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FLOOD PROTECTION PROPOSALS FOR McMURRAY



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Consulting Hydraulic Engineers
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May 6, 1964

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1. AUTHORIZATION FOR REPORT.

This study and report are authorized by a letter from Mr. F.L. Byrne, Secretary, Provincial Planning Board, of the Province of Alberta dated March 19, 1964, from which the following is an excerpt:

"It was also agreed that the terms of reference for this work be the same as per your letter of March 18th, paragraphs 2 and 3 quoted below:

"The investigation would be of the alternatives, or combinations of them, to protect the proposed town against flooding due to ice jams; the alternatives are (i) direct action of any kind against ice jams, (ii) protective diking, (iii) flood control on the Clearwater.

A report would explain, with reasons, the merits of the various courses that appeared feasible and economic, the approximate extent of the works involved, and quantities on which costs could be based, with sufficient information for you to verify them and proceed to detailed design after deciding on a policy".

2. INTRODUCTION.

The town of McMurray is located in the valley at the junction of the Athabasca and Clearwater Rivers about 240 miles north of Edmonton. It is bounded on the west by the Athabasca and a 200 ft. high hill, on the south by Hangingstone Creek, on the east by the Clearwater River, and on the north by the Snye. The Snye is a channel connecting the two rivers about a mile upstream of their confluence. McDonald Island, whose flat surface lies from 20 to 30 ft. above the normal water level, occupies the area between the Snye and the two rivers.

Since 1870 McMurray has been continuously occupied by a Hudson's Bay Co. post located near the junction of the Snye and the Athabasca close to the present business district. The lowlying prairie area near the Clearwater is occupied by scattered houses and, along the shore, by the shipping industry. Waterways, about 3 miles upstream on the Clearwater is a rail terminal where goods are transferred to barges for shipment down the Athabasca. The town of Waterways is built on an area of relatively low land confined between the river and a hill.

Spring break-up of the Athabasca River occasionally produces severe floods in the McMurray - Waterways area. With development of the Athabasca oil sands the population of McMurray is expected to increase substantially so that lowlying land must be developed for housing. This report contains a study of past floods and of possible flood protection works.

3. ICE JAM FLOODS.

Spring Break-Up.

The Athabasca River changes its character near McMurray from a steep, confined river to a relatively wide flat one. This change takes place at Moberly Rapids about $1\frac{1}{2}$ miles upstream of the Snye, Fig. 1. Upstream of Moberly Rapids the river passes over a series of other rapids separated by reaches of the river in which the slope is about 5 ft. per mile. Downstream of McMurray the river is much flatter; local variations in the slope near McMurray are shown on Fig. 1. In comparison, the Clearwater River has a slope of about 0.75 ft. per mile in the Waterways area.

The drainage area of the Athabasca above McMurray is about 50,000 square miles and all of it lies in latitudes south of McMurray. Except for the headwaters area in the mountains, the process of spring snow melt is normally nearing completion in most of the drainage basin before the river ice near McMurray has been significantly weakened by the spring thaw. The Clearwater drainage basin lies at about the same latitude as McMurray and usually breaks up after the Athabasca (see Appendix A).

Ice break-up usually proceeds downstream (Ref. 1); however, river slope has a significant effect on break-up and it is probable that break-up occurs in parts of the 85 mile long rapids area above McMurray while the ice cover upstream of the rapids area is still intact. Mr. H. Monson, formerly employed in maintaining the telephone line between McMurray and Athabasca reported a jam near the mouth of the

House River, about 100 miles upstream of McMurray, in which the river level rose approximately 80 ft. in a few hours. He stated that many smaller jams occurred almost every year.

The magnitude of an ice jam flood depends upon the thickness and strength of the river ice and upon the size and suddenness of the flood wave which breaks the ice. Thick, strong ice breaks into large cakes which are capable of jamming at any obstruction. A sudden flood wave is required to break the ice and produce conditions which could cause a serious jam. The quantity of ice available is virtually limitless, since, with a 3 ft. ice cover, the Athabasca upstream of McMurray contains about 1,000,000 cubic yards of ice per mile.

Behind a flood wave which breaks the ice the river carries a water-ice mixture which may not contain sufficient water to float the ice clear of the river bottom. The resistance of the mixture to flow increases with the relative amount of ice present, that is the higher the percentage of ice in the mixture, the larger the force required to push the mixture along the river. In steep reaches gravity helps move the mixture; in flat reaches gravity is less effective and a larger hydrostatic force is necessary. The depth of flow in a flat reach must be greater than in a steep one because the increased hydrostatic force necessary to keep the mixture moving can only be obtained by an increase in depth. A decrease in water content of the mixture increases its resistance to flow. If water is allowed to drain from the main channel behind the head of the moving ice pack, the depth of mixture necessary to sustain motion is increased and the ice pack may come to a halt. Prolonged ice jams therefore tend to form

just downstream from points at which water can escape from the main channel.

Opposite the Snye the Athabasca River broadens so that a break-up wave of ice and water mixture arriving at this point would tend to spread out with some of the ice coming to rest on the bottom. The resulting jam would then build up, breaking through in places, but each break-through into the Athabasca channel would not likely be sustained because the channel is very wide and the ice-water mixture passing through the break would, in most cases, be drained off the top of the flow which contains a small percentage of water and so the mixture would contain insufficient water to carry away the ice passing through the break. A break-through into the Snye channel however would normally be sustained since the Snye banks channel the flow and the ratio of water to ice in the mixture would remain nearly constant. Ice and water would then move through the Snye and the level in the basin formed by the Snye and lower Clearwater River would rise. When the level at the Athabasca end of the Snye reached that necessary to move the Athabasca pack, flow into the Snye would decrease or stop and break-up on the Athabasca would continue downstream.

Fig. 2 shows the river in 1963 after ice had ceased to move through the Snye. Fig. 3 to 5 show the Clearwater end of the Snye in 1963; the Athabasca ice had moved a short distance upstream into the Clearwater and downstream to Locke Island at the confluence of the Clearwater and the Athabasca before coming to rest. It is likely that Athabasca River ice blocked the channels on either side of Locke Island thereby making the Athabasca level at the Snye the controlling

level for flood water in the McMurray area.

Usually the ice pack would move downstream from the junction with the Slave more or less uniformly with some spill of ice and water into the shallow left-bank areas. Ice jams can occur below Locke Island but there is no reason to expect them to raise the level at McMurray above that due to the main flood wave. One source of large ice cakes to form these jams is "icings" caused by springs and small creeks along the river. When a spring or creek runs throughout the winter its water spreads out over the Athabasca ice, freezing into a fan shaped mass called an "icing". These may be 20 or 30 feet thick in places, and so can form the basis of a major jam.

A major flood would occur approximately as described although it is possible for spring floods to occur as a series of smaller flood waves each of which behave approximately as would a larger wave.

Observed Floods.

Information about past floods was obtained from a wide variety of sources all of which are discussed in Appendix A. No government agency attempts to record floods due to ice at McMurray; the records of the Water Resources Branch of the Department of Northern Affairs and National Resources for the station on the Athabasca at McMurray apply only to the ice-free period and therefore are of limited value.

The largest flood on record occurred in 1875, five years after the establishment of a Hudson's Bay Co. post at the point shown on Fig. 14. This site was located by one of the older residents of the area, Mr. Joseph Shott, and from a written description of the flood

given by H.J. Moberly (Ref. 2), the maximum flood level was established as being between elevation 825 and 830.

The second greatest recorded flood occurred in 1936. This flood was observed by several people who still reside in McMurray. Maximum water levels obtained from a number of water marks are in close agreement and show that the maximum elevation during the flood was, for all practical purposes, the same from McMurray to the Northern Transportation Co. Ltd. docks.

There is no doubt that some significant floods occurred between 1875 and 1925, however no information on these could be obtained. Mr. Joseph Shott, a life long resident, whose father worked with H.J. Moberly says that, to his knowledge, there was no large flood between 1875 and 1936.

Fig. 10 is a frequency graph of the maximum break-up flood levels. The return period plotted along the base of the graph provides, in terms of the line fitted to the observed levels, an estimate of the average number of years between the recurrence of successive floods that would overtop various elevations. For example the graph indicates that, on an average, 100 years will elapse between successive floods that exceed the elevation 827. Since this graph is based upon a relatively small number of points it is at best an approximation to the true graph.

The chance of a flood exceeding a given elevation in any one year is the inverse of its return period, for example, the chance of a flood to elevation 822 or higher in any one year is 1 in 50. If a building was erected at this elevation, the chance of the structure

suffering some flood damage in its useful life of say 25 years is given by Fig. 11 as 0.4 or 40 in 100. If a water level of 833 was required to move the building off its foundation, the chance of this occurring in any one year is about 1 in 200 and the chance of this occurring during the 25 year life of the building is 0.12 or 12 in 100.

There is no record of any loss of human life as a result of ice jam floods at McMurray. At the present time aircraft are readily available to patrol the Athabasca upstream and so provide a warning of impending break-up.

4. FLOODS DURING OPEN WATER SEASON.

Information on flows during the open water season were obtained from the Department of Water Resources of the Province of Alberta and the Water Resources Branch of the Department of Northern Affairs and National Resources.

The station at the Snye was in operation from 1937 to 1959. Only water levels during the open water season were recorded. Since the Snye connects the Athabasca River and the Clearwater River just upstream of the confluence of the two streams, stages in the Snye reflect the discharges in the Athabasca as well as the discharges in the Clearwater. However since the Athabasca River is much larger than the Clearwater River and has peak discharges in the order of 10 times the peak discharges in the Clearwater River, high stages in the Snye will be caused mainly by the high discharges in the Athabasca River and thus the stage record in the Snye can be compared to the discharge record of the Athabasca River. The longest discharge record available for the Athabasca River is for the station at Athabasca which is 190 miles upstream of McMurray.

Fig. 12 shows the frequency distribution for the maximum annual stages for the Snye (Athabasca at McMurray). In order to carry out the frequency analysis, elevations were converted to approximate mean depths (approximate mean bed level was taken at elevation 785). On Fig. 12 however, geodetic elevations are shown again. The best fit straight line was computed using statistical methods. It is generally accepted that this type of data, plotted on logarithmic probability paper, should be fitted by a straight line. Fig. 12 shows that the stages recorded in 1954 and in 1944 deviate from this line so are

"rare" floods. The graph shows the 1954 flood to have a frequency of about 0.1% or once in 1000 years and the 1944 flood of about 1.4% or once in 70 years. To check the reliability of the frequencies of these floods, a similar analysis was carried out for the maximum annual daily mean discharges of the Athabasca River at Athabasca. The results of this analysis are shown in Fig. 13 and the best fit straight line computed using statistical methods. The 1954 and the 1944 flood flows have a return period of 400 years and 140 years respectively. Although this does not correspond exactly to the figures found above for the shorter record of the Snyc stages, it does confirm that these two floods are uncommonly large.

Since the stage record of the Snyc is too short to carry out a reliable frequency analysis, the frequency curve was shifted using the discharge data of the Athabasca at Athabasca. This was done by making the 1954 elevation for the Snyc correspond to a return period of 400 years as found for the 1954 flood in the Athabasca and using the median value as found from the Snyc data. If we had used the 1944 flood in the Athabasca to adjust the Snyc stage frequency analysis a curve with lower water levels would have resulted. The adjusted curve shows the once in 1000 years flood level to be elevation 801.5 which is far below the values that can be expected due to ice jams.

The Clearwater River does not have a sufficiently long period of record for a frequency analysis. On occasion the Clearwater flow is relatively large when the Athabasca is relatively low and this causes the Snyc to flow from east to west, the reverse of its normal direction. The following is quoted from a memorandum on file with the Department of

Highways of Alberta, February 13, 1963, D.A. Bailey, Location Engineer, McMurray, to Mr. H.J. Stephens, Edmonton:

"The water in the Snye usually flows from west to east but on occasions when the Clearwater is very high the water has been known to flow from east to west. This situation happened two years ago (1961) and is reported to have flowed that way all summer. This caused considerable silting in the Snye and for a year after was shallow enough to prevent the usual usage as a seaplane base".

Hangingstone Creek has a relatively steep gradient and is reported to have produced severe flash floods due to summer rains on occasion. Mr. W. Schlader of McInnes Products Corporation stated that this creek produced a large flood in July 1933 or 1934 which overflowed the banks and deposited a great deal of silt and that a similar creek entering the Clearwater near Draper washed out several railway trestles during the same storm.

5. POSSIBLE FLOOD PROTECTION WORKS.

5.1. Power Dams on the Athabasca.

Since all severe floods on record are due to break-up of the Athabasca, the most complete protection possible would be given by dams on this river.

In its 1963 Annual Report (Ref. 3) the Alberta Power Commission discusses plans for development of the Athabasca. These consist of a power dam with a large reservoir at 6-Mile Rapids just upstream of the town of Athabasca and six additional power dams between Athabasca and McMurray. The report states that the 6-Mile Rapids site might be considered for development around 1972. No possible date is given for construction of the other dams.

If constructed, the 6-Mile Rapids storage would absorb spring floods and greatly reduce possible flooding in McMurray. The projected plant at Mountain Rapids, about 8 miles upstream of McMurray operated in conjunction with the 6-Mile Rapids plant would virtually eliminate flooding.

The cost of these power dams is in the order of \$50,000,000 to \$100,000,000 each and so they could not be built solely in order to prevent flooding at McMurray. At the present time the cost of generating electricity from coal and oil is decreasing rapidly compared to the cost of hydro power and it is quite possible that construction of these plants will be postponed, perhaps indefinitely.

5.2. Diking the Snye.

As explained in Chapter 3, the Snye drains water from the river

during break-up and so allows formation of an ice jam just downstream of its junction with the Athabasca. A dike across the Snye would cause the point of formation of a major jam to move down to the mouth of the Clearwater where the river level is more than 3 feet lower than at the Snye. Since the Athabasca cross-section is about the same at these two points, about the same rise in level would be required to break up the jam. A dike across the Snye would therefore reduce the ~~maximum~~ flood water levels at McMurray by slightly more than 3 ft.

