No. 2

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
TOPICAL REPORT NO. 73

13

MACKENZIE RIVER DRAINAGE BASIN
DAM SITE INVESTIGATION

SITE NO. 10

HORN LAKE DAM SITE

(MAP AND PRELIMINARY REPORT)

BY
E. B. OWEN

OTTAWA
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HORN LAKE DAM SITE

General Description

Horn Lake dam site is the third from the upstream end of a multiple stage power development proposed for McDougall Pass in the Northwest Territories. It is about 3 miles downstream from Bear Creek site, the second site in the development, which is described in Topical Report No. 62.

At Horn Lake site McDougall Pass trends in an easterly direction. It is bounded on the south by a steep, rocky bluff which ascends well beyond the limit of the area mapped and on the north by a series of low bluffs interspaced with narrow terraces which ascend to a height of about 150 feet above the floor of the Pass. Above the latter bluffs a gently undulating terrace extends about one mile north to Horn Lake. The average width of McDougall Pass at the site is about 2,000 feet. A small, fast-flowing stream known as Rat River flows easterly along its south side. In the site area the Rat drops 8 feet within a distance of about 2,700 feet. This is somewhat less than the average gradient of about 25 feet per mile for the Pass as a whole. To develop the entire power potential at the site the reservoir would have to extend back to the tail water of Bear Creek site, a distance of about 3 miles. It would also extend into the valley of Bear Creek the only stream of any size emptying into the reservoir. The difference in elevation between the two sites is about 59 feet. Consequently the dam will be a relatively low-head structure, some 2,600 feet in length, extending from the rock bluff along the south side of the Pass north to the terrace on which stations G-2 and A-17 are located.

Three terraces, 15, 75 and 100 feet above the river, occur on the bluff forming the right (south) abutment. The upper two are narrow, irregular bedrock terraces whereas the lower is the alluvium-covered flood plain of Rat River. Several low river-cut bluffs with an average height of 4 feet occur on the floor of the Pass for about 1,000 feet north of the river. These were probably formed by Rat River when it flowed at a higher elevation. The small, stream-lined deposits of sand and gravel on the terraces separating the bluffs were doubtless formed at the same time.

Unconsolidated Deposits

Four types of unconsolidated deposits were identified at Horn Lake dam site. A fifth type, glacio-fluvial sand and gravel, occurs on the bluff along the south side of the Pass immediately upstream from the site. The deposits at the site are as follows:

1. Recent alluvium: This material consists of silt, sand and gravel which has been deposited by the present Rat River. The gravel contains numerous large, rounded boulders of hard, durable rocks, chiefly quartzite and sandstone, which are not of local origin. The alluvium occurs along both sides of Rat River as well as on the wide bars which, at the site, divide the river into several channels. The coarser material occurs on the bars or beneath the river channels whereas the flood plains along the sides of the river are covered with the finer silty and sandy material.

2. Talus: Talus is material derived from the mechanical disintegration of adjacent bedrock. At Horn Lake site it occurs only on the right abutment where, with the exception of two small outcrops, it

covers the entire slope. On the lower part of the bluff it is covered with a thick layer of moss. The size of the rock fragments varies from sand to irregularly shaped boulders 5 feet in diameter. Much of the talus on the abutment originated in bedrock exposures higher up on the bluff. The thickness of the talus is nowhere believed to be greater than 10 feet.

3. Alluvium: This material consists of stratified silt and fine-grained sand with minor quantities of gravel which covers the floor of the Pass north of Rat River between elevations 785 and 825. It is believed to have been deposited by Rat River when this stream was flowing at a higher elevation. The material is covered with a thick layer of moss and decayed vegetation the bottom part of which is usually frozen. Consequently the alluvium was observed only in the blast holes for the seismic line nearest the river and in a few shallow test pits in areas where the moss cover was thin. The gravel occurs as small, shallow, stream-lined deposits which probably existed as bars in the former river. It is relatively dirty containing a high proportion of silt-size material.

