone, 1981). Above-normal winter precipitation in the Fort Nelson and Fort Simpson regions favoured a larger than normal break-up flood, once snowmelt was underway.

TABLE 1. Climatic data for Fort Simpson A., N.W.T., October 1981 to May 1982.

Month	Total Precipitation		Mean Air Temperature	
	mm	% normal	°C	difference from normal
Oct.	157.5	579	-2.6	-1.2
Nov.	49.4	167	-14.2	+1.0
Dec.	36.9	161	-21.9	+1.8
Jan.	11.1	79	-35.8	-8.3
Feb.	9.2	65	-23.6	-0.1
Mar.	9.2	82	-16.9	-3.2
Apr.	18.4	121	-2.2	+0.2
May	18.9	62	6.8	-0.3
Oct.-Apr.	291.7	217	-16.7	-1.4

TABLE 2. Climatic data for Fort Nelson A., B.C., October 1981 to May 1982.

Month	Total Precipitation		Mean Air Temperature	
	mm	% normal	°C	difference from normal
Oct.	99.4	387	0.1	-1.1
Nov.	32.1	120	-11.7	+0.5
Dec.	7.9	31	-21.7	-1.1
Jan.	34.2	130	-31.6	-8.5
Feb.	27.7	114	-18.7	-1.6
Mar.	19.8	80	-10.1	-1.0
Apr.	25.0	116	0.6	-0.6
May	86.6	230	8.1	-1.6
Oct.-Apr.	246.1	140	-13.3	-1.9

TABLE 3. Climatic data for Watson Lake A., Y.T., October 1981 to May 1982.

Month	Total Precipitation		Mean Air Temperature	
	mm	% normal	°C	difference from normal
Oct.	50.1	144	-0.3	-0.4
Nov.	24.0	63	-10.5	+3.0
Dec.	14.7	36	-25.6	-3.1
Jan.	27.9	79	-35.4	-10.2
Feb.	11.4	40	-20.3	-2.0
Mar.	10.6	44	-11.6	-1.2
Apr.	12.1	66	-2.5	-2.0
May	32.1	139	6.2	-1.2
Oct.-Apr.	150.8	69	-15.2	-2.3

At Fort Simpson, daily maximum temperatures rose above 0°C on April 6 and remained positive with the exception of April 15 (Figure 4). However the maxima from April 29 to May 12 were less than 9°C, and daily minima were primarily negative until May 17. Fort Simpson had only 70 and 86% of its normal sunshine in April and May respectively, and precipitation was not excessive. Thus atmospheric conditions did not favour rapid deterioration of the ice cover prior to break-up in the Simpson region.

C. 1982 Break-up Observations

Break-up observations were made from small fixed-wing aircraft and helicopters as conditions warranted, and ice conditions were recorded on sketch maps and by means of 35 mm oblique photography. Figures 5 to 14 present ice conditions as viewed over the period May 7 to 17, subject to the limitations imposed by the map scale. For example, shore leads were present throughout the study reaches on May 7, and stranded ice was present along all banks during and after the ice run, but it was not possible to display this information without exaggerating its extent.

The following is a summary of the 1982 break-up.

1. May 6, 1130 MST: Within a 10 km radius of Fort Simpson, ice cover on the Liard and Mackenzie Rivers was continuous, but there were

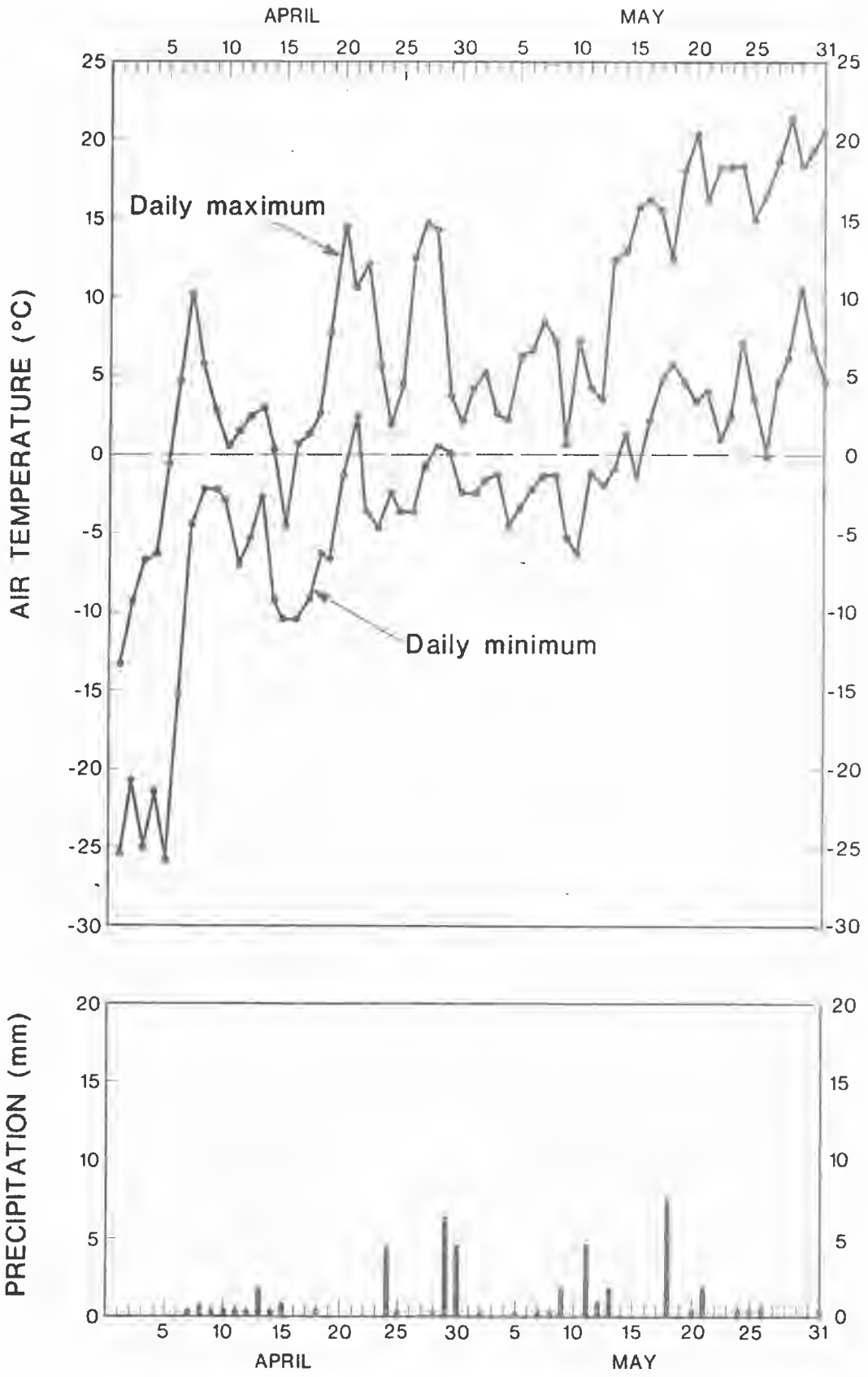


FIGURE 4. Air temperature and precipitation data, Fort Simpson airport, N.W.T., April 1 - May 31, 1982.

shore leads throughout indicating a rise in water level from the winter low.

2. May 7, 1540-1650 MST: (Figure 5). The ice cover was continuous with shore leads (e.g. Photograph 1) with the following exceptions:

(a) LKP 79 (Liard kilometre-post 79): Poplar River open and breaking into Liard;

(b) LKP 77 to 67 (Photograph 2): open water above rapids at "Beaver Dam" (LKP 59);

(c) Beaver Dam to LKP 53: a few small open water areas;

(d) MKP 302; MKP 356, 357: small open water areas;

(e) MKP 318 to 320: open water at Green Island rapids, with broken ice below (Photograph 3).

Liard ice appeared weaker than Mackenzie ice, overall (compare Photographs 4 and 1).