5.3. McMurray Town Dikes.

Protection against most floods is possible by placing dikes around the town (Fig. 14). These would eliminate damage from floods whose ~~maximum~~ level did not exceed that of the top of the dikes. Whatever the height of the dikes, however, it would be theoretically possible for them to be overtopped according to the frequency graph, Fig. 10.

Diking the town area could give the citizens a false sense of security. If the dikes were overtopped, the town would be flooded to the level of the top of the dikes almost immediately. A flood equal to that of 1875, in which the water rose 35 to 40 ft. in one hour, would almost certainly result in loss of life if the area had not been previously evacuated. After several years with no flood damage, because of dikes, it is unlikely that a decision to evacuate would be made in time. Poor maintenance could contribute to the dike breaching at lower levels.

6. ECONOMICS OF FLOOD PROTECTION WORKS.

6.1. Diking the Snye.

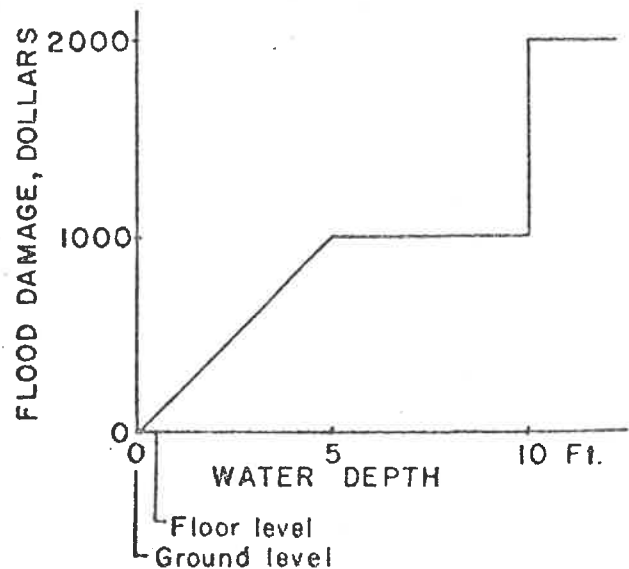
The proposed design for the Snye dike, Figs. 14 and 16 was chosen initially because it corresponds to the maximum water level which could possibly have been reached in the worst flood on record, 1875. The cost of the structure increases sharply with elevation beyond that chosen (830) since it would then be necessary to extend a major dike along the Athabasca shore of McDonald Island. It is practical to protect the Island by means of a 5 ft. high dike constructed, by bulldozer, from local materials, plus a protective tree belt about 200 ft. in width along the Athabasca. The dike is set back from the river in order to reduce the volume of earth fill required and to allow ice to pack against the upstream face thereby eliminating any need for expensive rock or concrete protection. The flat side slopes, shown as 4 on 1 are required for an earth fill structure but here they would serve to force river ice upward, above the water level, increasing the effective height of the dike. A dike connecting the Snye dike and the proposed highway (Fig. 14) is essential to prevent water by-passing in extreme floods. This connecting dike is shown well back from the river bank, so that ice could pack on the first bench and provide some protection from erosion as well as increase the effective height of the dike. An earth dike placed close to the river is likely to be damaged by ice unless protected by a facing of very large rock.

In view of the fact that no loss of life ever occurred in ice jam floods at McMurray it is essential that these structures be justified on economic grounds even though this cannot now be done precisely.

Except for minor floods, the cost of flood damage is often born by governments, or by the individuals concerned via flood insurance. In any case flood damage is ultimately a charge against society as a whole and the disposition of the costs is not properly a subject for this report. The probable cost of flooding associated with various development schemes is therefore computed without regard to the method of payment or to administration charges.

The cost of flood damage is based upon the diagram below. This assumes a single dwelling house without a basement or outbuildings placed on a concrete foundation with the floor one foot above the ground. The costs are taken to be zero if the flood just reaches the ground level on which the house is built and to increase progressively with water depth to \$1,000 at the point at which the water is 5 ft. deep (4 ft. above the floor). No further increase in cost is assumed until the water depth reaches 10 ft.,

at which point the building would likely be moved off its foundations, increasing the cost of repairs to about \$2,000. For the purpose of the calculation it is assumed that one acre of land is occupied by 3.8 houses. No allowance was made for damage to roads or other utilities.



FLOOD DAMAGE
TO A SINGLE HOUSE

Houses damaged in past floods have probably cost less to repair than is assumed here; those damaged in future floods may cost more.

The probable annual cost of flooding averaged over a long period was calculated for complete development of the town above elevations 810, 815 and 820 with no dikes and with the Snye dike in place. The average return periods of ice jam floods (Fig. 10) and the estimated repair cost for a single house were used in this calculation. The total cost of a single flood to any elevation was computed by multiplying the number of houses at each level below the flood peak by the estimated repair cost for each house flooded. From the resulting graph of flood elevation vs. total cost per flood, the average annual cost of flooding between each two foot interval was determined by multiplying the total cost of a single flood to the mid point of the interval by the probability of floods falling within this interval. The probability of a flood falling within a given height interval is the difference in the probabilities of floods associated with the end points of the interval, that is, the difference of the inverse of their return periods. The long term average annual cost of flood damage is the sum of the average annual costs for all height intervals above the lowest level at which development is allowed.

For the purpose of this study it was assumed that negligible development will exist on the limited area between elevations 830 and 840, above 840 it was assumed that no further damage can occur. There is about 150 acres of developable land above elevation 830, most of it higher than elevation 850. 50 acres of this may be occupied by a highway and so would not suffer significant damage from a flood. The remaining

100 acres is assumed to be above any possible flood.

Table I shows the results of this calculation:

TABLE I
AVERAGE ANNUAL COSTS WITH AND WITHOUT SNYE DIKE
NO TOWN DIKES

Minimum elevation of development, ft.	810	815	820
Developed area below elevation 830, acres	675	460	260
Cost of Snye dike (crest at elevation 830)	\$127,000	\$127,000	\$127,000
Annual interest and maintenance charges on Snye dike @ $5\frac{1}{2}\%$ + $\frac{1}{2}\%$	\$7,600	\$7,600	\$7,600
Average annual cost of flooding, dike installed	\$70,000	\$30,000	\$11,000
Total average annual cost of dike and flood damage	\$77,600	\$37,600	\$18,600
Total average annual cost of dike and flood damage per developed acre below elevation 830	\$115	\$82	\$72
Average annual cost of flooding with no dikes	\$105,000	\$44,000	\$15,000
Average annual cost of flooding per developed acre below elevation 830 with no dikes	\$156	\$96	\$58

Note: Total average annual costs per acre with and without the Snye dike are equal at about elevation 817 (350 acres developed below elevation 830).

The savings shown in Table I could vary by a factor of 2 or more depending on the estimated repair costs for a single house. A more

complete cost analysis based on industrial as well as housing development would also affect these costs as would any errors which may exist in the flood frequency curve used.

Diking the Snye would make about 325 acres on McDonald Island available for development of housing, recreational facilities and possibly an airstrip parallel to the Clearwater River for use by small planes. While contours of the Island are not at present available it is likely that about 200 acres would be suitable for housing. Table I does not include an allowance for the value of the land gained on McDonald Island or for any flood damage which could occur there.

Some silting would occur at the point where the Snye joins the Clearwater. This could be removed by occasional dredging.

6.2. Town Dikes.

Three different dike locations (Fig. 14), parts of which coincide, were selected for this study. Dikes to elevation 819 and 824 corresponding to return periods of 50 and 100 years respectively, were studied at each location.

There is some doubt about the adviseability of a dike at locations 1 and 2 because of the high permeability of the sand-gravel layer and the thin covering of soil above it which could allow rapid seepage of water into the diked area. Appendix B lists all the available soil data and while this appears to indicate an adequately thick surface soil layer in the vicinity of the dike, a detailed soil survey of the area is recommended before location 1 or 2 is approved for dike construction. The high location 3 requires a smaller dike, for which the surface soil

layer appears adequate.

As for the Snye dike discussed in Section 6.1., the calculations of probable flood damage are based upon development below elevation 830 and any possible development on McDonald Island is disregarded.

The cost of damage to a single house is the same here as used in Section 6.1. Construction of houses with concrete basements in the area much lower than the top of the dikes is inadvisable since water pressure transmitted through the subsoil layer of sand and gravel could either blow-up the basement floors or float the whole structure a few inches.

Table II lists the average annual costs associated with town dikes. Fig. 18 plots the calculations so as to show comparative costs at various developed areas. It shows that, at the same developed area, the cost of dikes plus flood damage per acre of developed area is generally greater when town dikes are provided than when they are not. In all cases the Snye dike to 830 is assumed to be provided.

TABLE II

AVERAGE ANNUAL COST OF TOWN DIKES WITH Snye DIKE INSTALLED

	<u>Location 1</u>		<u>Location 2</u>		<u>Location 3</u>	
Elevation of top of dike	819	824	819	824	819	824
Developed area on mainland below elev. 830, acres	600	600	540	540	450	450
Return period of damaging flood, years	50	100	50	100	50	100
Cost of town dikes	\$183,000	\$437,000	\$148,000	\$357,000	\$85,000	\$227,000
Cost of Snye dike	\$127,000	\$127,000	\$127,000	\$127,000	\$127,000	\$127,000
Total cost of dikes	\$310,000	\$564,000	\$275,000	\$484,000	\$212,000	\$354,000
Annual interest charges ($5\frac{1}{2}\%$) and maintenance ($\frac{1}{2}\%$) for dikes	\$18,600	\$33,840	\$16,500	\$29,040	\$12,720	\$21,240
Average annual cost of flood damage based on diagram on page 15	\$47,500	\$35,200	\$41,400	\$31,200	\$29,200	\$23,400
Total annual cost of dikes and flood damage	\$66,100	\$69,000	\$57,900	\$60,200	\$41,900	\$44,600
Total annual cost per developed acre on mainland below elev. 830	\$110	\$115	\$107	\$112	\$93	\$99

6.3. Highway Location.

It is possible to locate the highway passing through McMurray either along the edge of the hill, the dark line shown on Fig. 14, or along a route through lowlying land. The lower location would make about 50 acres of high land available for development in exchange for about the same

area of lowlying land. If the town dike were built, the highway could occupy part of the area allocated to the dike and the amount of lowlying land required would be less.

Assuming the highway is undamaged by flooding at either location, that the Snye dike is in place, and that a town dike is not built, the reduction in probable average annual cost of flood damage due to housing development at the higher location would be about \$6,000, equivalent to an initial investment about \$110,000 at $5\frac{1}{2}\%$ interest. If a town dike was built to elevation 824, the reduction in probable average annual cost of flood damage would be about \$3,500.

7. CONCLUSION.

Fig. 18 shows the cost data for the flood protection works considered, that is (a) no dikes, (b) Snye dike, (c) Snye dike to elevation 830 with town dikes at elevation 819 and at 824 in locations 1, 2 and 3. The total annual cost consists of the interest, $5\frac{1}{2}\%$, and maintenance, $\frac{1}{2}\%$, for the dikes plus the probable average annual cost of flood damage. Interest charges on the dikes are here assumed to exist in perpetuity, whereas the normal method of financing would be to charge a somewhat higher annual rate over a 25 or 40 year period. The probable average annual cost of flood damage is based upon an annual cost of damage to a single house (Chapt. 6) and a housing density of 3.8 houses per acre. No allowance is made for damage to utilities.

The cost figures used for the calculation of average annual flood damage are estimates and do not include any allowance for loss of human life which could result from future floods. The cost of the dikes is based upon current contract prices.

Fig. 18 includes results for the flooding costs assumed in Chapt. 6, for twice those costs, and for one-half those costs. The figure shows that installation of the Snye dike alone becomes economical when the area required for development below elevation 830 is in excess of about 350 acres, corresponding to about the 817 contour. With other flooding costs this elevation varies as indicated by Fig. 18. The possibility of developing McDonald Island, not included here, would make the Snye dike more attractive than indicated.

Installation of a town dike at location 1 in addition to the Snye dike, would only be economical if 600 acres or more below elevation 830

were required for development and the flooding costs were twice those given in Chapt. 6. A town dike could lead to loss of life in a sudden flood and in addition some doubt exists regarding the engineering feasibility of a town dike at location 1 or 2. Therefore there could be merit in deferring its installation till a firm decision on development of the Athabasca power projects has been reached.

Installation of a dike across the Snave as shown on Figs. 14 and 16 is recommended.

Edmonton, Alberta, May 6, 1964.

T. BLENCH & ASSOCIATES LTD.

A handwritten signature in dark ink, appearing to read 'T. Blench', is written over a horizontal line.

Dr. T. Blench, P. Eng.

ACKNOWLEDGEMENT

Residents of McMurray were extremely helpful in providing information about past floods. The names of persons supplying data are recorded in the report where pertinent facts are discussed. In particular, thanks is due to Captain G. Hampton of Northern Transportation Co. Ltd., who kindly loaned the photographic negatives from which figures were reproduced, and to Mr. Julian Mills of McMurray who supplied a good deal of general information about the area.

The Hudson's Bay Co. Ltd. have provided excerpts from their records relative to flooding at McMurray. This invaluable information has been provided with the stipulation that it be made available only to Government and attention is drawn to two letters reproduced in Appendix A which preclude further reproduction without the Company's express permission.

The cooperation of many Federal and Provincial Government agencies is gratefully acknowledged.

LIST OF REFERENCES.