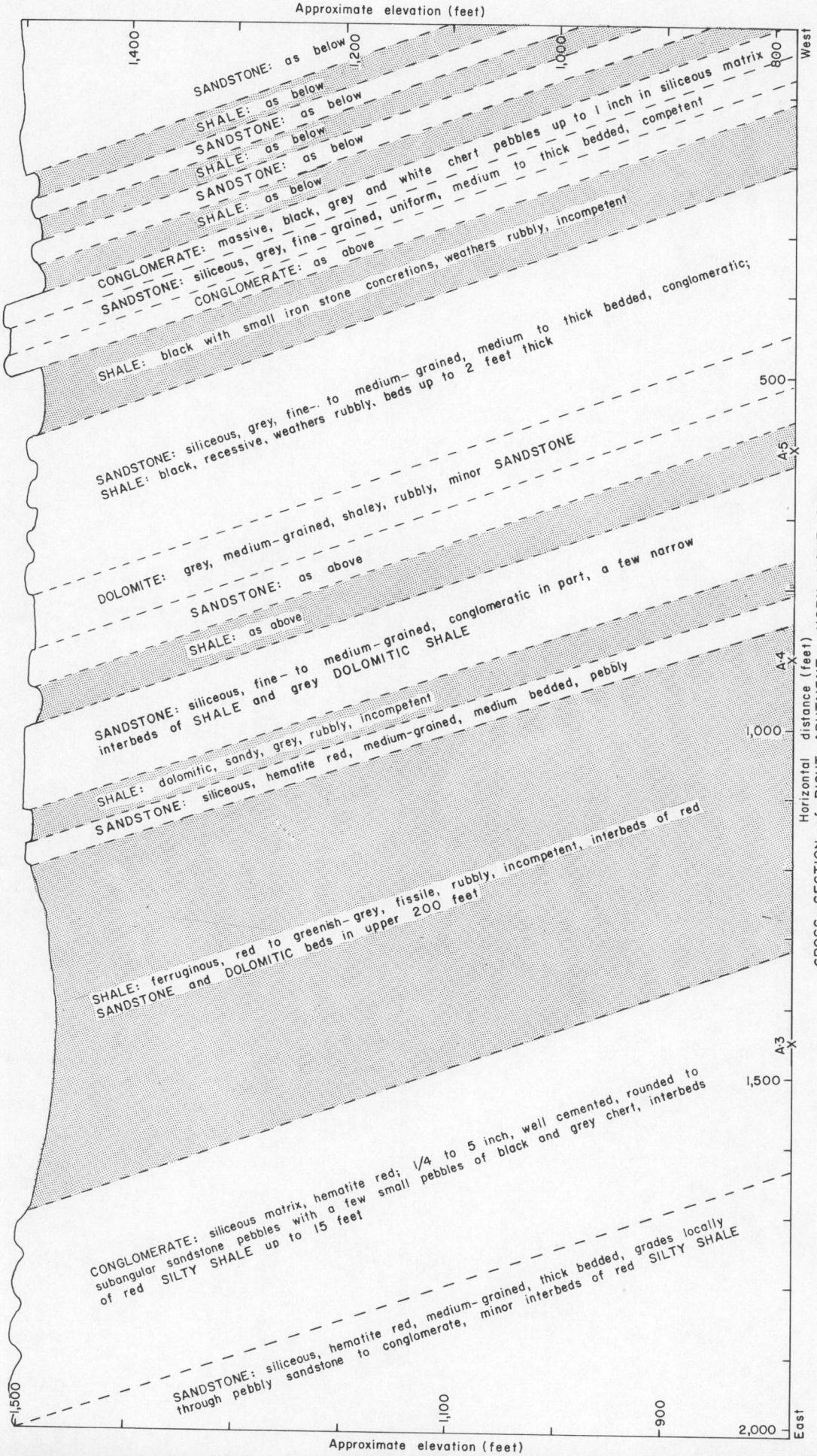
4. Glacio-Lacustrine and/or Alluvium: This material consists of faintly stratified silt and clay with some fine sand which exists above elevation 825 north of the river. The material covers the slope on which the left abutment will be located and extends north across the undulating terrace above the bluff to Horn Lake. It was observed in the blast holes for the seismic line farthest from the river and in several test pits put down on the bluff. The material was frozen in all instances where it was encountered. Irregular ice lenses up to 2 inches in width are

common. A sample taken 3 feet below ground surface was forwarded to the the soils laboratory of the Water Resources Branch in Vancouver. The resultant curve is included at the end of this report.