3. May 8: Inflows from the Petitot and Birch Rivers were breaking the Liard ice cover (Parkinson, 1982; Wood, 1982).

4. May 9, 1500-1615 MST: (Figure 6). The Liard was broken downstream to the ferry crossing where a jam had formed by noon (Photographs 5, 6). At the ferry crossing, discharge was evident along

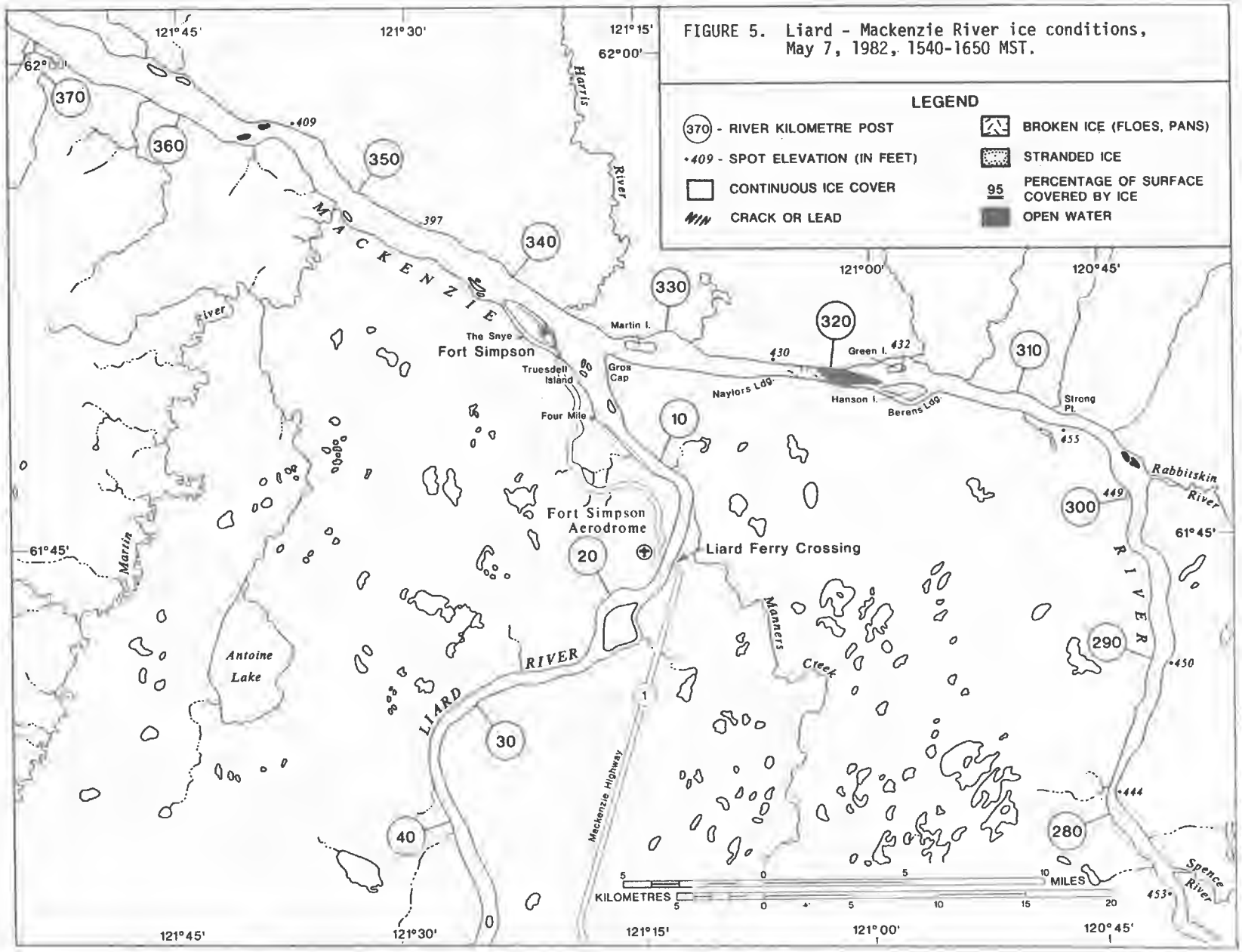


FIGURE 5. Liard - Mackenzie River ice conditions, May 7, 1982, 1540-1650 MST.

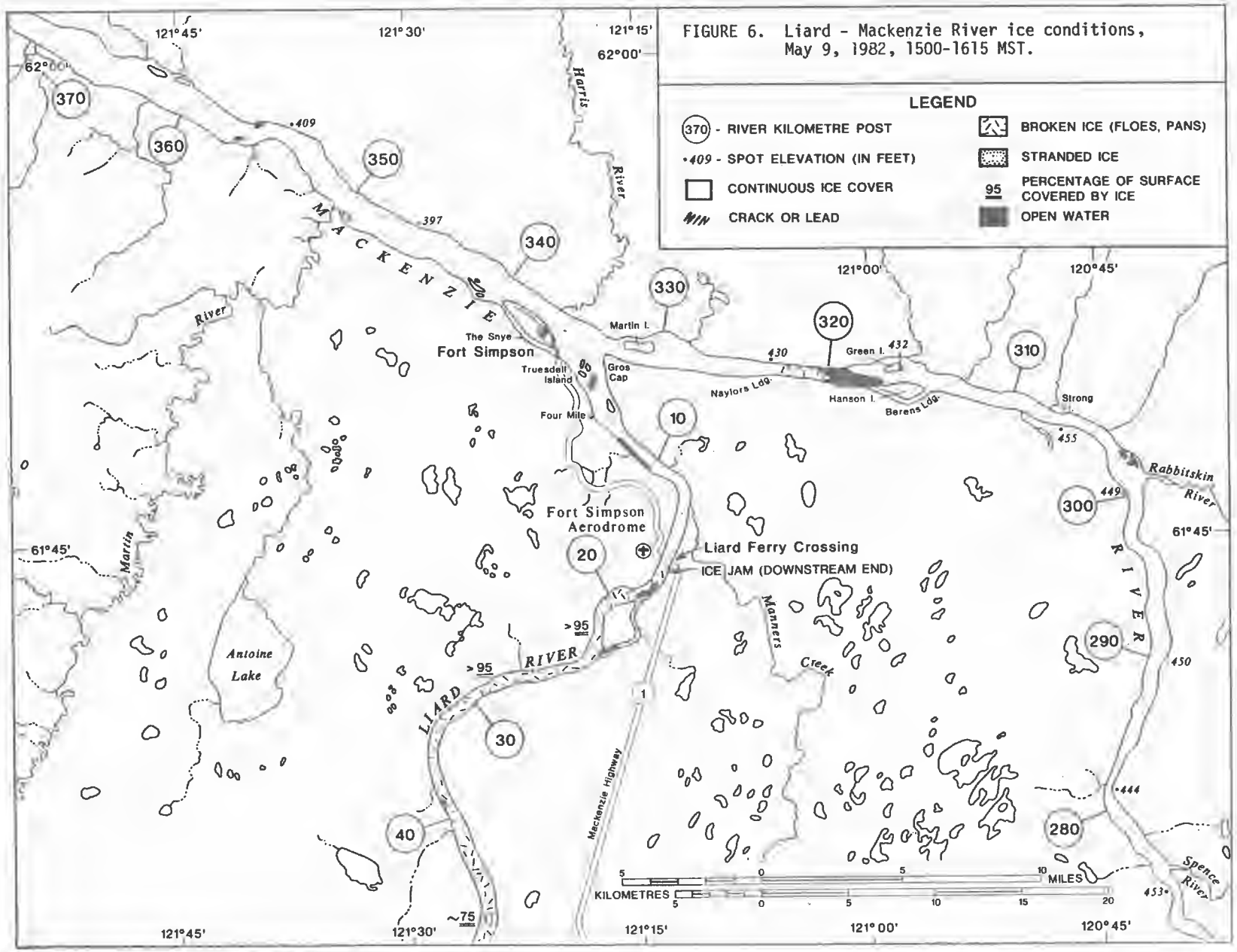


FIGURE 6. Liard - Mackenzie River ice conditions, May 9, 1982, 1500-1615 MST.

both shores and atop the ice cover near midstream (Photograph 7). Excluding a couple of small openings, there was solid pack ice from the ferry crossing upstream to near LKP 40, and floe sizes decreased upstream. More open water was appearing on the Liard below the ferry crossing, but there was little change on the Mackenzie.

5. May 9, 2100-2130 MST: (Figures 7 and 8). The jam at Liard ferry crossing broke at approximately 1900 MST and at 2100 MST the situation was as shown in the figures. The Liard had thrust past Truesdell Island into the Mackenzie (Photographs 8, 9) and the flood wave caused by jam release had cracked the Mackenzie ice cover downstream to MKP 357 by 2110 MST (Photograph 10), indicating a speed for the wave of about 20 km/h. Though broken, the Mackenzie ice at Fort Simpson was static.

6. May 10, 1150-1305 MST: (Figures 9 and 10). Altimeter surveys indicated a water level rise on the Mackenzie at Fort Simpson of approximately two metres in the 24-hour period ending 0840 MST, May 10. At about 1010 MST, Mackenzie ice started to move in front of the village. Some ice thrust had occurred along the eastern half of Fort Simpson island prior to that time (Photograph 11), but this was insignificant in comparison with what occurred as a large Mackenzie ice floe moved past the island (Photograph 12). At 1100 MST the Liard ice front passed the Water Survey of Canada gauge house at Fort Simpson.