1. MacKay, D.K. Trends and Factors Affecting Break-up and Freeze-up Dates in the Nelson River Drainage System. Geographical Paper No. 35, Geographical Branch, Department of Mines and Technical Surveys, Ottawa.
2. Moberly, H.J. and Cameron, W.B. When Fur Was King, J.M. Dent and Sons, Ltd., Toronto, 1929, pp. 141-2, pp. 151-2.
3. Annual Report of the Alberta Power Commission, Edmonton, 1963.
4. The Beaver. Hudson's Bay Co. Ltd. publication June 1936, p. 61.
5. Fowler, E.D. Department of Northern Affairs and National Resources, Fort Smith, N.W.T. Letter to Mr. R.K. Deeprose, Department of Water Resources, Edmonton, Alta, 6 December, 1963.
6. D.O.T., Canada. Break-up and Freeze-up Dates of Rivers and Lakes in Canada. CIR-3156 ICE-2, 30 Jan. 1959. Meteorological Branch, Department of Transport, Canada.
7. Bituminous Sands of Northern Alberta: Occurrence and Economic Possibilities, Report on Investigations to the end of 1924, Mines Branch Report 632, Department of Mines Ottawa (1926).
8. Stanley, Grimble and Roblin Ltd., Consulting Engineers, Extract from waterwell file, Town of McMurray.
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APPENDIX A

ICE JAM FLOOD DATA

1875 Flood.

The following is a quotation from page 151, H.J. Moberly's account of this flood (Ref. 2):

"The winter of 1874-75 was a bitter one, with deep snow and never a thaw until April. On the 2nd or 3rd of that month, however, a further heavy fall of snow was followed by a sudden rise in temperature. The change of weather and weight of the melting snow caused the ice for the eighty-five-mile stretch of rapids above the fort to break up, and it came down the Athabasca with terrific force. On striking the turn in the stream at the post it blocked the river and drove the ice two miles up the Clearwater in piles forty or fifty feet high. In less than an hour the water rose fifty-seven feet, flooding the whole flat and mowing down trees, some three feet in diameter, like grass.

Fortunately, the spur of the hill just above the fort sloped to the river, forming an eddy. The flood caught only one of the houses, but this was at once swept away. When the water had mounted almost to the bank I ordered everyone back to the high ground, but fearing that if the rise reached the house its contents would be damaged, I stayed behind and, shutting the doors, commenced to carry what articles I could to the upper rooms.

Presently I noticed water trickling in under the doors. I was too much occupied, however, to take the time to look out, until a large tree dashed in at the window. I knew now that I was in for a cold bath.

After I had with great difficulty got out of the trap a hundred yards of water five to ten feet deep still separated me from dry land. When, at times wading and again swimming, I at length reach it and safety no one with ague ever shook harder than did I after my ducking.

We cleared away the snow and made a comfortable camp, and here we remained for five days before we could re-occupy the houses. Out of thirty-seven oxen for the transport service one only escaped. The rest were drowned".

On April 1st, 1964, Mr. Joseph Shott, age 78, pointed out the site of the original Hudson's Bay Co. post located as shown on Fig. 14. The elevation of the ground surface at this point is about 823. The site is about 100 yards from a steep rise or terrace in the ground roughly parallel to the 825 contour at the west end of Franklin Avenue. The post was a log structure and would have been carried away had the water risen 57 ft. (to about elev. 847 or 24 ft. above the ground) as stated in the above quotation. While the dimensions of the buildings are not available, it is likely that they would have floated had the water depth reached more than about 7 feet. The maximum water level must therefore have been no more than 830. The lowest possible maximum level was about 2 ft. above the ground or elevation 825.

Mr. Shott's comments on his father's stories of the "big flood" in which many cattle died in the "Prairies" area, were in agreement with other available accounts of the incident.

Extracts from the Hudson's Bay Co. files, included in this Appendix, provide further details of this flood. The second paragraph of Enclosure 1 locates the fort on the left bank of the Athabasca. Since the location

described, "A beautiful Prairie", exists only near the right bank, it would appear that Mr. Moberly was facing upstream when he gave the description.

It should be noted that the above quotation states the flood occurred on the ~~2~~ or 3rd of the month whereas Moberly's report to the Hudson's Bay Co. gives the date as April 20.

1881 Flood.

The only information on this is contained in the extracts from the Hudson's Bay Co. files. This description does not give the maximum level but appears to indicate a level only a few feet below the ground at the post (Elev. 823). The island referred to as the potatoe island is believed to be currently known by the names McDonald Island or McMurray Island.

1885 Flood.

The only available information is that supplied by the extracts from the Hudson's Bay Co. files. The maximum level was at least elevation 817.

1925 Flood.

The maximum elevation of this flood at Waterways was 811.7. This figure was obtained from a plan of the railway line at Waterways obtained from the Northern Alberta Railways Co. No other details are available.

1928 Flood.

The maximum elevation at Waterways was 815.6. This was obtained from the same drawing as the 1925 flood level.

1936 Flood.

High water occurred at Waterways on April 22, 1936, and the maximum elevation was 820.6 ft. according to the railway line plan obtained from Northern Alberta Railways Co.

Mr. R. Denholme of McMurray gave an account of the 1936 flood which flooded his boat building shop located on the Clearwater River on the eastside of Northern Transportation Co. Ltd. docks. Subsequently Mr. Henry Christofferson of Northern Transportation Co. Ltd. pointed out the high water mark on the inside wall of the building. By means of a surveyor's hand level this was measured as 30 ft. above the Clearwater ice level on April 1, 1964. Comparison of the ice level with the 1963 high water level of elevation 812.35 marked on the flag pole at Northern Transportation Co. docks showed the elevation of this water mark to be 820.35 ± 0.5 ft.

Mr. Sam Dulong who resides on the north side of Franklin Ave. near Peter Pond school pointed out the maximum level reached by the 1936 flood in his kitchen. This level was established as 2.0 ± 0.5 ft. above Franklin Ave. where the road surface is at about 817.5. Therefore the maximum level at this point must have been between 819 and 820.

The ice first broke at 7 p.m. on April 21, 1936 (Ref. 4).

Mr. W. Schlader of McInnes Products Corporation, Northern Hardware Bldg., Edmonton, stated that the water level at McInnes' dock near

Waterways rose about 6 ft. between 11.00 p.m. April 21 and 7.00 a.m. April 22, to about 2 ft. above the warehouse floor.

Accounts of the duration of the 1936 flood differ. The Roman Catholic Mission has an account in its diary which says that the flood started to rise overnight, approached near enough to the Mission to alarm the occupants during the morning and then receded in the afternoon. Mr. Denholme remembers water on the Prairie area for about 10 days; his boathouse is located on about the 810 contour.

1958 Flood.

Records of the Department of Northern Affairs and National Resources, Water Resources Branch state that the water level during spring break-up reached a gauge height of 26 ft. at the gauging station near Clarke Creek, Fig. 1. This is about 24 ft. above low water level. Northern Transportation Co. Ltd. personnel have no record or recollection of flood damage in 1958. Evidently this flood did not overtop the river banks at McMurray.

1962 Flood.

The maximum water level was elevation 807.74. This was determined by the Department of Northern Affairs and National Resources by leveling from high water marks (Ref. 5).

1963 Flood.

The maximum water was elevation 812.13 determined from high water marks (Ref. 5), Figs. 3 to 9 are photographs taken by Capt. George Hampton of Northern Transportation Co. Ltd. during the flood.

Mr. K. Hill showed the authors moving pictures of this flood which, among other points, showed that a definite jam occurred across the Athabasca just downstream of the Snye. Mr. Hill stated that the first "wave" of the 1963 flood advanced through the Snye at about 20 miles per hour, breaking the surface ice as it progressed. This was followed by a rapid rise in water level.

1964 Flood.

Due to a small snow pack and a mild winter this flood was not severe. The ice broke up at the Town of Athabasca on April 19 with about $1\frac{1}{2}$ ft. rise in water level - a very gentle break-up. On April 24, at about 11.00 p.m. the ice broke at McMurray. This was accompanied by a rapid rise in level of about $\frac{1}{4}$ ft. after which the river cleared itself of ice in a few hours. Ice was forced into the Snye but came to a halt when a large sheet of Snye ice came to rest against the north-east side of the Clearwater. The Clearwater ice went out during the night of April 28, 1964. On April 30, 1964, the Athabasca River was clear of ice to a point about 6 miles downstream of McMurray. The Snye was blocked with broken ice which showed no inclination to move on April 30, 1964.

General.

Table AI lists the recorded break-up dates, that is the times of first movement of the ice, at McMurray. The data from 1938 to 1958 are taken from Ref. 6, from 1959 to 1963 are from the McMurray office of the Department of Transport, and prior to 1938, from various sources

given elsewhere in this report.

There is some question about the accuracy of the 1954 and 1961 dates; Mr. W. Hill of McMurray states that the ice has always broken up before May 1st.

TABLE AI
DATE OF FIRST MOVEMENT OF ICE
ATHABASCA RIVER
AT McMURRAY, ALBERTA

<u>Year</u>	<u>Date</u>	<u>Year</u>	<u>Date</u>
1875	April 20	1953	April 21
1881	April 21	1954	May 9
1885	April 9	1955	April 17
1936	April 21	1956	April 20
1938	April 27	1957	prior to May 3
1939	April 21	1958	April 15
1940	April 25	1959	April 13
1941	April 14	1960	April 12
1942-47	Missing	1961	May 8
1948	May 1	1962	April 24
1949	April 15	1963	April 20
1950	April 28	1964	April 24
1951-52	Missing		

Average break-up date - April 22

Earliest recorded break-up date - April 9

Latest recorded break-up date - May 9

FLOODING AT FORT McMURRAY AND WATERWAYS

Years

- 1870 Fort McMurray established on left bank of Athabasca River at its confluence with the Clearwater River (H.B.C. Arch. B.39/b/20, pp.146, 268). See Enclosure No. 1.
- 1871-74 No Fort McMurray journals. No references to flooding in correspondence, etc.
- 1875 Flooding at Fort McMurray. See Enclosures Nos. 1 and 2.
- 1876-77 No Fort McMurray journals. No references to flooding in correspondence, etc.
- 1877 Plan of Fort McMurray by H.J. Moberley dated 1 June 1877 (H.B.C. Arch. B.307/z/1) shows the post on right bank of Athabasca River at the junction with the Clearwater. The date of the move has not been traced.
- 1878-80 No references to flooding in Fort McMurray journal, H.B.C. Arch. B.307/a/1.
- 1881 Flooding at Fort McMurray. See Enclosure No. 3.
- 1882-84 No references to flooding in Fort McMurray journal, H.B.C. Arch. B.307/a/2.
- 1885 - Clearwater River overflowed. See Enclosure No. 4.
- 1886-87 No references to flooding in Fort McMurray journal, H.B.C. Arch. B.307/a/4.*
- 1888-90 No Fort McMurray journals. No references to flooding in correspondence, etc.
- 1891-92 No references to flooding in Fort McMurray journal, H.B.C. Arch. B.307/a/5.
- 1893-98 No Fort McMurray journals. No references to flooding in correspondence, etc.

* H.B.C. Arch. B.307/a/3 is a journal of a journey from Athabaska Landing to Fort McMurray, August to September, 1885.

Year

1899

No Fort McMurray journal. The post was apparently closed during trading season 1898-99. (H.B.C. Arch. A.12/39 (letter 5086); B.39/b/39, fo.85; Archives Dept. File, Fort McKay).

1913

Fort McMurray was again in operation as a fur trade post. No journals from this time onwards have survived in our archives and reports, where they exist, make no references to floods.

1939

Post established at Waterways on the Clearwater River, about 3 miles from Fort McMurray. (Archives Dept. File, List of Changes in Posts and Outposts since 1 June 1939). There are no records for Waterways post in our archives.

ENCLOSURE NO. 1

Extract from copy of letter from Chief Trader Roderick MacFarlane to Chief Commissioner James A. Grahame at Fort Garry, dated 'En Route Clear Water River', 14 June 1875.

"I beg to transmit to you herewith copy of Mr H.J. Moberly's Report to me dated 25 April 1875*...

Fort McMurray is situated on the left bank of the Athabasca River at its confluence with the 'Clear Water' - the buildings are upwards of 50 feet above the winter level of the water. A beautiful Prairie extends for 2 miles to the rear of the post along the clear water river. On the East it is bounded by a hummock of tall pines and poplars and on the South by a high ridge of land. A supply of excellent hay for 60 head of Cattle can be obtained on this Prairie. For the sake of shelter and convenience of watering the Animals during Winter, the Byres were erected in the midst of said timber, also their keeper's house.

On the morning of 20 April last James Daniel (a) the man in charge on becoming aware that the river was breaking up, immediately liberated the Oxen and began to drive them to the highlands beyond the Woods, but before he could get them through, the water rose so suddenly that he barely escaped with his own life and had to leave the poor animals to their fate. Had the Ice, however, not completely surrounded, as it did, the said woods, all of them would have escaped by swimming; but as the water and ice continued high for 5 or 6 days, it was impossible to render them any assistance from the Fort, and the poor brutes after swimming about and making the most strenuous efforts to escape, at length perished one by one, their bodies being since found scattered at intervals in all directions ... The Athabasca broke up very suddenly and quite unexpected while the water rose higher than was ever before known; and after making full and particular enquiries on the spot, I feel satisfied that no blame can justly attach to any one for this unfortunate and much to be regretted occurrence...

A Flood similar to that of 1875 has probably never before happened, and is not likely to occur again so soon; At all events, after this spring's experience, I think I may safely venture to state that with the precautionary measures to be taken in future, no danger need be apprehended that we shall again lose any Animals or property from this cause ...'.

* See Enclosure No. 2.

ENCLOSURE NO. 2

Extract from copy of letter from Henry J. Moberly, clerk in charge of Fort McMurray, to Chief Trader Roderick MacFarlane, officer in charge of Athabasca District at Fort Chipewyan, dated Fort McMurray, 25 April 1875.

'I have now the painful duty to perform of letting you know that we have had a very sudden Inundation here, a few days ago, accompanied by serious loss to the Hudson's Bay Company.

On the 20 Instant about 2 hours after daylight, the river suddenly gave signs of breaking up and in half an hour from that time the water had risen about 60 feet, and the whole place was flooded - the water and ice passing with fearful rapidity and carrying off everything before them. We had just time to escape to the hill, in our immediate vicinity, with the families, bedding and a little Provisions and Ammunition, and to throw up stairs the Furs and most of the valuable property, when the water was already rushing through the Fort. From the time the river first gave signs of starting hardly half an hour elapsed before there was 5 feet of water in the highest building in the Fort, and the Interpreter's house was carried bodily away and dashed to pieces in the Woods; the Workshop and Men's houses have been almost destroyed.

As soon as the river appeared bad, I gave immediate orders to have the Cattle driven to the high lands; and altho' their Keeper James Daniel did all that could be done and even risked his life to save them, still there was no time, as the water rose so suddenly, and I regret to say they all perished ... I had been expecting high water this spring, altho' nothing like what has happened: But the Weather was still very cold - the snow had hardly melted any, and the Ice on the river to all appearance as solid as in Winter - and no one expected the river to break up for 10 days, and then only if the Weather changed and got warm ...