Bedrock

General Description

Bedrock is exposed only in the right abutment. It consists chiefly of fine- to medium-grained, grey, non-calcareous sandstone interbedded with soft, black, laminated shale. The sandstone varies from thin-bedded where the strata range from 1 to 6 inches in thickness and are separated by thin interbeds of shale to massive, 10-foot beds which are in themselves extremely competent. The rock frequently weathers on surface to a bright orange-brown. Three massive beds of chert conglomerate with an average thickness of 10 feet are interbedded with the massive sandstone exposed at the site. The chert pebbles are well rounded, black, grey and white in colour and are firmly cemented in a siliceous, sandy matrix. They range up to 1 inch in diameter. There are no thick shale beds exposed at the site. However, shale outcrops on the south side of the ridge forming the right abutment and is believed to underlie part of the talus on the abutment slope. A section showing the relation of the various rock strata that occur on the abutment is included on the following page. These would be encountered in any diversion tunnel located in the abutment. The per cent of shale present is about 40.


Approximate elevation (feet)
1,400
1,200
1,000
800
West
SANDSTONE: as below
SHALE: as below
SANDSTONE: as below
SHALE: as below
SANDSTONE: as below
SHALE: as below
CONGLOMERATE: massive, black, grey and white chert pebbles up to 1 inch in siliceous matrix
SANDSTONE: siliceous, grey, fine- to medium-grained, uniform, medium to thick bedded, competent
CONGLOMERATE: as above
SHALE: black with small iron stone concretions, weathers rubbly, incompetent
SANDSTONE: siliceous, grey, fine- to medium-grained, medium to thick bedded, conglomeratic;
SHALE: black, recessive, weathers rubbly, beds up to 2 feet thick
500
A-5
DOLOMITE: grey, medium-grained, shaley, rubbly, minor SANDSTONE
SANDSTONE: as above
SHALE: as above
SANDSTONE: siliceous, fine- to medium-grained, conglomeratic in part, a few narrow interbeds of SHALE and grey DOLOMITIC SHALE
A-4
SHALE: dolomitic, sandy, grey, rubbly, incompetent
SANDSTONE: siliceous, hematite red, medium-grained, medium bedded, pebbly
1,000
SHALE: ferruginous, red to greenish-grey, fissile, rubbly, incompetent, interbeds of red SANDSTONE and DOLOMITIC beds in upper 200 feet
A-3
1,500
CONGLOMERATE: siliceous matrix, hematite red; 1/4 to 5 inch, well cemented, rounded to subangular sandstone pebbles with a few small pebbles of black and grey chert, interbeds of red SILTY SHALE up to 15 feet
SANDSTONE: siliceous, hematite red, medium-grained, thick bedded, grades locally through pebbly sandstone to conglomerate, minor interbeds of red SILTY SHALE
1,500
1,100
900
2,000
East
Approximate elevation (feet)
Horizontal distance (feet)
CROSS SECTION of RIGHT ABUTMENT — HORN LAKE SITE