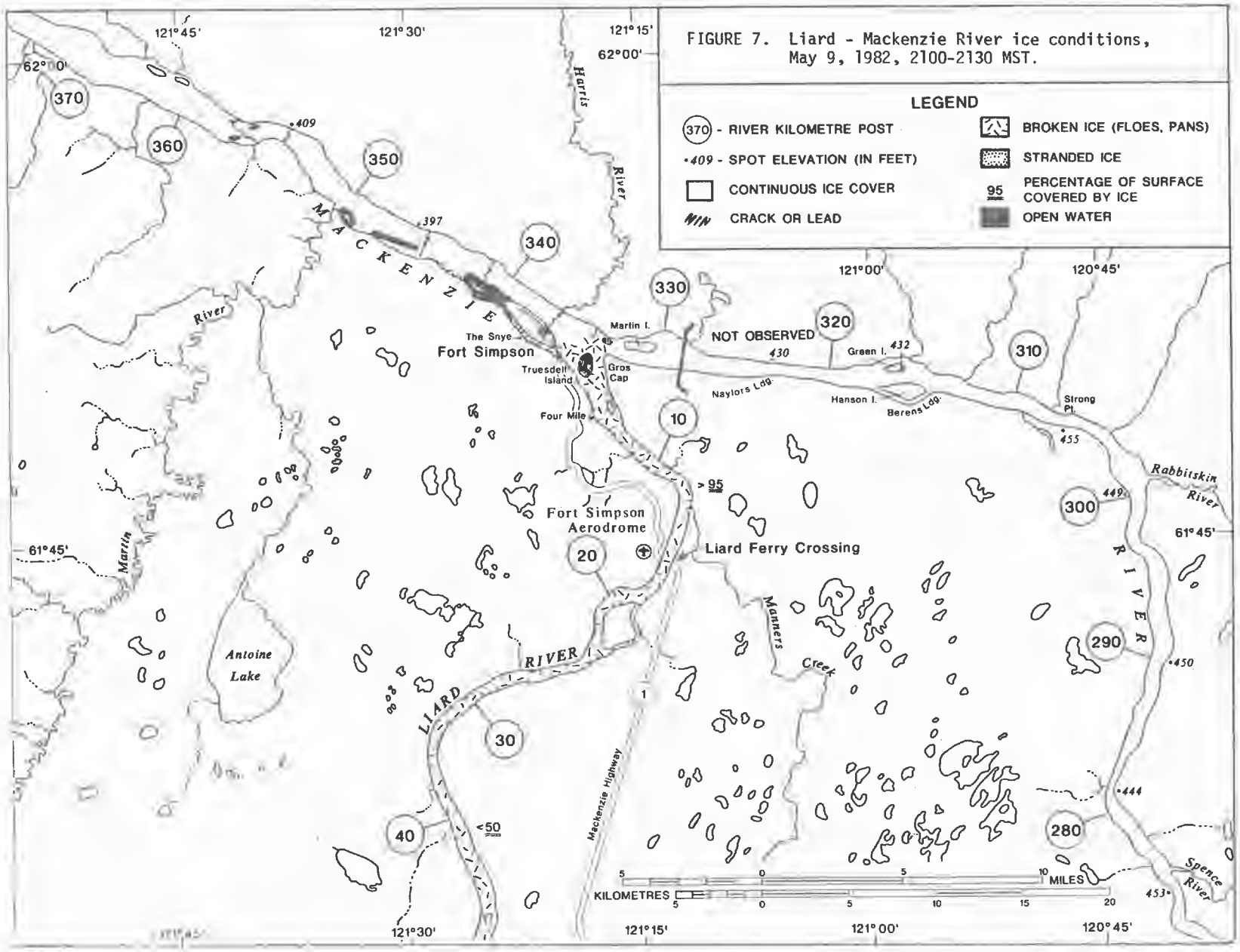


FIGURE 7. Liard - Mackenzie River ice conditions, May 9, 1982, 2100-2130 MST.

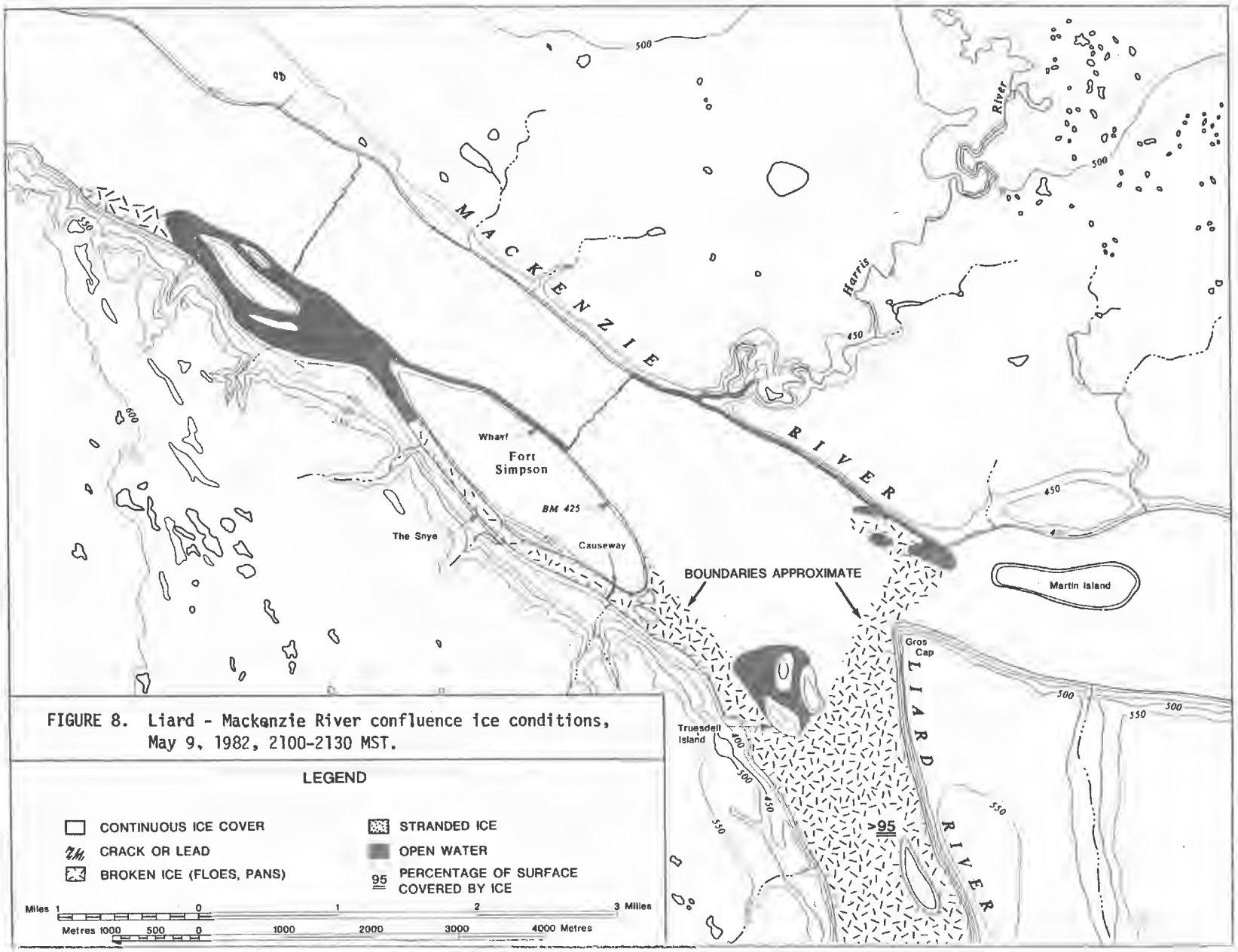


FIGURE 8. Liard - Mackenzie River confluence ice conditions, May 9, 1982, 2100-2130 MST.