The Ice and Water swept clean over the Prairie up the Clear Water River, which accounts for all the Cattle being drowned as they could not hold against such a torrent ... It may take 2 weeks before the Ice, which is now piled up at least 80 or 100 feet in the Athabasca and Clear Water Rivers, clears off ...'.

(H.B.C. Arch. B.39/c/2)

- 37 -

ENCLOSURE NO. 3Extracts from Fort McMurray Journal188121 April

'... At 7 PM the river started suddenly with a rush and continued running for an hour. It first ran down the main channel which was speedily choked up between the potatoe island and the little island opposite the post; it then found an outlet down the gensicle[sic] or "shny" - this finding no outlet into the main channel dammed up the Clearwater and overflowed the big prairie up to the poplar at the mouth of the hay track; the channel between the little island and the opposite shore began to run after the "shny" stopped and so continued for an hour. After this the ice became completely jammed. As soon as the "shny" got blocked up the water rose over the bank and began to pour into the square. McLeod & Kipling, who had till then been carrying to the high bank all loose private property, were then sent to drive the cattle into the barley field for the night. Having done so McLeod watched till dawn when Mr Cowie got up and found the water had gone down four feet during the night altho' it had rained heavily.'

22 April

'... River still jammed ...'.

24 April

'... Water falling on prairie. The ice jam still solid'.

26 April

'... Ice stationary'.

28 April

'... Ice settling down owing to water falling'.

29 April

'... The ice in the mid channel flowed slowly all afternoon finding a passage between the small island and the opposite shore ...'.

1 May

'... The river is now running almost free of ice in mid channel but around the banks immense heaps of ice remain extending half across the river from the upper end of the potatoe island'.

[No further references to flood conditions].

ENCLOSURE NO. 4Extracts from Fort McMurray Journal1885

- 9 April 'This morning at 4 the River broke open and ice began running till mid-day - the water rising to within 6 feet of level of fort ...'.
- 10 April '... The Clearwater overflowing its banks. Ice in Athabasca still sticking ...'.
- 17 April '... The ice in the river still sticking'.
- 19 April 'The Athabasca River is still jammed up with ice piled high aground on each side with floating ice in the middle which moves a little now and then and stays at present opposite the mouth of the Clearwater which is completely blocked up with the ice piled up by the Athabasca.'
- 1 May '... The Athabasca River began rising on Sunday [26 April] and is now three feet higher than then. The ice piled on the banks crumbles and tumbles constantly'.
- 2 May '... The river went down a foot this morning but rose in the evening owing to the bursting of the bar run at the mouth of the Horse Trail Creek'.
- [No further references to flood conditions].

(H.B.C. Arch. B.307/a/4)



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of the Hudson's Bay Company,

signed (R.A. Reynolds)
Secretary

Hudson's Bay Company

INCORPORATED 2ND MAY, 1870.

BEAVER HOUSE
GREAT TRINITY LANE
LONDON, E.C. 4

TELEPHONE:
CENTRAL 3223

TELEGRAPHIC ADDRESS:
HUDSONSBAY, LONDON, E.C. 4



R/GK

6 April 1964

Mr T. Blench,
Department of Civil Engineering,
University of Alberta,
Edmonton,
Alberta,
Canada.

Dear Sir,

We thank you for your letter of 23 March 1964 requesting information from our archives relating to flooding at Fort McMurray and Waterways.

We shall be pleased to assist the Government of Alberta and will let you have the results of our search in due course.

Yours faithfully,
For the Governor and Committee
of the Hudson's Bay Company,

Alice M. Johnson.
Archivist.

APPENDIX B

SOIL AND SUBSOIL DATA

The land located below about the 830 contour (Fig. 14) in the McMurray - Waterways area consists of a surface layer of silty clay of moderate permeability resting on highly permeable, water bearing, sands and gravels. The whole area is underlain by limestone rock.

Fig. 15, based on data from Ref. 7, includes a profile showing the geology of the area and also shows the locations of the boreholes described in Table BI.

Data for holes no. 1 to 6 were obtained from the Research Council of Alberta (Ref. 6). Stanley, Grimble and Roblin, Consulting Engineers, Edmonton, kindly supplied the data quoted for holes 4A to 8A inclusive (Ref. 8).

Location Y is in the area of the Northern Transportation Co. Ltd. docks where several well points put down in recent years have required about one 22 ft. length of pipe to reach a waterbearing zone.

Mr. George Golowski, whose 4 ft. square dug well is located at position Z, reports that its water surface goes up and down with the surface of the Clearwater River. This indicates that the underlying sands and gravels are extremely permeable.

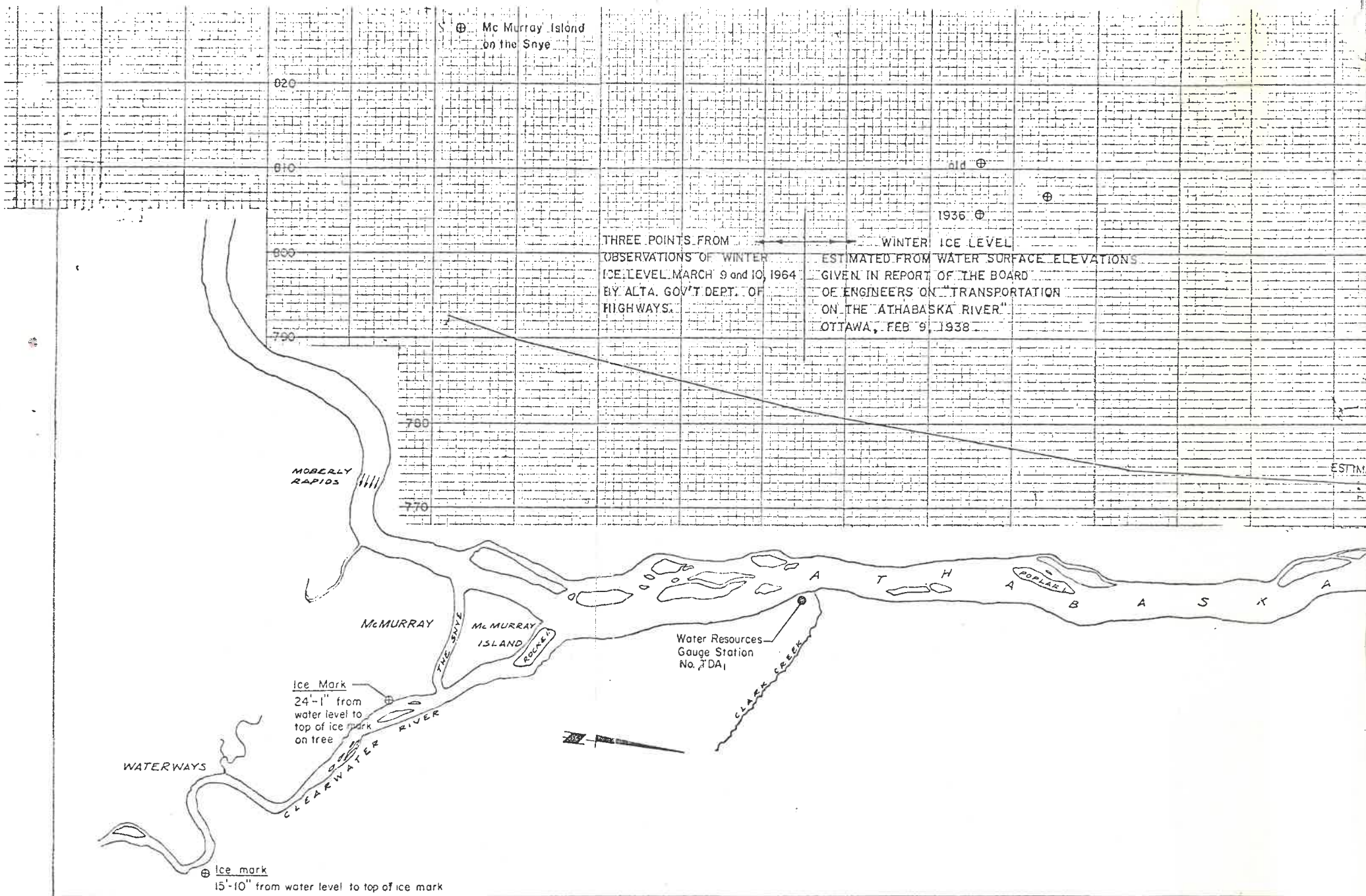
The depth of the more impermeable soil crust at position X is reported by Mr. Julian Mills to be 12 to 13 feet.

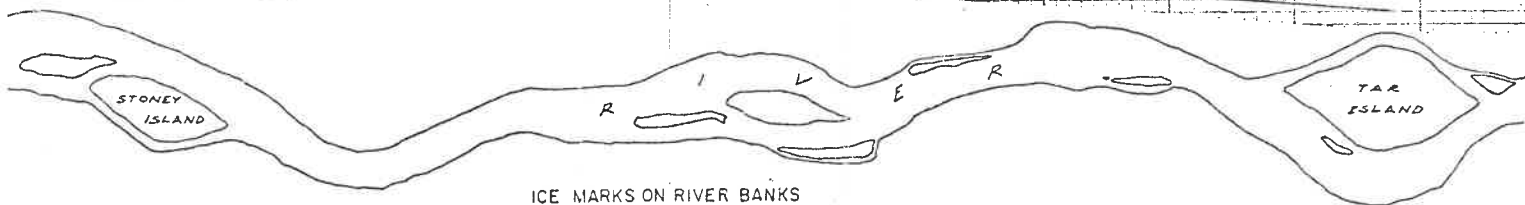
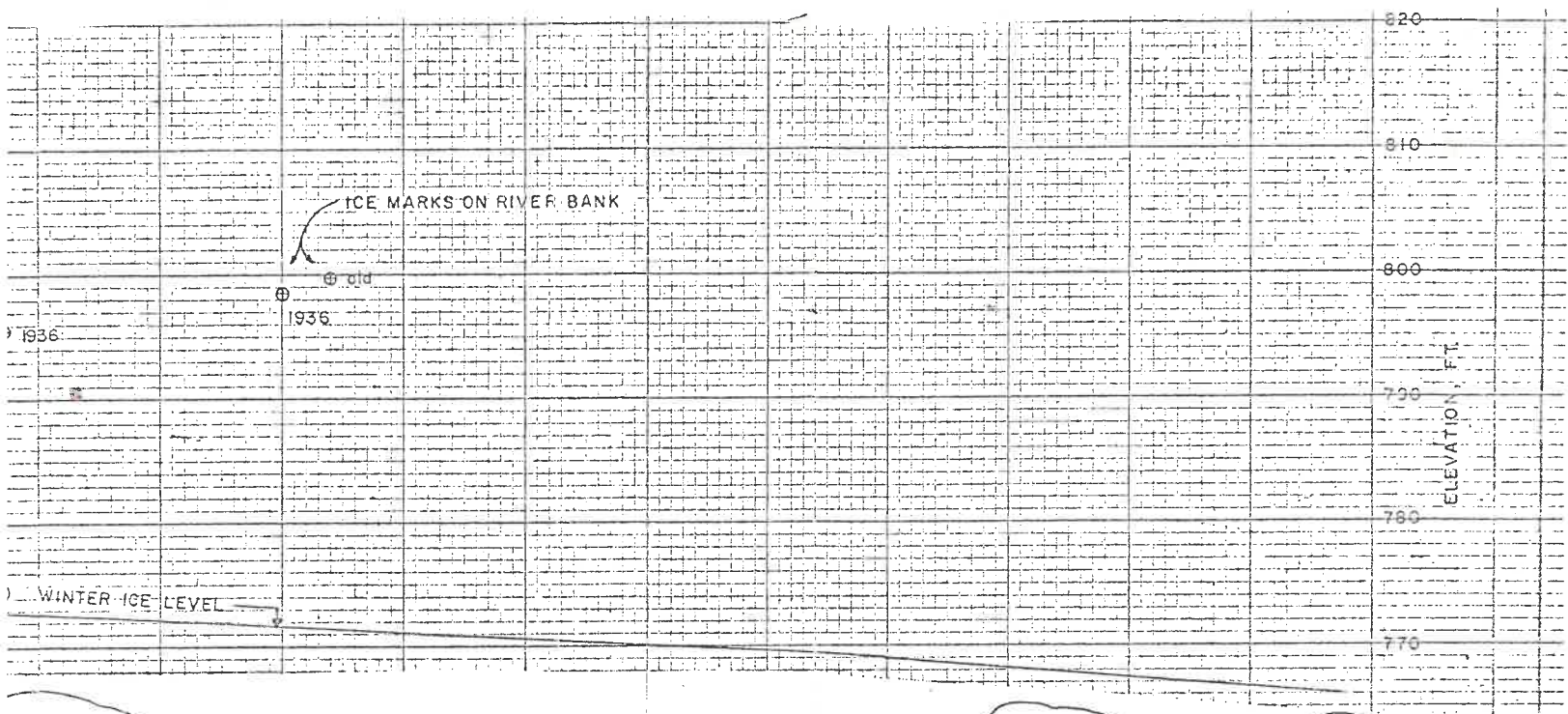
TABLE BI
BORE HOLE DATA

<u>Hole No.</u>	<u>Name</u>	<u>Surface Elev.</u>	<u>Depth Below Surface</u>	<u>Material</u>
1	McMurray Water Well	825.7 ft.	0-8 ft. 8-18 18-26 26-27 27-33 33-37 37-40 40-42 42-61 61-	silty clay sandy clay gravel, pea size sand gravel sand gravel sand gravel with large boulder limestone (Elev. 764.7)
2	Bear Rodeo No. 1	817	0-30 ft. 30-	river gravel and sand limestone (Elev. 787)
3	Alberta Govt. Salt No. 1	815	0-13 13-16 16-42 42-55 55-60 65-83 83-95 95-	loose dirt sand (wet) alluvial mud sand, white sand and boulders limestone sand and boulders limestone (Elev. 720)
4	Industrial Mineral Ltd.	825	0-100 100-	sand and gravel limestone (Elev. 725)
5	Industrial Mineral Ltd.	853	0-10 10-23 23-42	clay gravel and small boulders sand limestone (Elev. 811)
6	Alberta and Great Waterways	800	0-116 116-127 127-	sand and gravel boulder and sand limestone (Elev. 673)
4A	McMurray Well No. 4	815	0-0.5 0.5-4 4-10	top soil silty sand slightly organic fine sand with tar sand particles