Bedrock Structures

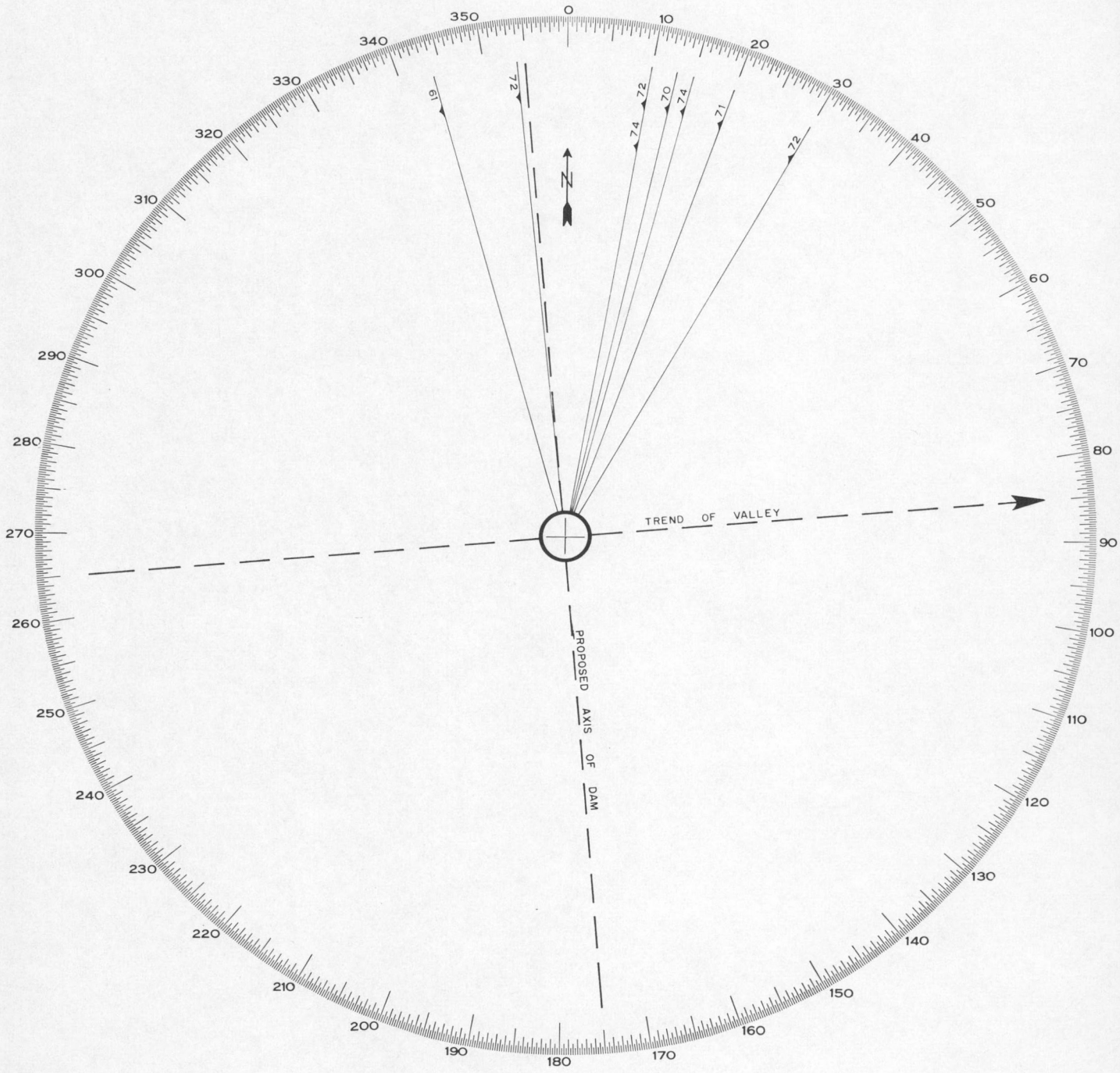
Many of the attitudes on the accompanying rosettes were taken from bedrock exposures above and upstream from the map-area. Those from the latter area were included because these rocks would be encountered in the upper end of the diversion tunnel.

Bedding and jointing are the most important bedrock structures at the site. The strike of the strata varies from north 16 degrees west to north 30 degrees east and the dip in general is about 72 degrees west. Consequently the bedding intersects the proposed axis of the dam at 10 to 30 degrees and dips steeply upstream.

The most prominent joint set intersects the axis at 65 to 90 degrees and dips steeply into the right abutment. The spacing is variable ranging from one inch to several feet.