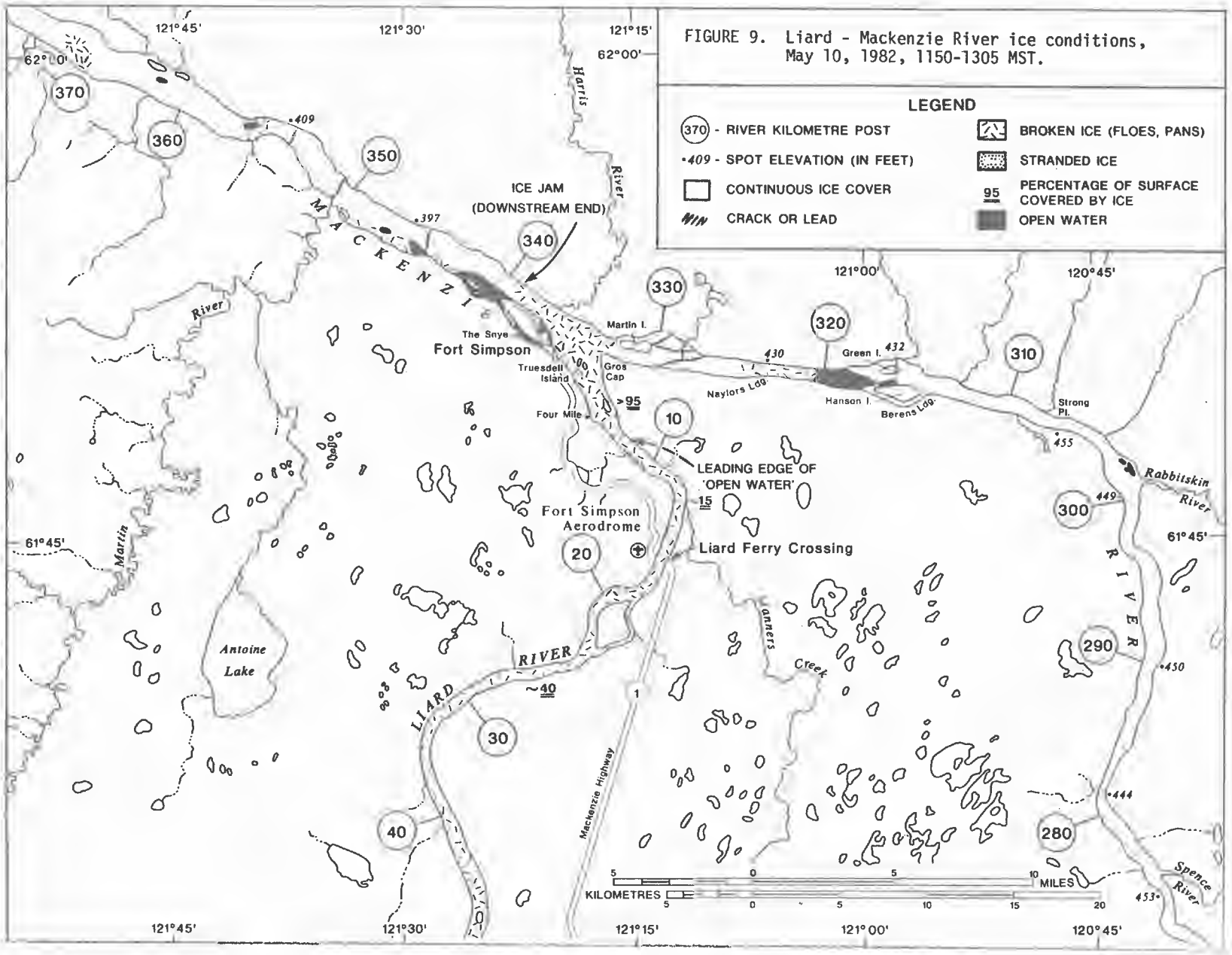


FIGURE 9. Liard - Mackenzie River ice conditions, May 10, 1982, 1150-1305 MST.

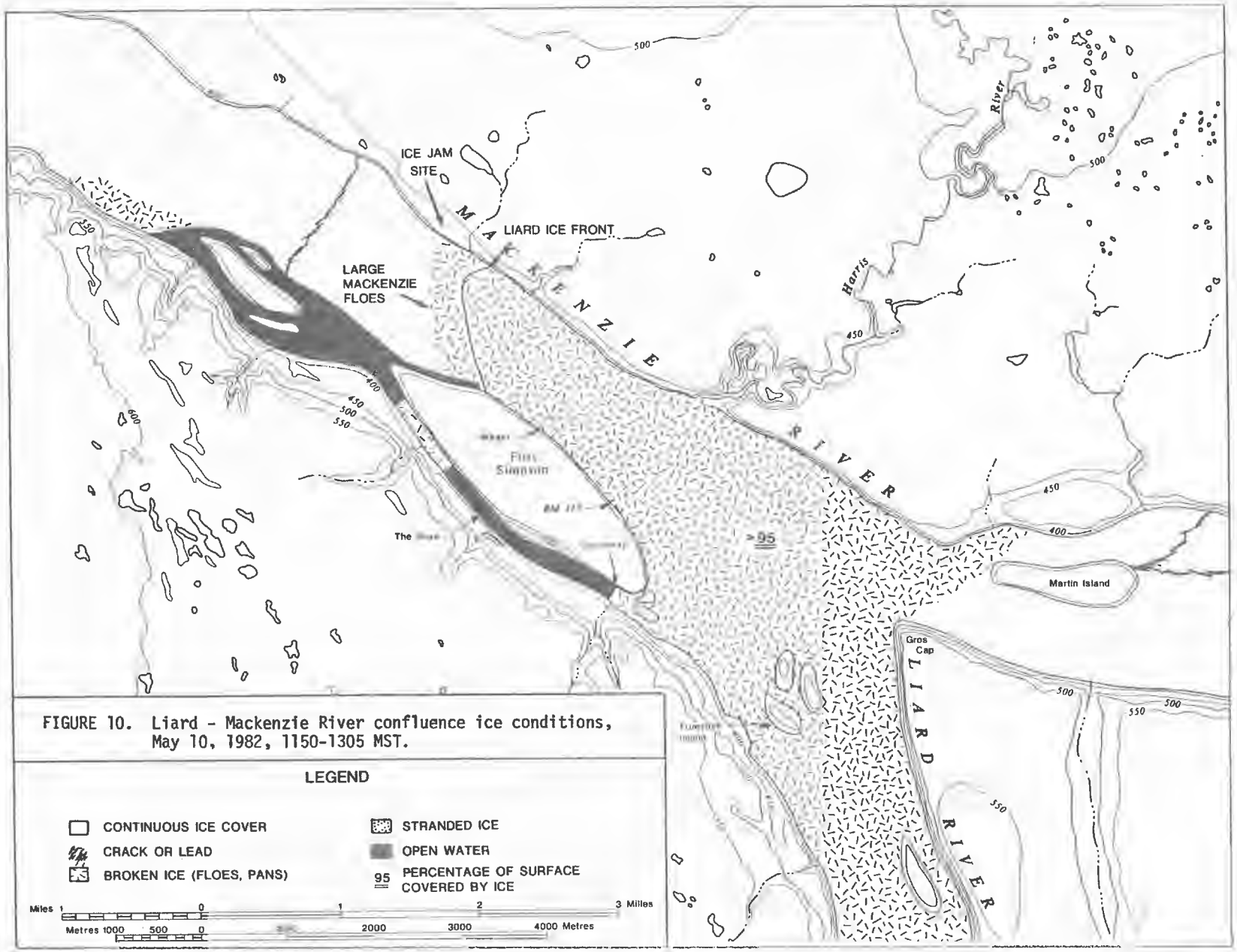


FIGURE 10. Liard - Mackenzie River confluence ice conditions, May 10, 1982, 1150-1305 MST.

Aerial reconnaissance between 1150 and 1305 h revealed an ice jam developing at the downstream end of Fort Simpson island (Photographs 13, 14, 15). Mackenzie ice was grounding on the shoals which run obliquely downstream from the end of the island, and discharge was observed alongside the island at that point. Downstream of this, a large floe was unable to pass through a channel narrowing near MKP 354, and ice thrust was occurring on the right bank at MKP 354 and the left bank at MKP 352-353.

Upstream, backwater had cracked the Mackenzie ice cover for two or three kilometres above Martin Island. The leading edge of open water on the Liard was near LKP 7 (Photograph 16), with pack ice below this to the jam at MKP 340. Backwater from this jam caused a rise in water level of approximately four metres, and the water elevation at Fort Simpson peaked at approximately 121.7 m a.s.l.

7. May 10, 1810 MST: The jam at MKP 340 released and the ice started to move again. As the ice run continued, an open lead appeared and grew in width between the stranded shore ice and the moving ice in the river (Photograph 17). Near-shore ice velocity was estimated at about 6.5 km/h at 1900 MST. The ice was still running at 2300 MST when darkness set in and obscured further observations.

8. May 11, 0630 MST: Ice continued to run past Fort Simpson, at about 5 km/h in the nearshore zone. The Mackenzie water level at Fort

Simpson was as high as it had been during the occurrence of a jam at MKP 340 the previous day, possibly due to subsequent jamming further downstream.

9. May 11, 1520-1700 MST: (Figure 11). By this time the ice run at Fort Simpson was considerably depleted and the leading edge of open water was near MKP 381. Stranded shore ice was present throughout the lower Liard and the Mackenzie below Martin Island, though only the larger accumulations are shown in Figure 11. Between MKP 320 and Martin Island, Mackenzie ice was broken but stationary. Backwater effects from jamming on the Mackenzie were evident as far upstream as Green Island rapids.

10. May 12, 1150-1440 MST: (Figure 12). The leading edge of open water was well downstream, reaching MKP 472 at about 1730 h. A minimal ice run continued on the Liard and the Mackenzie below Liard (Photographs 18, 19), and broken Mackenzie ice remained in place above Martin Island.

11. May 15, 1805-1900 MST: (Figure 13). Large floes originating from the Mackenzie above Martin Island began passing Fort Simpson at about 1500 h (Photograph 20). A rise in water level of about 0.5 m accompanied this ice run causing some stranded shore ice to be entrained in the flow and confining the on-going Liard ice input close to the left bank of the Mackenzie. Mackenzie floes were as far downstream as MKP 360 by 1815 h.