<u>Hole No.</u>	<u>Name</u>	<u>Surface Elev.</u>	<u>Depth Below Surface</u>	<u>Material</u>
			10-49 49-	fine white sand limestone (Elev. 766)
5A	McMurray Well No. 5	817.3	0-0.5 0.5-2 2-6 6-10 10-25 25-45 45-50.5 50.5-	top soil organic clay yellow plastic clay sand, silty clay reddish-white fine sand containing black particles darker reddish-white fine sand containing a lot of black particles coarser white sand limestone (Elev. 766.8)
6A	McMurray Well No. 6	823.0	0-0.3 0.3-4 4-6 6-25 25-40 40-48 48-50.5 50.5-	top soil red organic silty soil red silty sand fine reddish-white sand with black particles reddish sand fairly coarse grayish medium fine sand with black particles clean coarse white sand with various coloured sands mixed in limestone (Elev. 772.5)
7A	McMurray Well No. 7	823.5	0-0.5 0.5-4 4-8 8-10 10-30 30-33 33-44.5 44.5-	top soil organic silt and reddish-white sand fine reddish-white sand same as 4' to 8' but darker coarser reddish-white sand with some grains of various colours sand grey tinged coarse grey-white sand, clean limestone (Elev. 779)
8A	McMurray Well No. 8	815.7	0-0.5 0.5-2 2-6 6-10 10-25	top soil dirty organic yellow clay dark yellow plastic clay sandy, silty clay fine reddish-white sand

<u>Hole No.</u>	<u>Name</u>	<u>Surface Elev.</u>	<u>Depth Below Surface</u>	<u>Material</u>
			25-35	slightly darker medium fine sand
			35-46	medium coarse sand with some coal particles
			46-49.6	coarse sand some particles of various colours
			49.6-	limestone (Elev. 766.1)
Y	Northern Transportation Co. wells	about Elev. 815	17 to 22 ft.	well points have to be put down about depth given to yield water. silty clay soil crust probably from 15 to 20 ft. thick here.
Z	House well of Mr. George Goloski	about Elev. 812	22 ft. total depth	well goes through silty clay and a few feet into sand/gravel layer.





ICE MARKS ON RIVER BANKS
SHOWN THUS ⊕

DATA FROM DEPT. OF PUBLIC WORKS
UNNUMBERED DWG., 1937



T. BLENCH & ASSOC. LTD.	
PLAN AND PROFILE ATHABASKA RIVER AT McMURRAY	
SCALE 1:50,000	30-4-64
	FIG 1

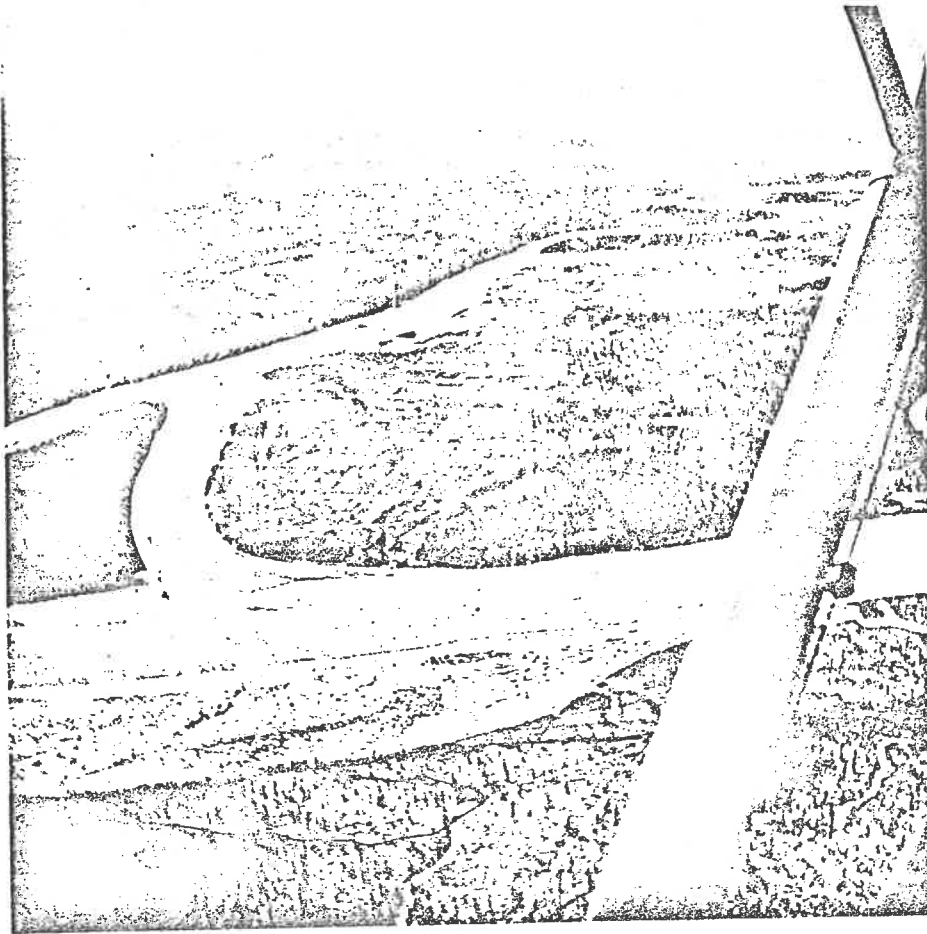


FIG. 2

1963 FLOOD
ATHABASCA RIVER
AT THE Snye

Water level
about Elev. 812.
Photo taken
after ice had
stopped flowing
through the Snye.

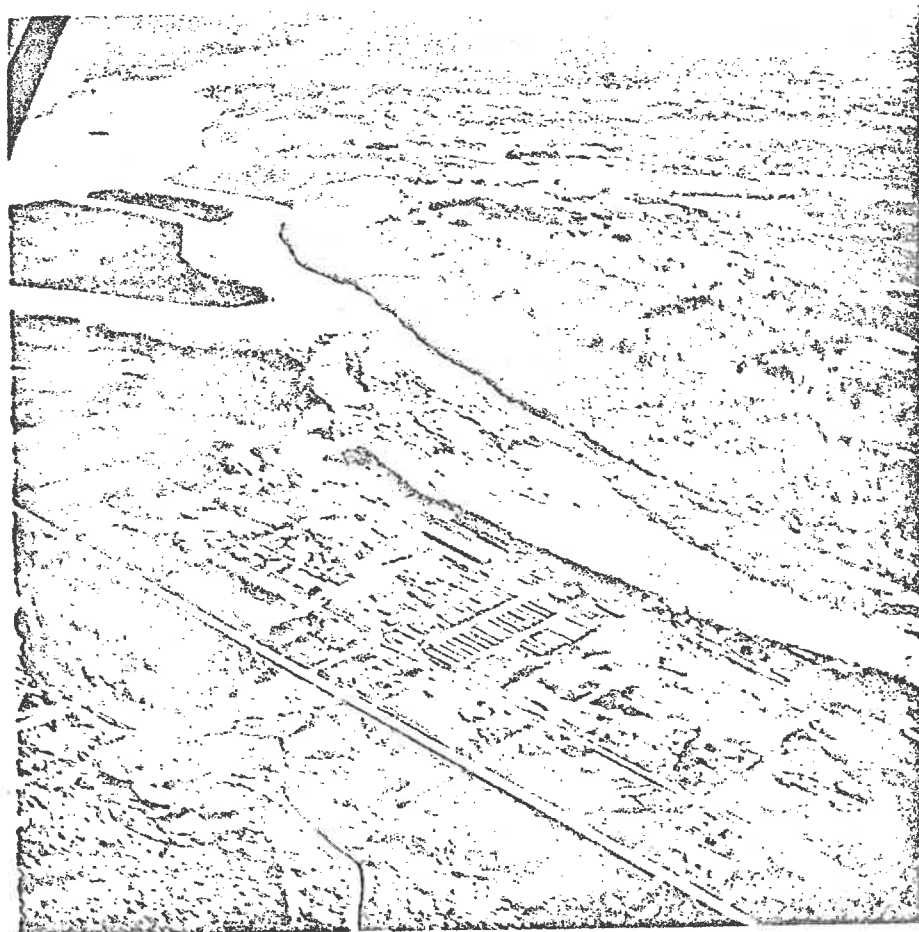


FIG. 3

1963 FLOOD
JUNCTION OF
CLEARWATER AND
ATHABASCA RIVERS



FIG. 4

1963 FLOOD
CLEARWATER RIVER
AT THE SNYE

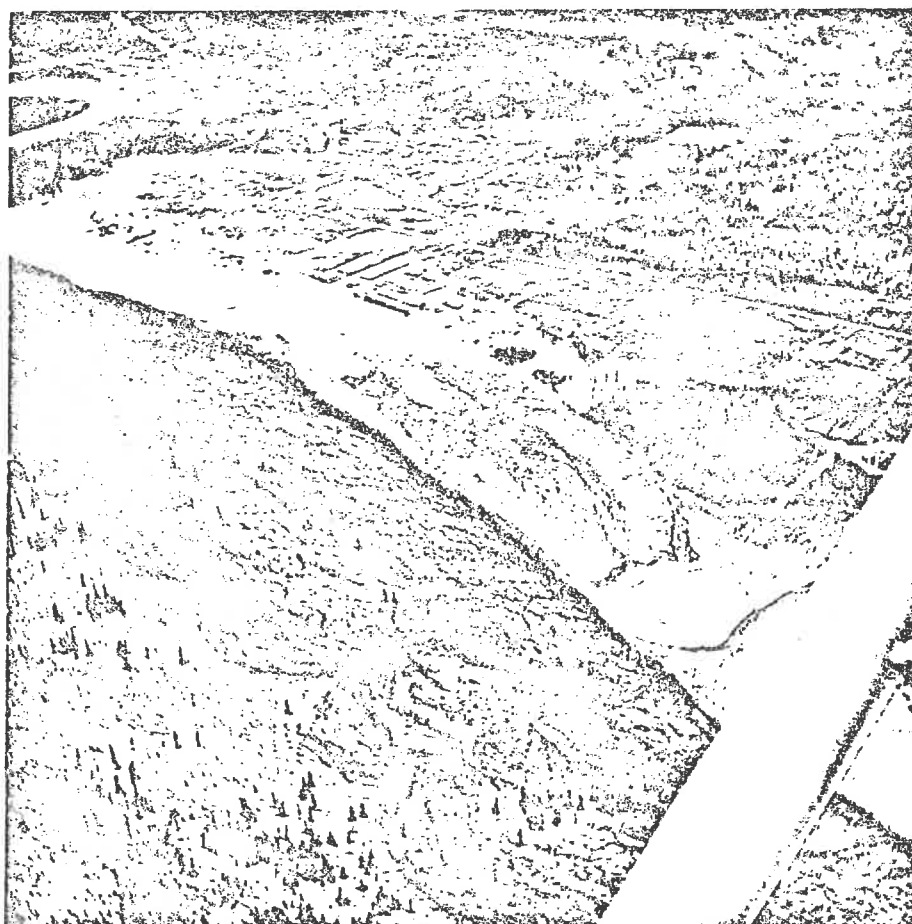


FIG. 5

1963 FLOOD
CLEARWATER RIVER
AT NORTHERN
TRANSPORTATION
CO. DOCK

Note upstream
limit of movement
of Athabasca
River ice.



FIG. 6

1963 FLOOD
NORTH
TRANSPORTATION
CO. LOCUS

Water level
approximately
Elev. 812.