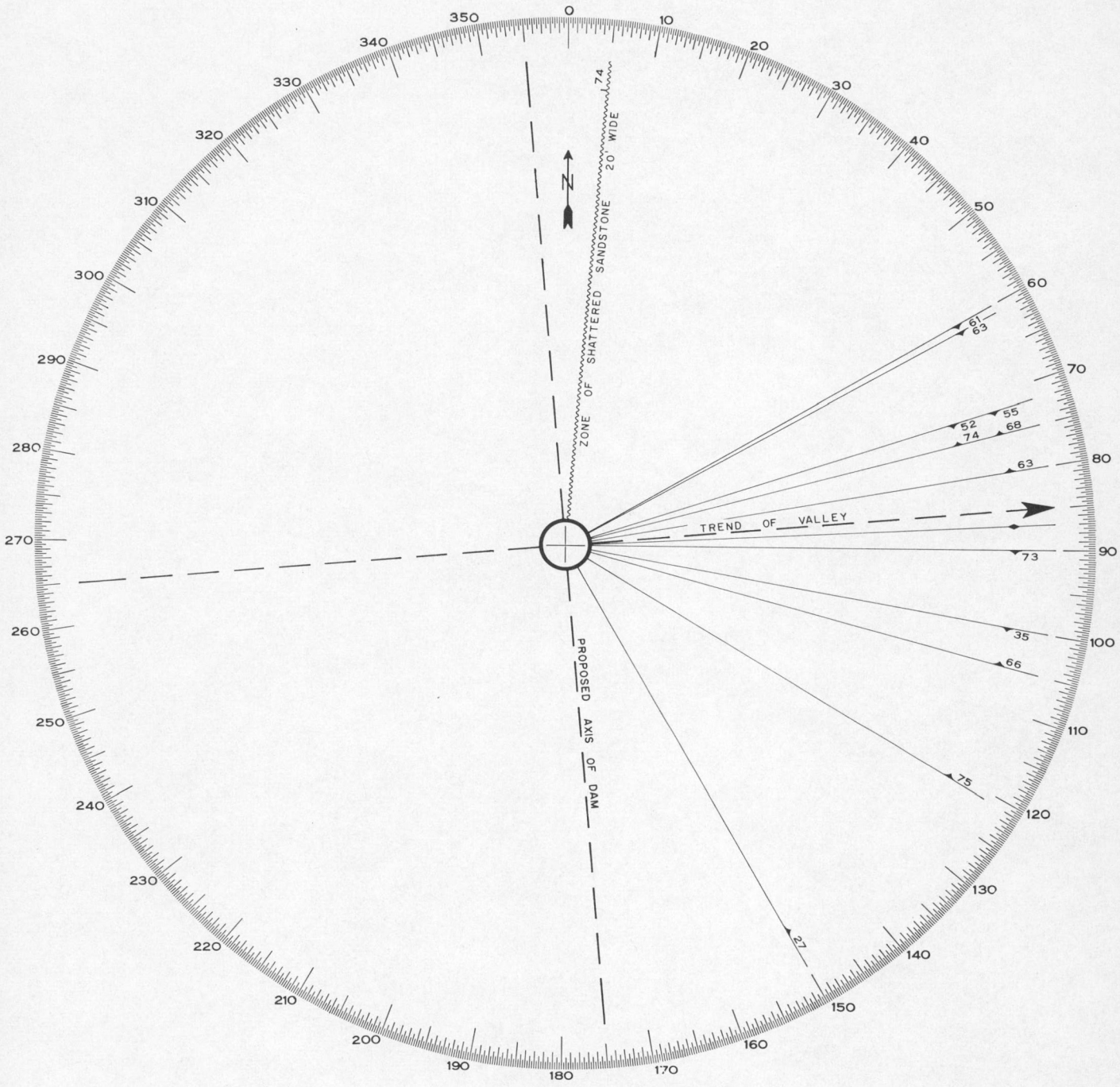
In places slickensliding occurs along the bedding and joint planes indicating some movement has occurred along these surfaces. Impervious, clayey gouge which could influence the movement of groundwater through the rock was not observed in any place and it is doubtful if such material exists.

A 20-foot zone of crushed rock, parallel to the bedding, occurs in the east side of the upstream outcrop. The permeability of the crushed material is probably high. The zone intersects the axis of the dam at 20 degrees and dips west at 74 degrees. The fact the zone is almost parallel to the axis and dips upstream suggests there is less possibility of reservoir leakage than through a similar structure parallel



BEDDING ROSETTE

The above illustration presents diagrammatically the direction and dip of the bedding in bedrock exposed at Horn Lake dam site



JOINT ROSETTE

The above illustration presents diagrammatically the direction and dip of the jointing in bedrock exposed at Horn Lake dam site

to the Pass. Grouting of the crushed rock should be successful as there are few fractures so small they will not be permeated by the grout.