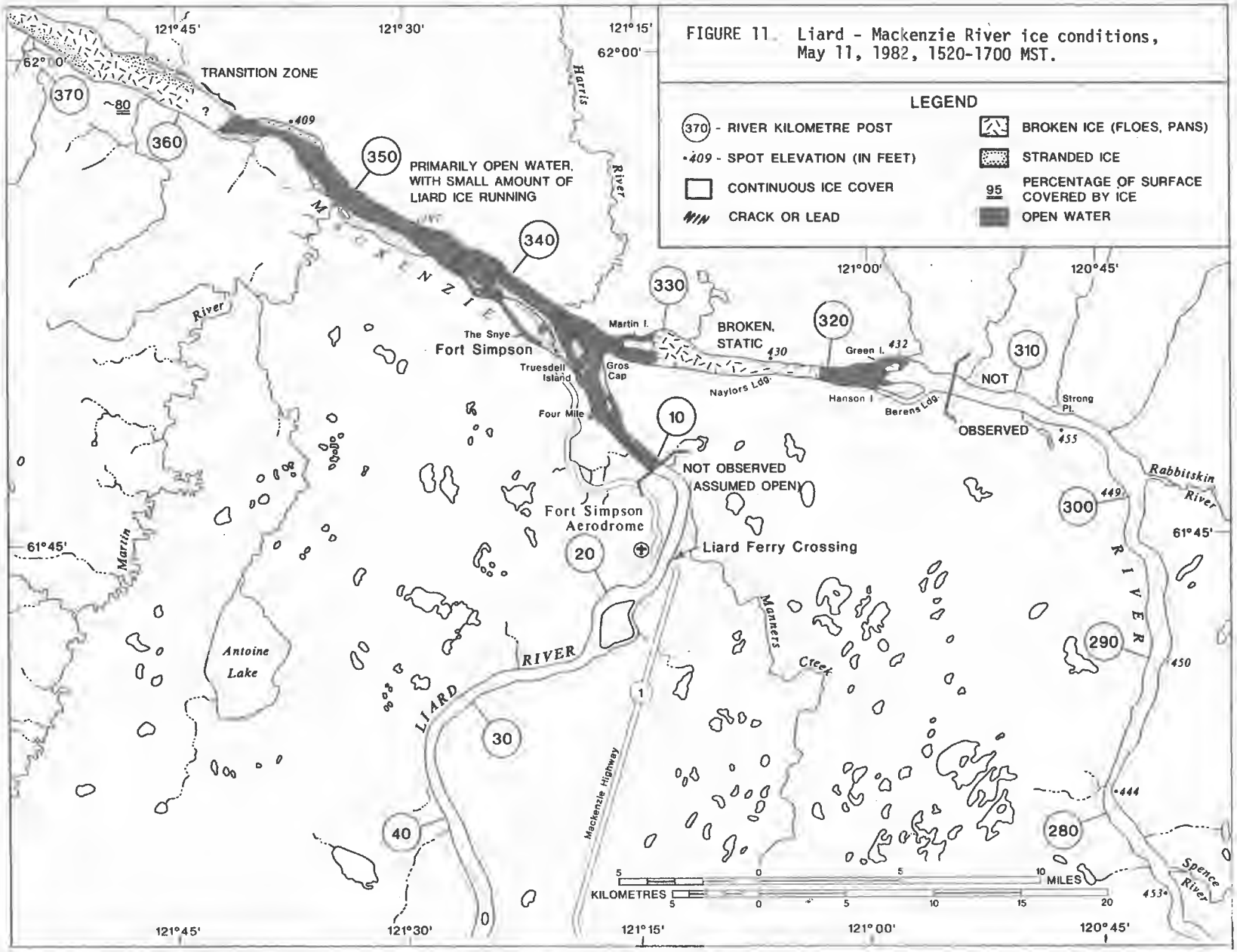


FIGURE 11. Liard - Mackenzie River ice conditions, May 11, 1982, 1520-1700 MST.
LEGEND
370 - RIVER KILOMETRE POST
•409 - SPOT ELEVATION (IN FEET)
CONTINUOUS ICE COVER
CRACK OR LEAD
BROKEN ICE (FLOES, PANS)
STRANDED ICE
95 PERCENTAGE OF SURFACE COVERED BY ICE
OPEN WATER
TRANSITION ZONE
PRIMARILY OPEN WATER, WITH SMALL AMOUNT OF LIARD ICE RUNNING
BROKEN, STATIC
NOT OBSERVED
ASSUMED OPEN
NOT OBSERVED
Fort Simpson
Fort Simpson Aerodrome
Liard Ferry Crossing
Martin I.
Green I.
Hanson I
Truesdell Island
Gros Cap
Four Mile
Naylors Ldg.
Berens Ldg.
Strong Pt.
Harris River
Mackenzie River
Marin
Antoine Lake
Manners Creek
Rabbitskin River
Liard River
Mackenzie Highway
Spence River
MILES
KILOMETRES
121°45'
121°30'
121°15'
121°00'
120°45'
62°00'
61°45'

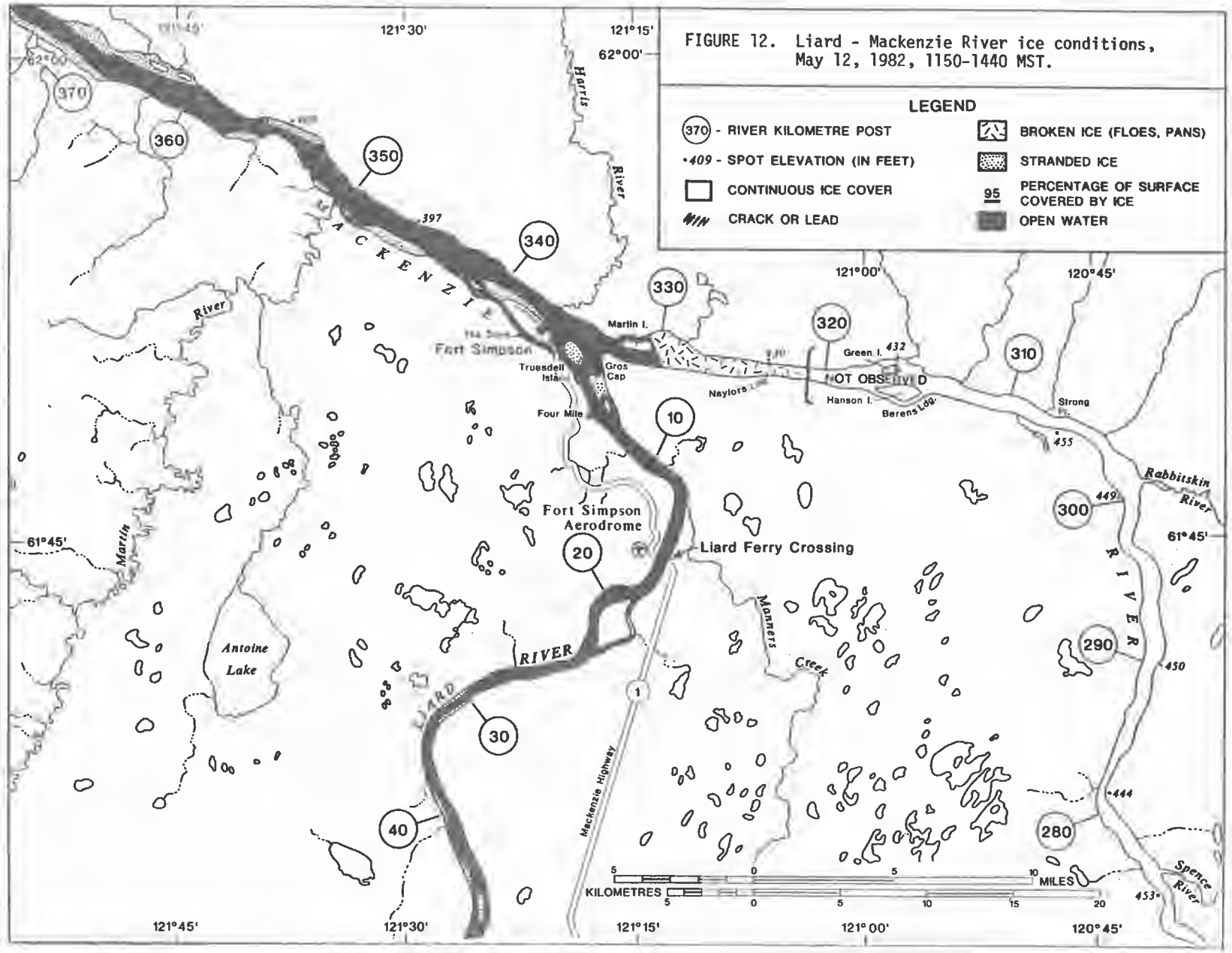
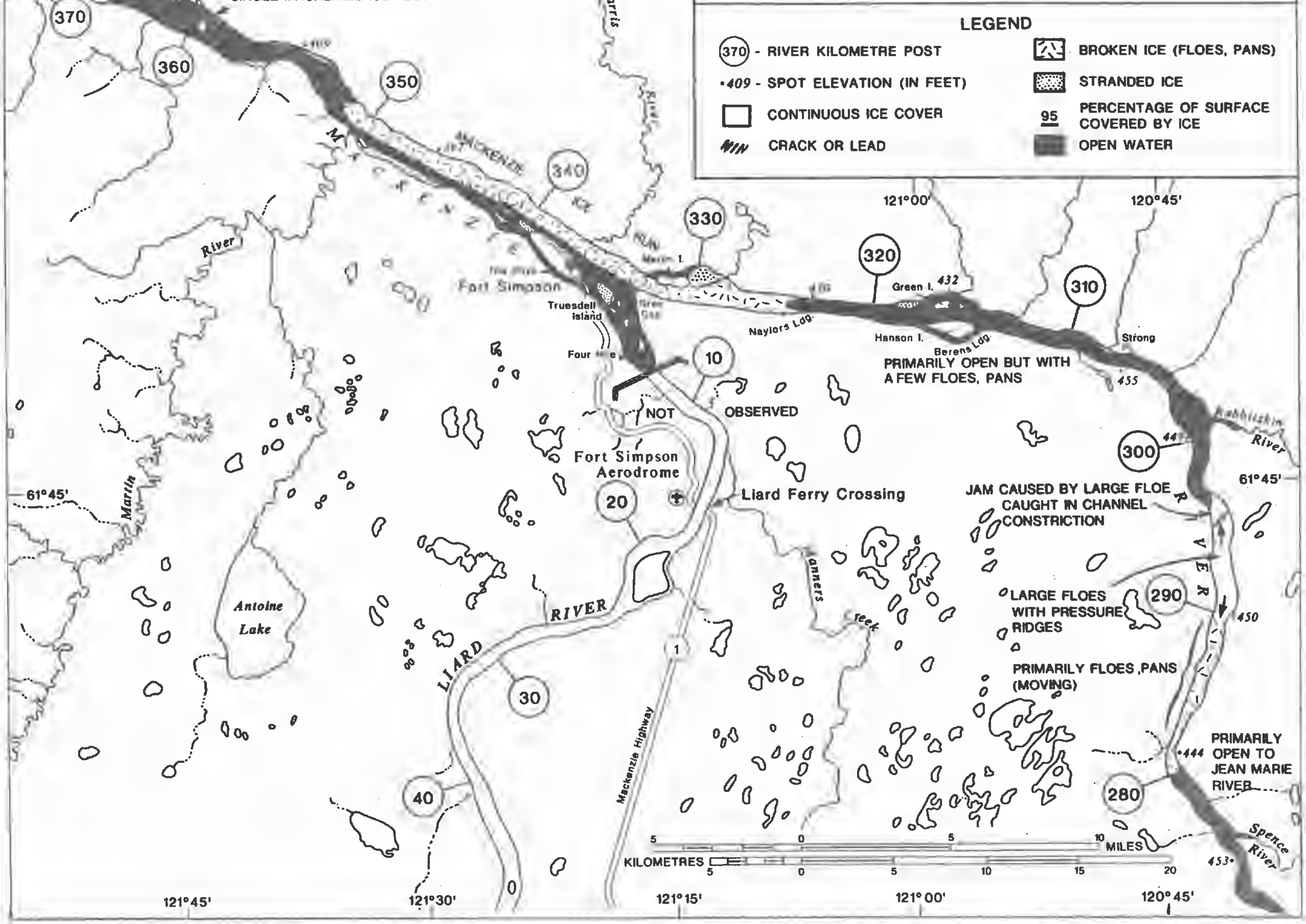