FIG. 7

1963 FLOOD
CLEVELAND RIVER
AT KING STREET

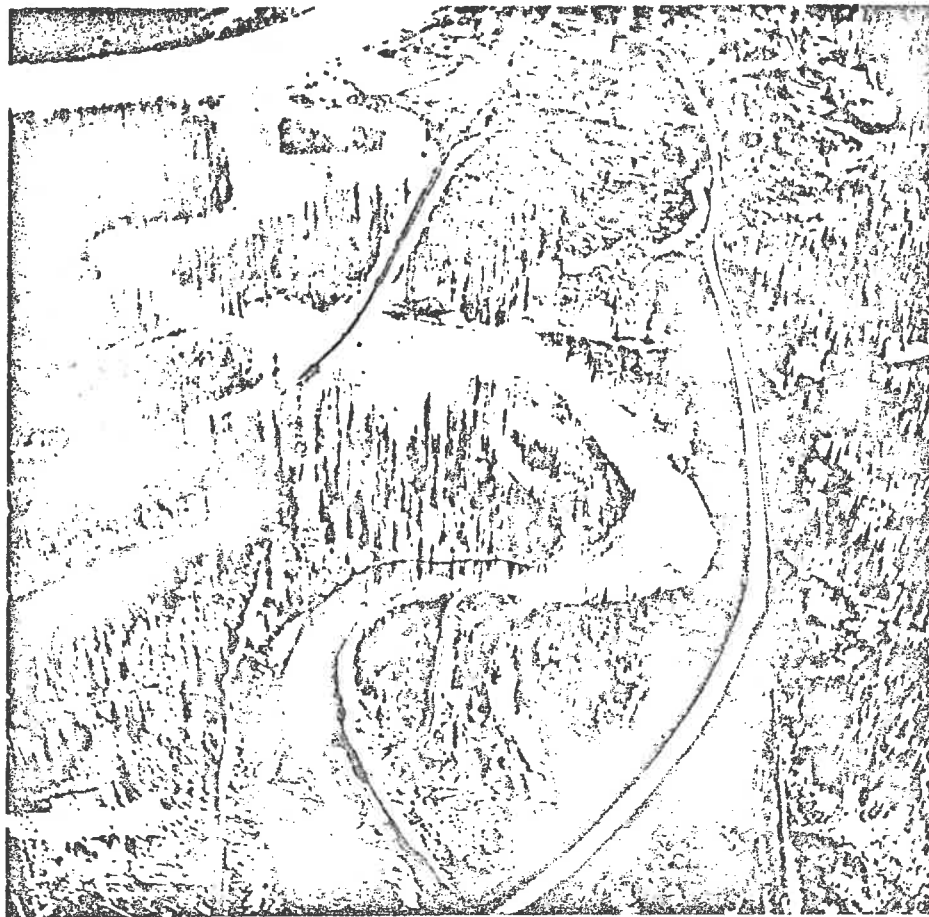


FIG. 8

1963 FLOOD
HAMILGSTONE
CRACK

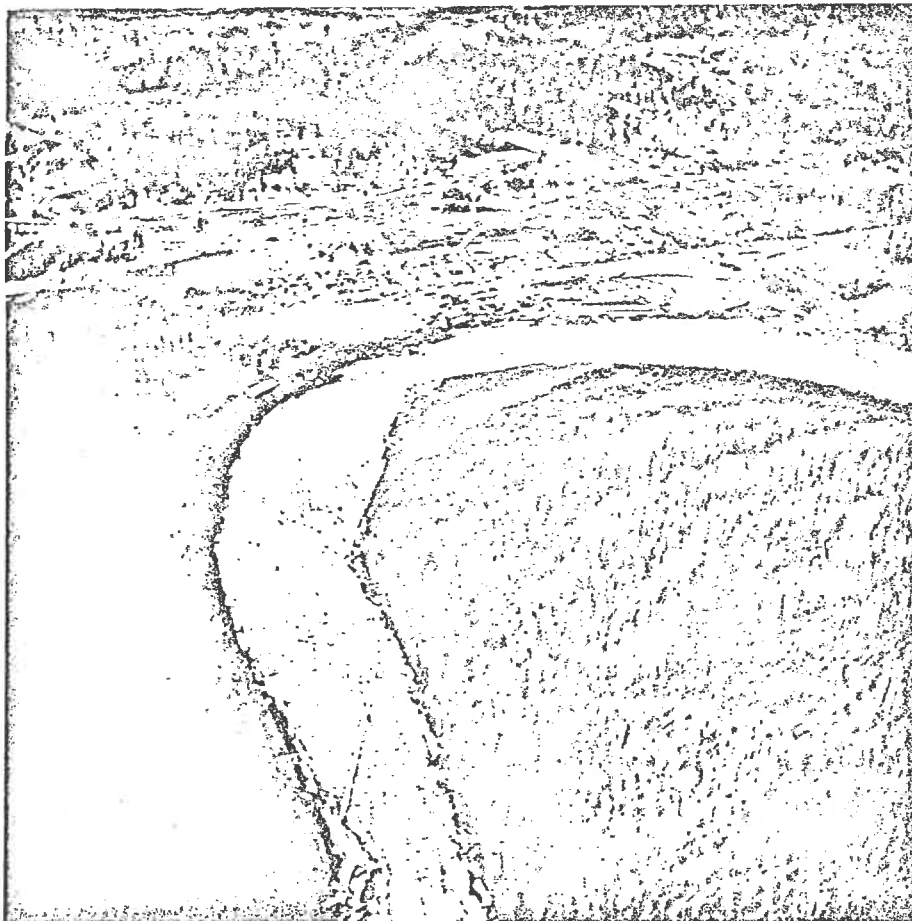


FIG. 9

1963 FLOOD
CLEARWATER RIVER
AT WATERWAYS

AVERAGE RETURN PERIODS
OF
ICE JAM FLOODS

Mc MURRAY, ALBERTA

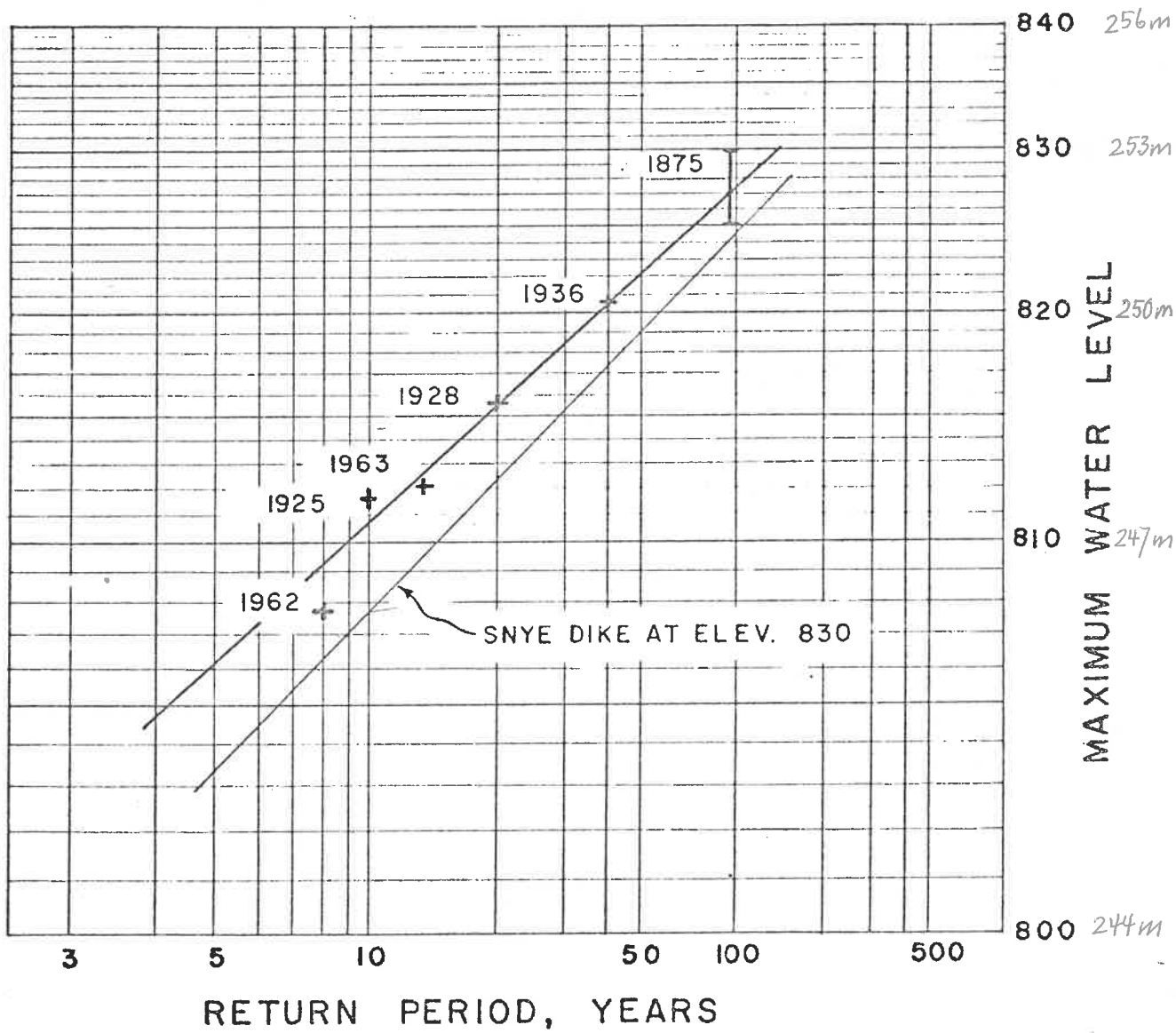
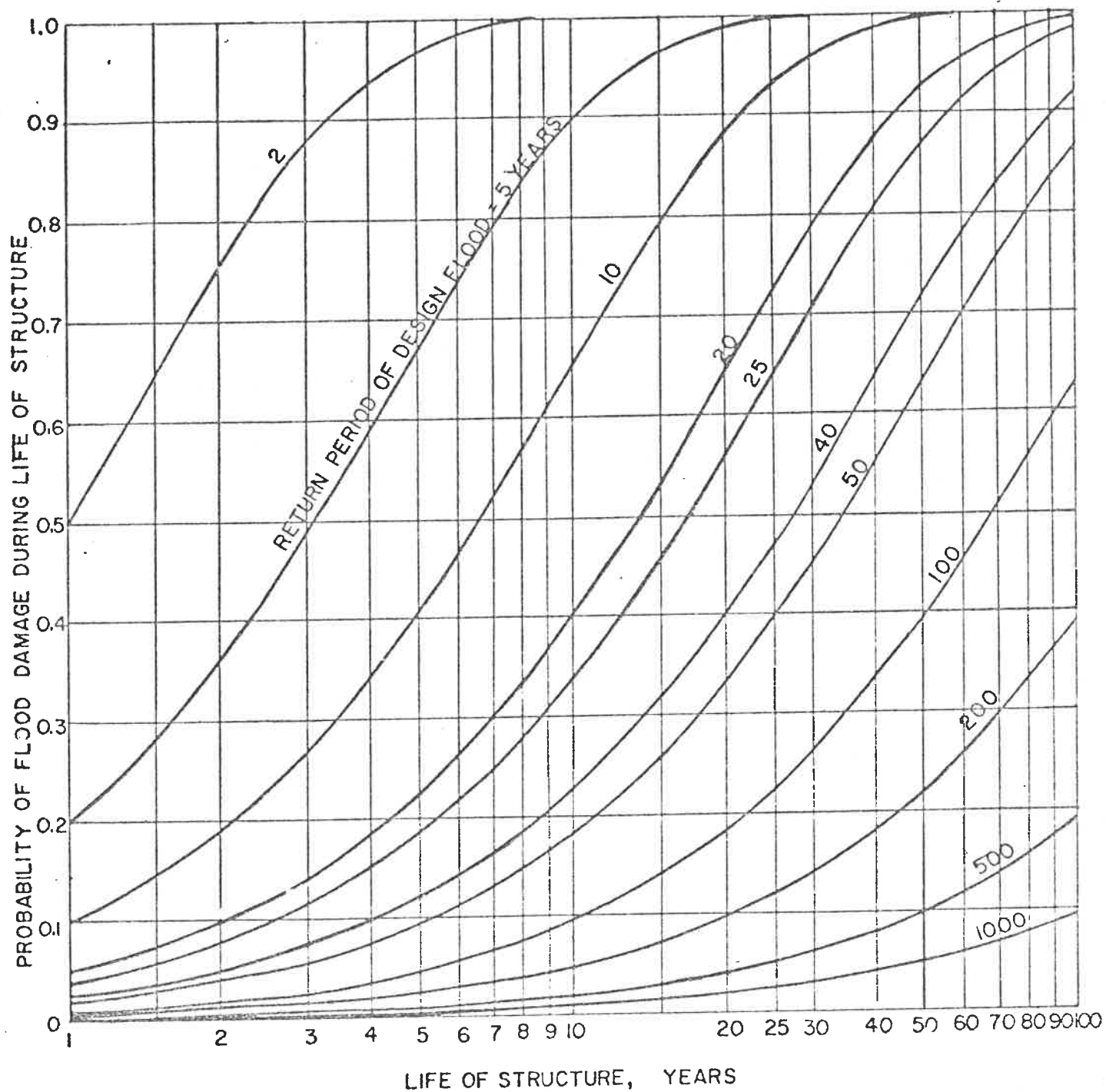


FIG. 10



PROBABILITY OF FLOOD DAMAGE DURING
LIFE OF STRUCTURE

FIG. 11

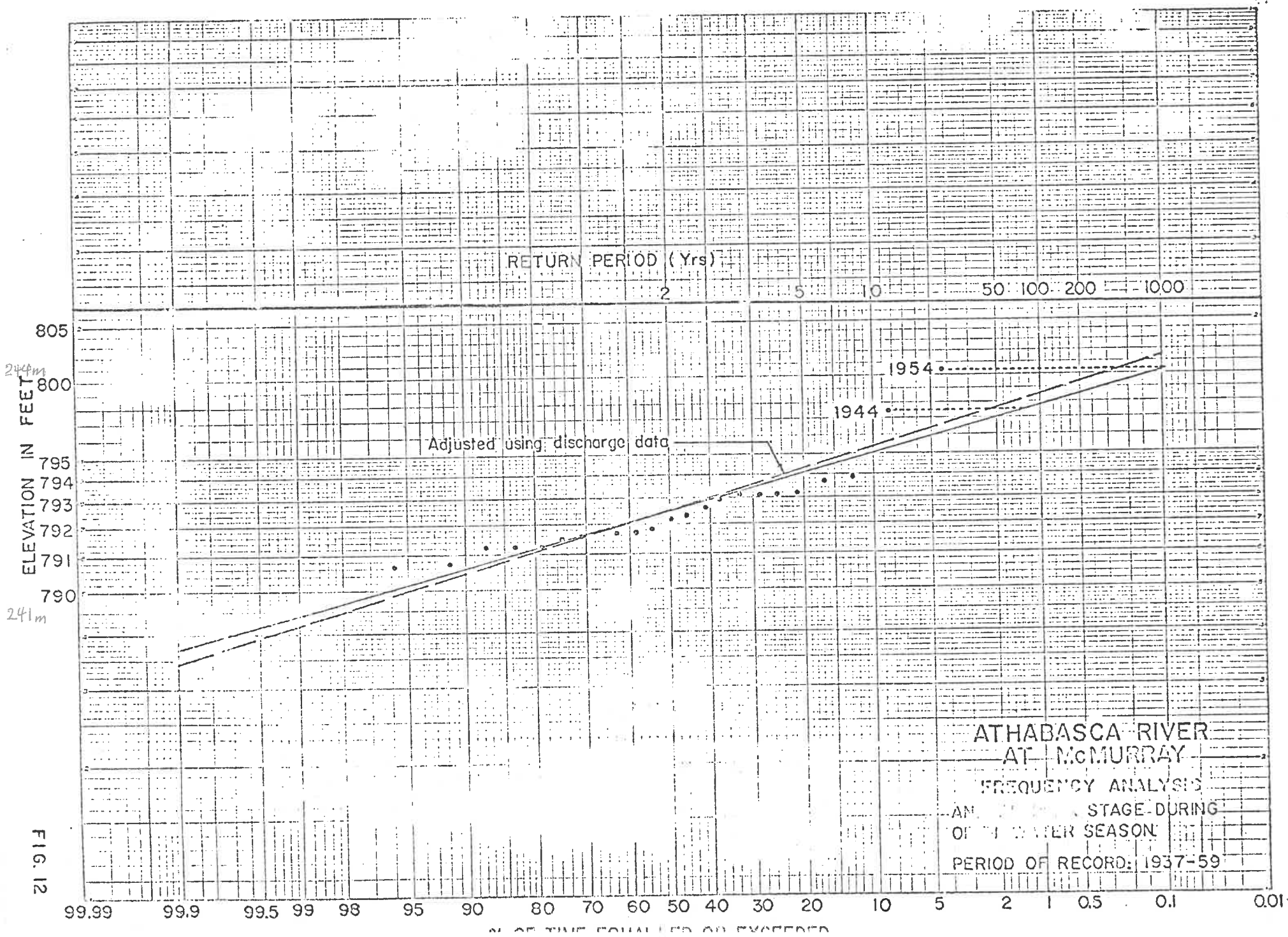


FIG. 12



DISCHARGE
PEAK
C. F. S.
ANNUAL

RETURN PERIOD (Yrs)