There is geological evidence a fault exists in the rock ridge forming the right abutment. This fault extends from a point two to three hundred feet upstream from the glacio-fluvial deposit on the west side of the ridge in a southeast direction across the south part of the ridge. The fault was not identified in the field but is assumed because there is a distinct displacement in the strata in this area. The fault could be avoided by any diversion tunnel in the abutment by locating the upstream end of the tunnel as close to the south side of the glacio-fluvial material as possible.

There is further geological evidence a large fault intersects McDougall Pass about 2 miles west of the site. This fault which trends in a southwest direction follows along the east side of the rock ridge immediately west of Horn Lake and probably crosses Rat River about a mile downstream from the mouth of Bear Creek. The strike of the fault is probably the same as that of the crushed zone in the right abutment.

Quality of Bedrock

The sandstone which constitutes most of bedrock exposed at the site is a competent rock and should provide suitable foundation and abutment material. However, the presence of interbeds of soft, laminated shale in the sandstone may adversely affect its properties. It is believed more extensive investigations will have to be conducted before the competency of the rock mass can be determined. The more massive

sandstone strata appear to be continuous throughout the area. It might be possible by test borings to select an individual bed on which the dam structures could be placed. If this could be done it would minimize the problems of foundation deterioration during construction, insure better bond with the rock and perhaps increase the strength of the foundation by spreading the bearing load. The sandstone is an impervious, well bonded rock. Any permeability in the rock mass will be due to the many bedding planes and intersecting joint fractures which are present. It is believed these could be cut off by pressure grouting. They would, however, exert considerable influence on the manner in which the rock would break when blasted.

Engineering Considerations

Depth of Overburden

Overburden on the steep, right abutment slope consists of a thin deposit of talus which is nowhere believed to be greater than 10 feet in thickness. The thickness of overburden on the left abutment and on the floor of the valley between the abutments is not known. The results of two refractive seismic profiles, one immediately north of Rat River and the other near the toe of the left abutment, were not available at the time this report was written.

Abutments and Foundations

More information is needed concerning the depth of overburden and the physical properties of bedrock occurring at the site before

the final location of the dam structures can be decided upon. Any diversion tunnel will have to be located in the right abutment. A description of the bedrock which would be encountered in this structure is included on a previous page in this report. The quality of the rock indicates the tunnel would have to be lined. The strike of the beds, which closely parallels the proposed dam axis, and their upstream dip is not favourable for dam construction because the interbedded shale probably has insufficient shear strength to resist the thrust of the dam. Test borings will be required in the left abutment area to determine the types of overburden and bedrock present as well as the elevation of bedrock surface. There is a possibility bedrock is not sufficiently high to provide abutment material for the dam. In this case the ~~south~~ north end of the dam will have to be keyed into frozen, clayey silt probably overlying sand and gravel of glacio-fluvial origin.

Alternate Site

An alternate site where a dam of sufficient height to create a reservoir extending back to Summit Lake exists in the Horn Lake area. The centre line of this dam would extend from the present right abutment to the south end of the rock ridge situated immediately west of Horn Lake. This dam would be considerably longer than the proposed Horn Lake dam but would do away with the dams at Fish and Bear Creeks further upstream. Bedrock exposed in the left abutment of the alternate site consists of massive quartzite and sandstone beds. However, the presence of a large fault along the toe of the abutment should be investigated.

Construction Materials

Aggregate

A small deposit of glacio-fluvial gravel occurs on the right side of Rat River a few hundred feet upstream from the site area. The quantity of natural aggregate available is about 60,000 cubic yards. The material consists of a coarse-grained, sandy gravel containing rounded to sub-rounded boulders of quartzite and sandstone up to 18 inches in diameter. Also included are a few well-rounded boulders of pink and grey granite. The gravel is exposed on a wide slope which rises 125 feet from the edge of the river. The elevation of the terrace at the top of the deposit is about 915 feet. The material is well stratified. The attitude of the bedding indicates it was deposited by water flowing in a westerly direction through McDougall Pass. A sample was forwarded to the Soils Laboratory of the Water Resources Branch in Vancouver for grain size analyses. The resultant curve is included at the end of this report.