FIGURE 12. Liard - Mackenzie River ice conditions, May 12, 1982, 1150-1440 MST.

FIGURE 13 Liard - Mackenzie River ice conditions, May 15, 1982, 1805-1900 MST.



At MKP 297, a large floe was caught in a narrow river bend (Photograph 21) producing a jam with ice floes upstream to MKP 280. From there to Jean Marie River (MKP 270) the river was primarily open, while above MKP 270 the ice was cracked but stationary as far as one could see.

12. May 15, 2230 MST: By this time the ice run from the upper Mackenzie (i.e. Mackenzie above Liard) was severely depleted.

13. May 17, 1915-1940 MST: (Figure 14). The Mackenzie was primarily open to near Jean Marie River but the banks were strewn with stranded ice (Photograph 22). Above Jean Marie River, the ice was cracked but remained in place.

14. May 18: Another upper Mackenzie ice run began passing Fort Simpson at about 0830 MST, indicating that some of the ice above Jean Marie River had "let go". This run was much reduced by 1930 h and minimal at 2100 h.

15. May 19: Another upper Mackenzie ice run began at Fort Simpson between 1830 and 2050 h. The Liard ice run at Fort Simpson was heavier as well due to rising water levels on the Liard caused by rainfall and rapid snowmelt within parts of the basin.

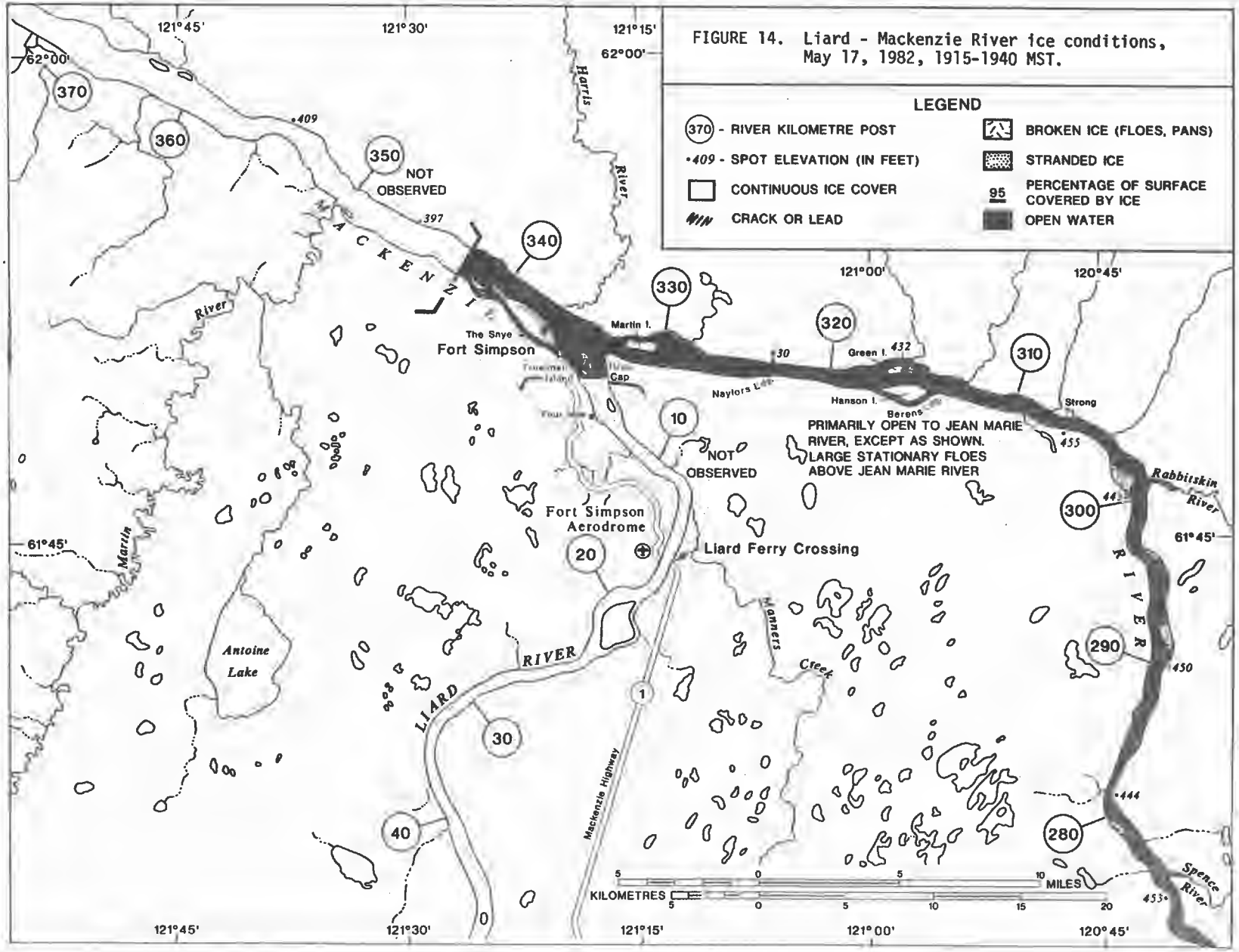


FIGURE 14. Liard - Mackenzie River ice conditions, May 17, 1982, 1915-1940 MST.