2 5 10 50 100 200 1000

1954
1944

ATNADASCA RIVER
AT ATNADASCA

FREQUENCY ANALYSIS
ANNUAL PEAK DISCHARGES
DURING OPEN WATER SEASON
PERIOD OF RECORD: 1914-30
1938-DATE

10,000

99.9 99.8 99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05

TIME EQUALLED OR EXCEEDED

ROCKE ISLAND

McDONALD ISLAND

THE SNYE

LOCATION 3

810

815

820

ATHABASCA

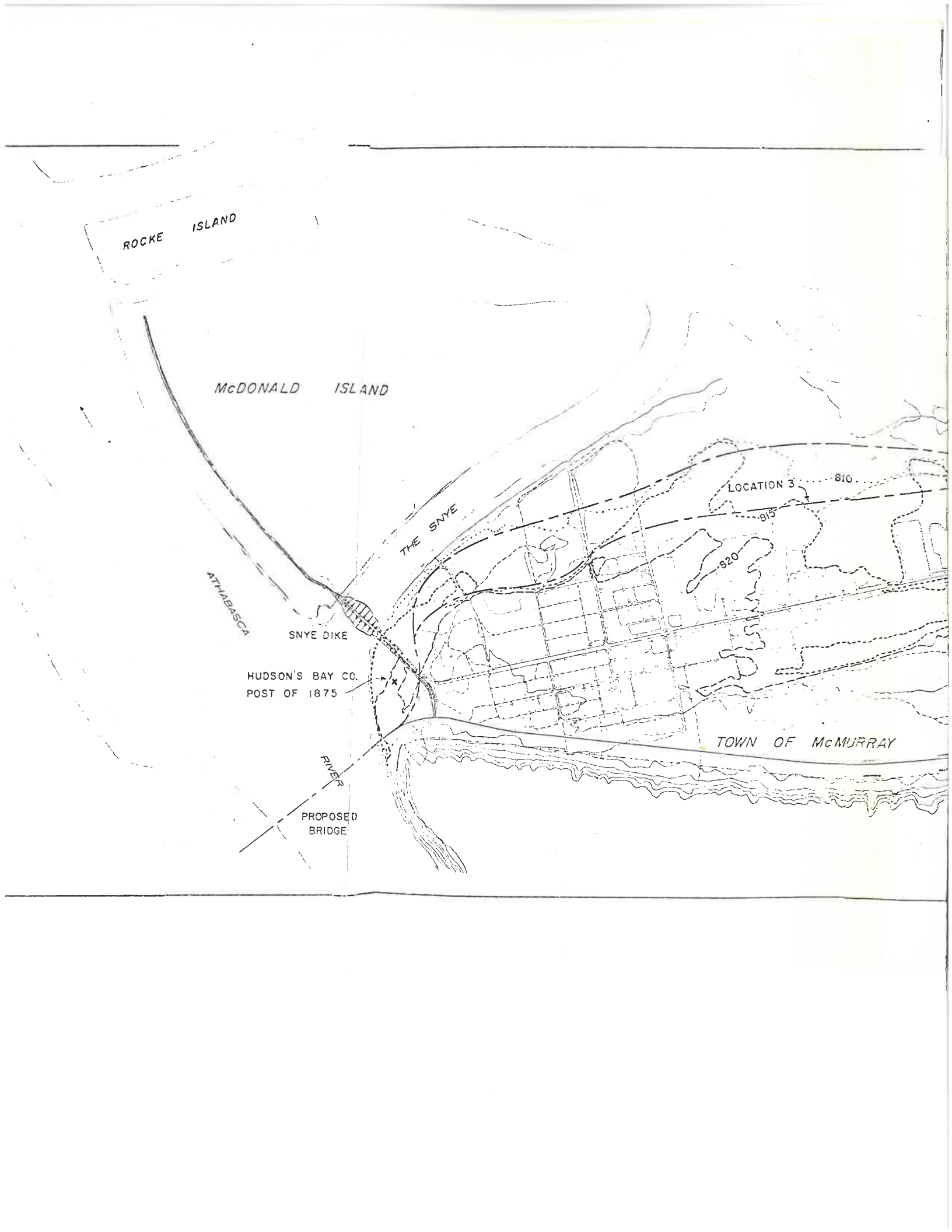
SNYE DIKE

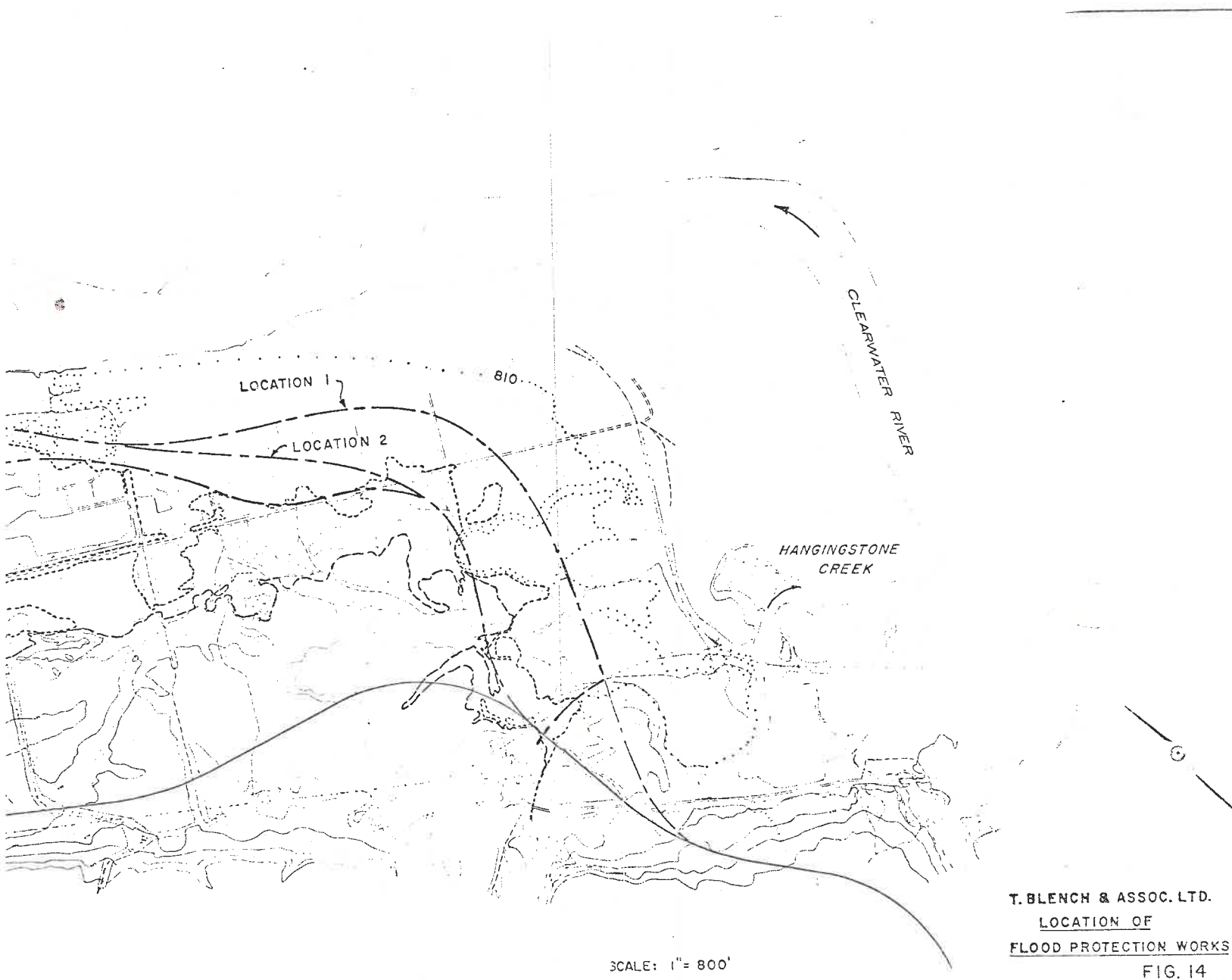
HUDSON'S BAY CO.
POST OF 1875

RIVER

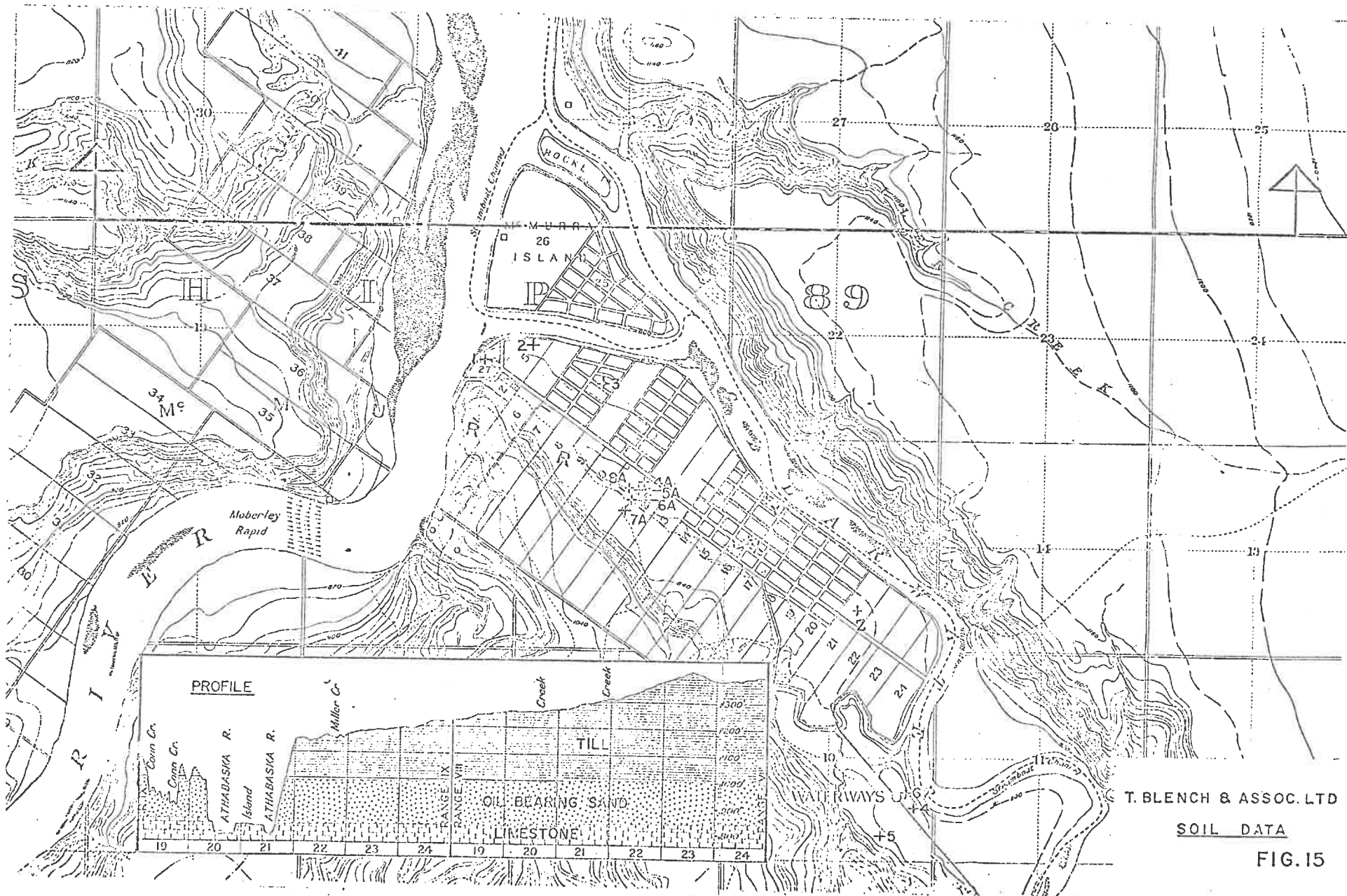
PROPOSED
BRIDGE

TOWN OF McMURRAY

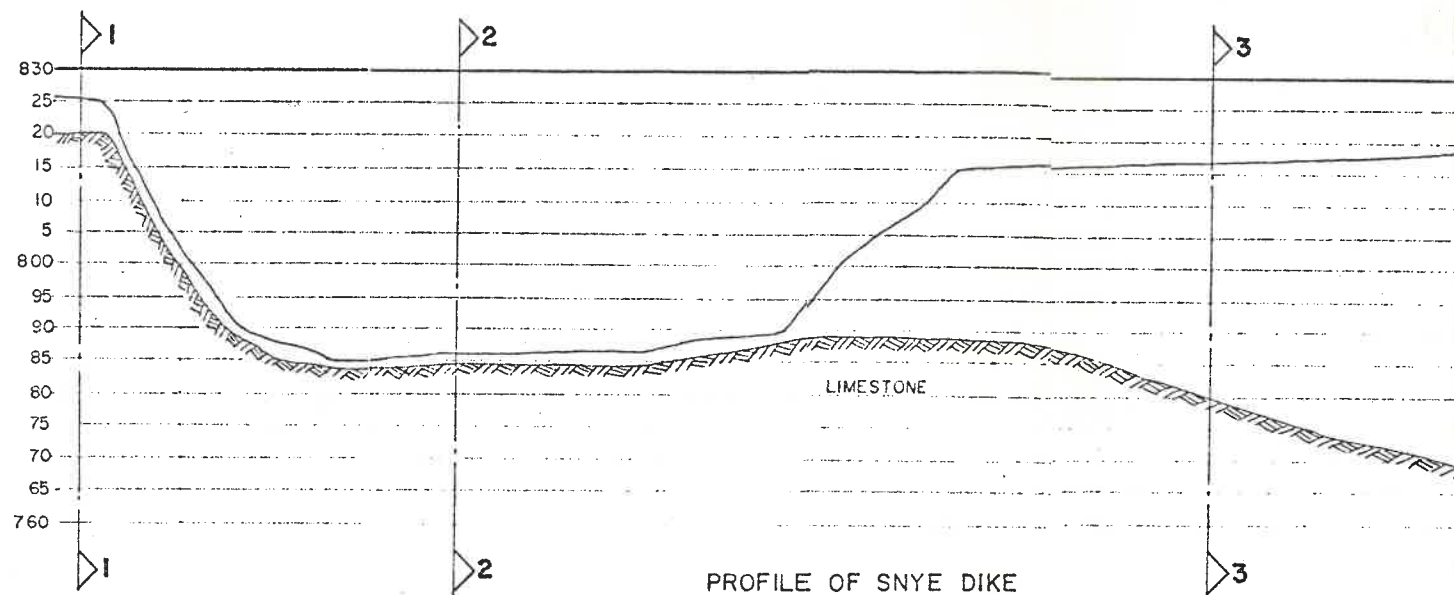




T. BLENCH & ASSOC. LTD.
LOCATION OF
FLOOD PROTECTION WORKS
FIG. 14

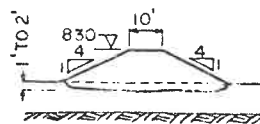


T. BLENCH & ASSOC. LTD
SOIL DATA
 FIG. 15

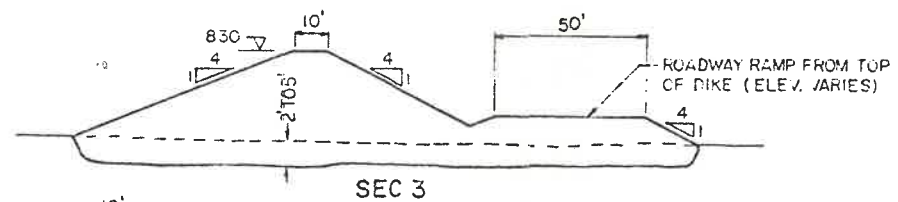