16. May 20, 2000 h: The Mackenzie ice run was depleted but water levels continued to rise at Fort Simpson resulting in the accelerated removal of stranded shore ice.

17. May 21: Water levels continued to rise, but the ice run at Fort Simpson was minimal since much of the stranded ice was now gone (Photograph 23).

18. May 22, 0815 MST: At Fort Simpson the Liard ice run was nearly finished, while a small amount of upper Mackenzie ice continued to pass.

D. Ice Thickness Observations

The thickness of stranded ice pans was measured at various points of access near Fort Simpson (Table 4). Thinnest ice was observed near "Four Mile" on the lower Liard, while at Streeper Brothers wharves on the Liard at Truesdell Island, thicknesses up to 130 cm were measured.

E. Water Temperature Observations

Liard and Mackenzie River water temperatures were measured in the vicinity of Fort Simpson during the break-up period, primarily in the nearshore zone (Table 5). Temperatures remained at or very near

TABLE 4. Thickness of stranded ice pans, Fort Simpson region, May 1982.

Site	Date	Time (MST)	Thickness (cm)	Comments
Mackenzie R. near Water Survey of Canada gauge	May 10	0840	75-85	approx. 50% white ice over black ice
Liard R. at Streeper Bros. wharf	May 10	2045	up to 130	
Liard R. at Four Mile	May 10	1430	50-60 with some up to 80	approx. 25% white ice over black ice
Liard R. at ferry crossing	May 9	1230	100-120	

TABLE 5. River water temperatures during break-up, Fort Simpson region, May 1982.

Date	Time (MST)	Temperature (°C)	Comments
A. Mackenzie River at Fort Simpson			
May 6	1915	0.0	in shore lead, left bank
May 10	0840	0.0	in shore lead, left bank
May 17*	1855	0.9	right side - Mackenzie water
	1855	4.0	mixing zone
	1855	3.3	left side - Liard water
May 19	0910	1.1	2 m from left bank
	2115	0.9	2 m from left bank
May 20	1115	2.7	2 m from left bank
May 21	1015	4.0	2 m from left bank
B. MKP 357*			
May 12	1415	0.4	Mackenzie water
	1415	0.9	Liard water
C. Liard River at ferry crossing			
May 8	1510	0.0	in shore lead, left bank
May 9	1650	0.0	in shore lead, left bank
May 19	1800	4.4	2 m from left bank
May 20	1635	4.5	2 m from left bank
D. Liard River above Truesdell Island*			
May 17	1905	3.3	right side
	1905	4.4	midstream
	1905	4.3	left side
E. LKP 40*			
May 12	1225	0.6	midstream

TABLE 5. (Contd.)

Date	Time (MST)	Temperature (°C)	Comments
F. Mackenzie River above Martin Island*			
May 17	1915	1.7;2.1	right side
	1915	0.6	midstream
	1915	1.0	left side

* with assistance of F. Parkinson. Note that these readings were acquired by means of a helicopter and "right side" and "left side" sites were at least 50 m off the bank. Subsequent readings taken between May 19 and 21 at sites A and C were obtained only 2 m from the bank and as such they reflect the cooling effect of melt water from stranded shore ice. Thus the apparent decrease in left side water temperature on the Mackenzie at Fort Simpson between May 17 and 19 is attributable to a change in sampling location.

0°C on the Liard at the ferry crossing and on the Mackenzie at Fort Simpson until at least May 9 and 10, respectively. On May 17 a helicopter survey of near-surface temperatures was done with Mr. F. Parkinson and the results are displayed in Figure 15. The Liard was considerably warmer than the Mackenzie, and its influence on the Mackenzie was apparent at Fort Simpson. Two small tributaries to the upper Mackenzie, Rabbitskin River (MKP 301) and Jean Marie River (MKP 270) were much warmer than the Mackenzie as well (Table 5).

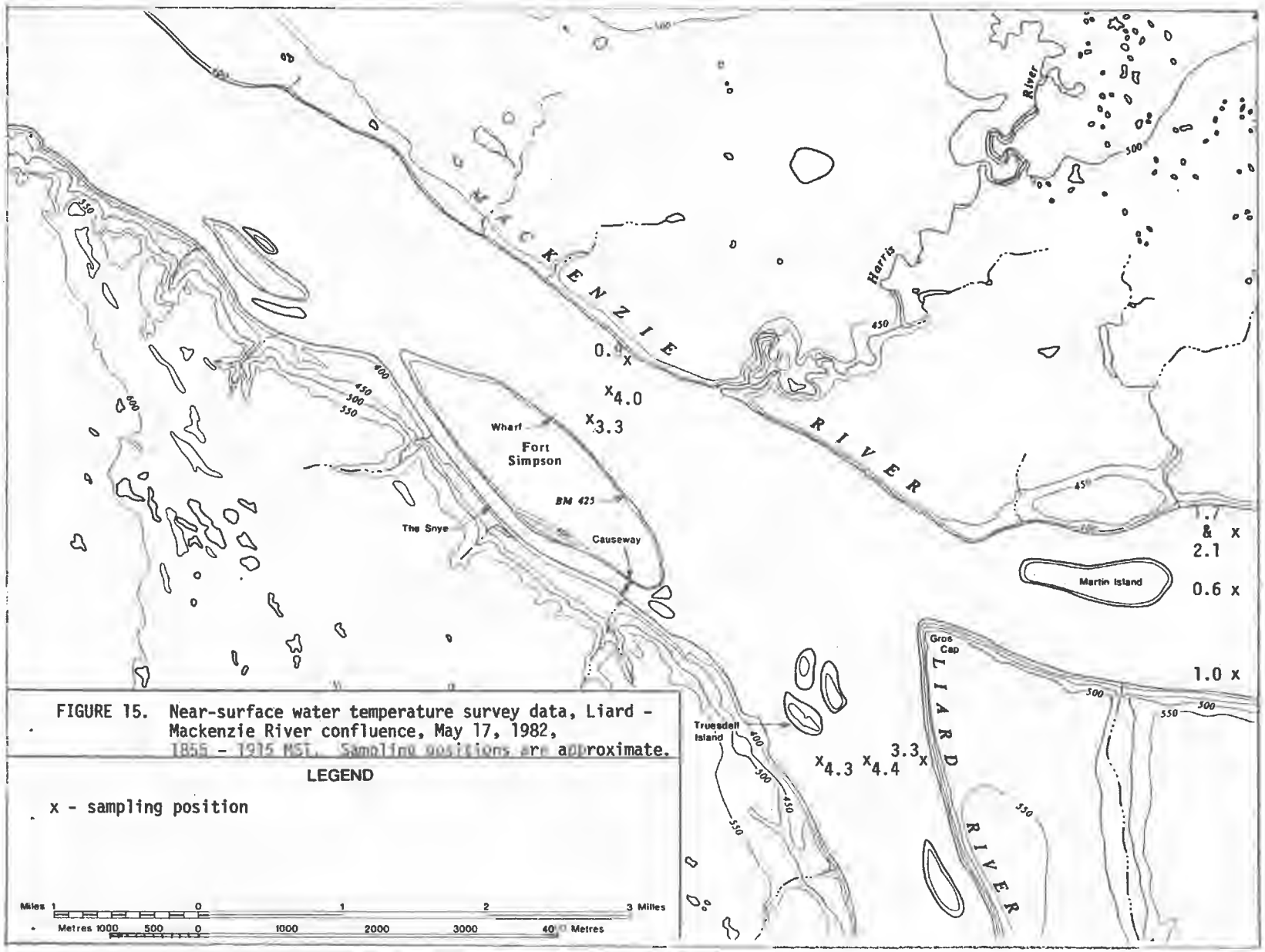


FIGURE 15. Near-surface water temperature survey data, Liard - Mackenzie River confluence, May 17, 1982, 1855 - 1915 MST. Sampling positions are approximate.

CHAPTER III

SUMMARY

River ice break-up commenced relatively late in the Fort Simpson region in 1982, but once underway it progressed rapidly. The ice cover did not break at Nelson Forks (LKP 425) until the night of May 5-6. The ice broke and moved at Fort Liard late on May 8, and by mid-day May 9, the Liard was broken to the ferry crossing near Fort Simpson, where a jam had formed. At about 1900 MST the same day, the jam released and the Liard broke into the Mackenzie.

At about 1010 MST, May 10, Mackenzie ice began moving at Fort Simpson but a jam formed at the downstream end of Fort Simpson island (MKP 340). The water level at Fort Simpson rose approximately four metres before the jam released at about 1810 MST. The water reached approximately 121.7 m a.s.l. prior to jam release and again during the night of May 10-11, likely the result of subsequent jamming below Fort Simpson. Not until May 15 did ice from the Mackenzie above the Liard begin to release, and at least two more upper Mackenzie ice runs were observed as the ice cleared in stages. This intermittent release was due at least in part to jamming, such as that observed during the evening of May 15 near MKP 297.

Ice thickness during break-up was observed to vary from 50 to 130 cm. Water temperatures greater than 0°C were first measured on the Liard (LKP 40) and the Mackenzie (MKP 357) on May 12. On May 17 the Liard was approximately 4°C near its mouth, but the Mackenzie above Martin Island was about three degrees colder.

The 1982 break-up was typical in that the Liard ice broke earlier than the Mackenzie. Ice jams formed but no flooding of any consequence occurred. Considerable ice thrust took place along river banks, but again no damage of any consequence was observed.

REFERENCES

Parkinson, F., 1982. Personal Communication. Lasalle Hydraulic Laboratories, Lasalle, Quebec.

Sherstone, D.A., 1981. "Ice Break-up in the Liard Basin". p. 49-123 in Spring Break-up, Mackenzie River Basin Study Report Supplement 3, Mackenzie River Basin Committee.

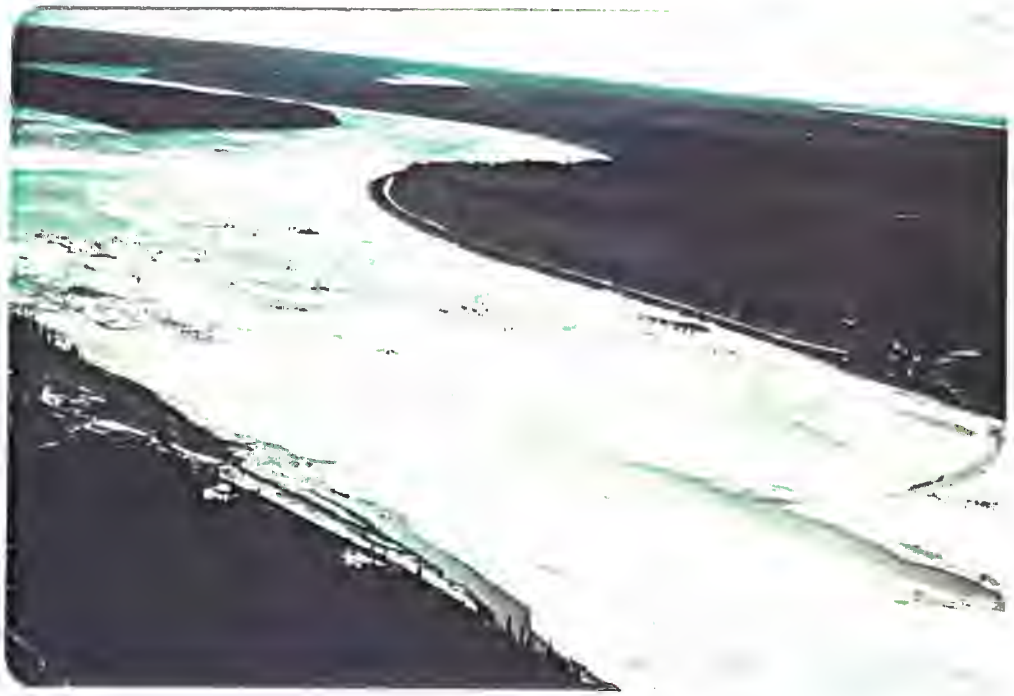
Wood, P., 1982. Personal Communication. Water Survey of Canada, Environment Canada, Fort Simpson, N.W.T.

PHOTOGRAPH 1. Liard River viewed upstream from LKP 21, May 7, 1982, 1540 MST, showing pre-break-up ice conditions. Note the deteriorating but continuous ice cover, shore leads, and bottomfast ice along right bank.

PHOTOGRAPH 2. Liard River viewed downstream, showing open water from LKP 77 to LKP 67, May 7, 1982, 1600 MST. Note the contrast in ice cover upstream of the open water, with the dark ice marking the high velocity portion of the channel.

PHOTOGRAPH 3. Mackenzie River, MKP 324 to MKP 317, view northeast, showing open water at Green Island rapids, May 7, 1982, 1630 MST.

PHOTOGRAPH 4. Mackenzie River, viewed upstream from Martin River through Liard River confluence, May 7, 1982, 1635 MST. Note shore leads around shoals and islands downstream of Fort Simpson island.



PHOTOGRAPH 5. Ice jam at Liard ferry crossing, viewed upstream past Sawmill Island, May 9, 1982, 1518 MST. Ice at the crossing is intact, but note overflow across the ice cover and discharge along shores. The winter ice road at the crossing has been inundated.

PHOTOGRAPH 6. Ice jam at Liard ferry crossing viewed upstream from left bank at the crossing, May 9, 1982, 1320 MST. Note ice shove on both shores.

PHOTOGRAPH 7. Liard ferry crossing viewed downstream from left bank during ice jam, May 9, 1982, 1245 MST. Note discharge along bank and overflow atop ice at right.

PHOTOGRAPH 8. Liard - Mackenzie River confluence showing Liard ice thrust into Mackenzie River, May 9, 1982, 2101 MST. The Liard flows from right to left, with Truesdell Island in the foreground. Note intact ice on Mackenzie River around Martin Island, at top of photo.

PHOTOGRAPH 9. Liard ice thrust into Mackenzie River, viewed southeast from right bank of Mackenzie, May 9, 1982, 2116 MST. Note transverse lead in Mackenzie ice at Fort Simpson.

PHOTOGRAPH 10. Mackenzie River viewed downstream from MKP 355, showing transverse cracks and leads at MKP 355 and MKP 357, May 9, 1982, 2109 MST.

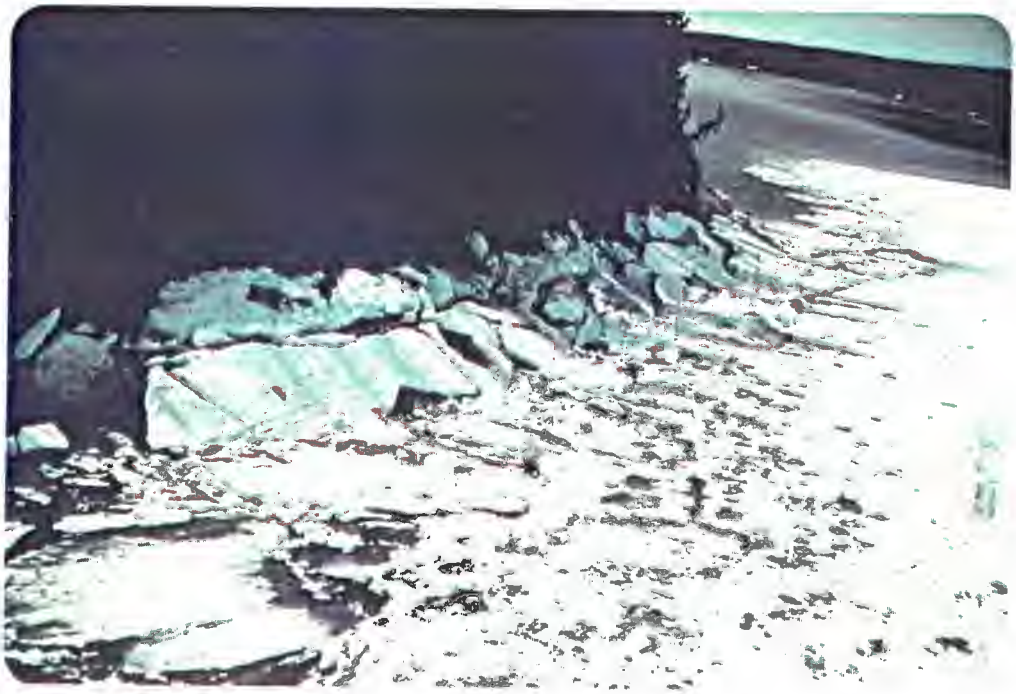
PHOTOGRAPH 11. Initial ice thrust, left bank Mackenzie River near Water Survey of Canada gauge, Fort Simpson, May 10, 1982, 0905 MST. Note ice thickness and structure, and transverse lead in background.

PHOTOGRAPH 12. Ice thrust along left bank Mackenzie River at Fort Simpson with Mackenzie ice floes in motion, May 10, 1982, 1034 MST.

PHOTOGRAPH 15. Mackenzie ice thrust on shoal at downstream end Fort Simpson island, viewed from the island, May 10, 1982, 1557 MST. Note discharge along shore.

PHOTOGRAPH 16. Lower Liard River viewed toward Mackenzie River, with leading edge of open water near LKP 7, May 10, 1982, 1259 MST.

PHOTOGRAPH 21. Large floe jammed at MKP 297, with ice thrust on right bank; view downstream, May 15, 1982, 1847 MST.



PHOTOGRAPH 22. Thrust and stranded ice, upstream end Martin Island near MKP 331, May 17, 1982, 1545 MST.

PHOTOGRAPH 23. Mackenzie River at Fort Simpson looking upstream toward Gros Cap, May 21, 1982, 2105 MST. Note minimal ice run and depletion of stranded ice along shore.