PROFILE OF SNYE DIKE

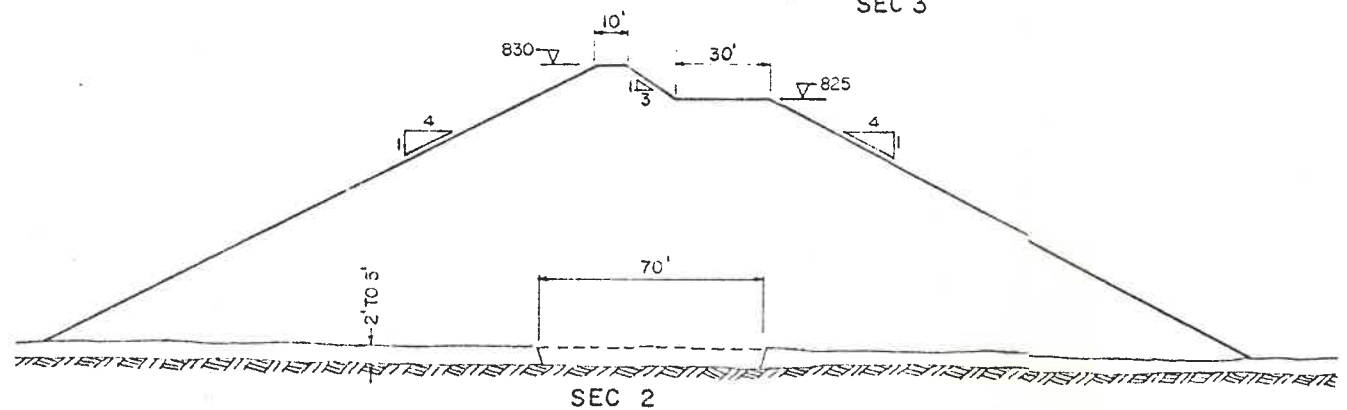
SCALE: Hor 1" = 100'
Vert 1" = 20'



SEC 1

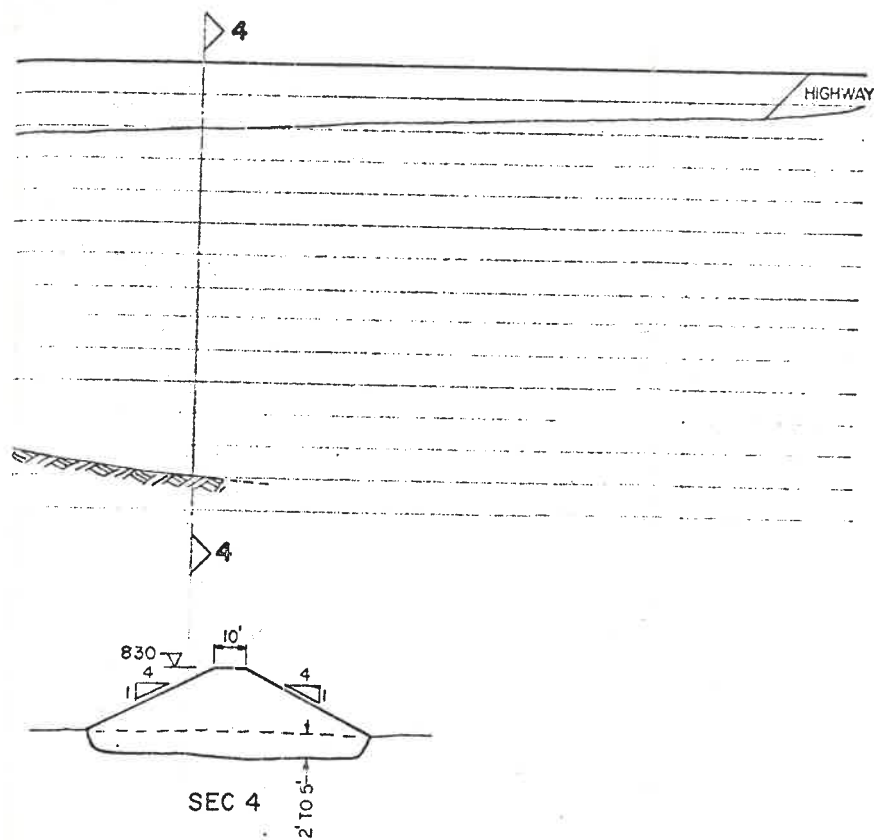


SEC 3



SEC 2

DIKE S
SCALE

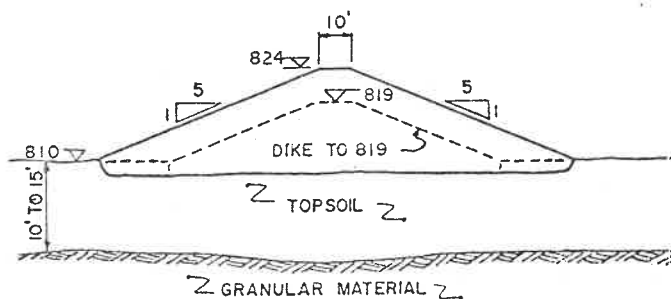
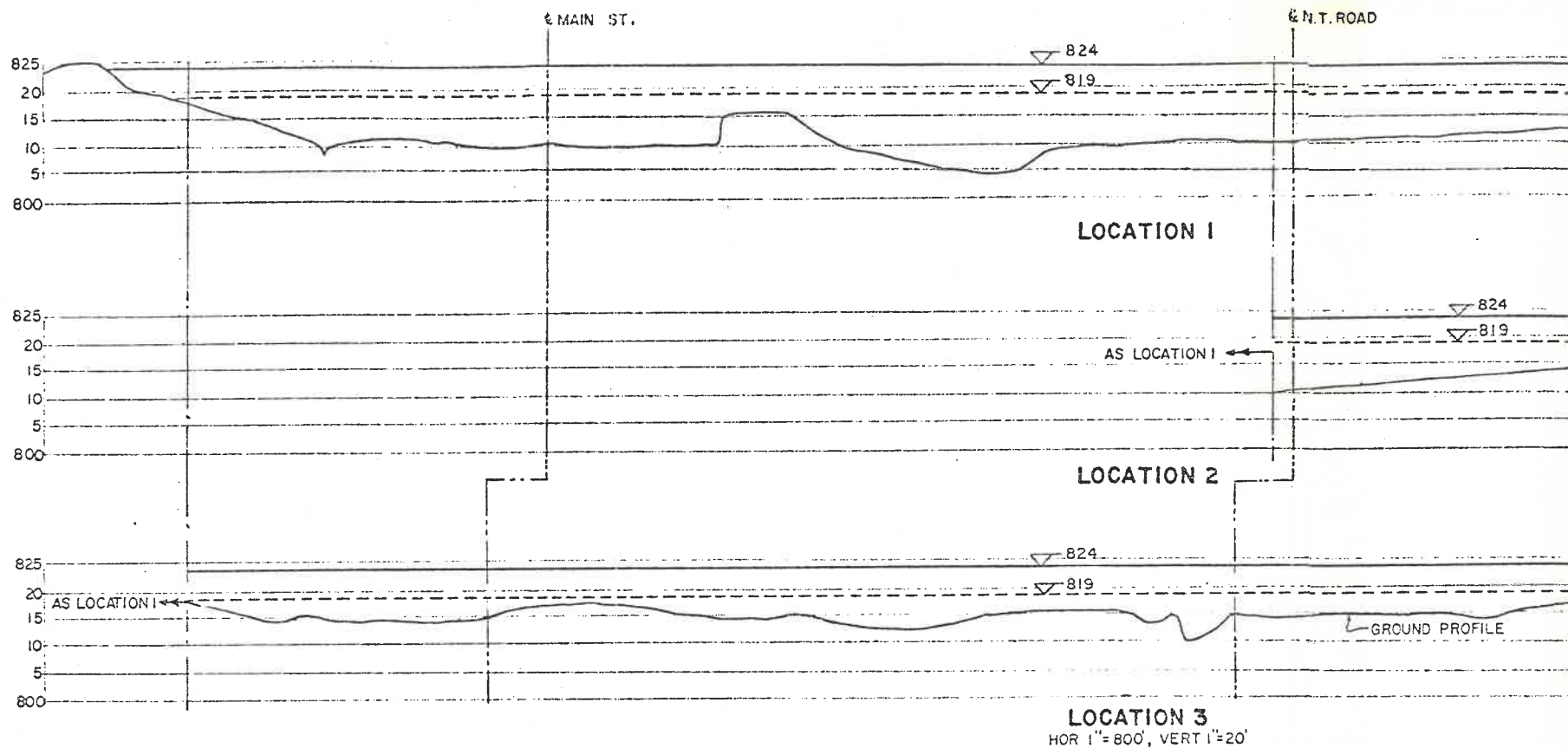


CTIONS

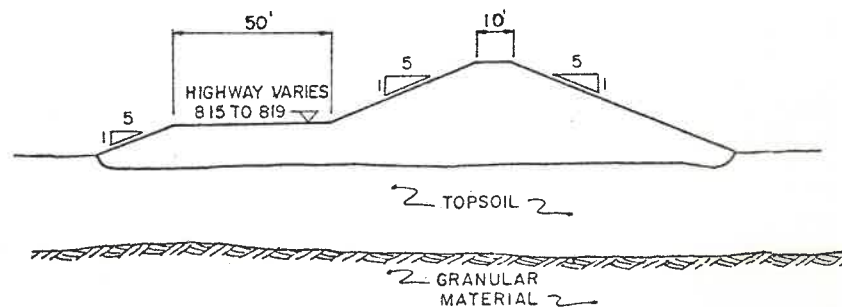
Hor 1" = 40'

Vert 1" = 20'

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PROPOSED FLOOD PROTECTION WORKS
SNYE DIKE
FIG. 16



SEC 1 DIKE ONLY



SEC 2 DIKE & HIGHWAY
 $\text{HOR } 1" = 40'$ $\text{VERT } 1" = 20'$

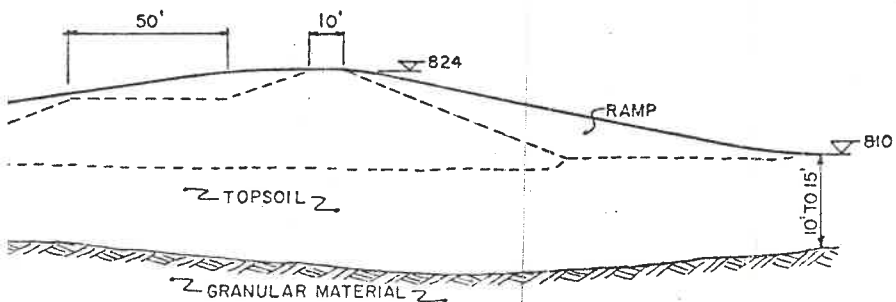


← KING ST. ← FRANKLIN AVE.

GROUND PROFILE

GROUND PROFILE

→ AS LOCATION 2



TYPICAL CROSS OVER SECTIONS

T. BLENCH & ASSOC. LTD.
PROPOSED FLOOD PROTECTION WORKS
TOWN DIKES
FIG. 17

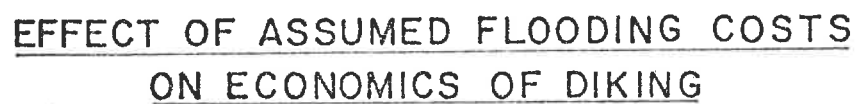


FIG. 18