The alluvial deposits of sand and gravel separating the numerous channels of Rat River at the site are a potential source of natural aggregate. The material is not frozen near surface and consequently the upper part should be relatively easy to excavate. The quantity available is at least 200,000 cubic yards. It is suggested test pits be put down, preferably during a period of low water, to determine the quality of the material and the depth to the frost line. Test borings would not be effective in sampling the material because of the many large boulders present.

Satisfactory fine and coarse aggregate could probably be manufactured from the sandstone exposed in the right abutment. The crushed material would have to be processed to eliminate the physically unsound shale. Bedrock more suitable for production of aggregate is exposed on both sides of the Pass about one-half mile upstream from the site. The rock consists of massive beds of quartzite and sandstone up to 10 feet in thickness. Narrow shale interbeds do not occur in these rocks although more massive shale beds are exposed along the west sides of the outcrops.

Impervious Material

The sandy, clayey silt which covers the terrace extending north from the left abutment to Horn Lake may be suitable for the impervious core of an earth or rock-fill dam. The thickness of the deposit is unknown as the frost line was encountered at 3 feet in the few test pits put down on the terrace. The silt readily thaws when the overlying layer of moss has been stripped. The resultant material is very fluid and could possibly be transported to the site by gravity. A grain size analyses curve for the material accompanies this report.

Pervious Material

The sand and gravel described under the aggregate heading could probably be processed to provide material suitable for the pervious shells, filters or drains of an earth dam. The quantity available, however, is small.

Riprap and Rock Fill

Suitable riprap and rock fill can be obtained from the massive sandstone beds exposed in the right abutment. However, much of the rock here consists of thin-bedded sandstone and shale and consequently only a portion of the fragments obtained will be satisfactory. Better material will be obtained from the massive quartzite and sandstone beds exposed on the ridge west of Horn Lake and from another smaller ridge of the same rock on the south side of the Pass about a mile upstream from the right abutment. Both ridges are easily accessible.

Groundwater

There is little information concerning groundwater conditions in the area about the proposed site. Seepages were not observed in either of the proposed abutments nor is there any indication they have occurred in the past. The terraces north of Rat River were very wet with one small pond located on the floor of the Pass. Considerable groundwater was encountered in all the test pits put down on the terraces usually immediately above the frost line.

Frozen Ground

Frozen ground is believed to exist beneath the entire site area. The alluvial silt and sand near the river are completely frozen and the frost line exists about 3 feet from ground surface in the silt on the upper terrace north of the site (July 26, 1962). Frost was not observed in the coarse alluvial gravels along Rat River but it probably exists at greater depths. Dry frozen conditions probably exist in bedrock in the right abutment.

Further Investigations - Conclusions

It should be remembered this report is based upon a preliminary geological investigation designed to furnish the engineer with general geological information regarding the proposed dam site. The data compiled is only sufficiently precise to permit office studies and obtain general cost estimates. In the case of alternate sites it is sufficiently accurate to aid the engineer in determining the most economic and suitable site.

It is believed more information is needed before the suitability of Horn Lake dam site can be assessed. The competency of the interbedded sandstone and shale in the right abutment should be determined. More information is required concerning the quality and thickness of the overburden covering the floor of the Pass and the left abutment. The various rock types and the elevations of the surface of bedrock underlying the overburden should be known. If the elevation of bedrock surface beneath the left abutment is low it is suggested the alternate site be considered. Here bedrock is exposed on both abutments. The availability of suitable material suggests a rock-fill type dam should be considered.

Chemical Analyses of Rat River Water

During the 1962 field season samples of Rat River water were taken at Fish Creek dam site about 6 miles west and at the point where Rat River leaves McDougall Pass and enters MacKenzie Delta. The samples were analysed for their mineral content by the Industrial

Waters Section, Mines Branch, Department of Mines and Technical Surveys, Ottawa. The reports on the analyses are included in the report on the Fish Creek site (Topical Report No. 71).

Grain Size Analyses Curves

The grain size analyses curves included in this report were prepared in the Soils Laboratory of the Water Resources Branch in Vancouver. The grain size sheet for potential aggregate shows the following information:

(a) Limits of coarse and fine aggregate based upon a 6-inch maximum size.

(b) A cumulative grain size curve for the sample.

(c) A curve showing the individual percentages of the coarse and fine fraction retained on each screen or sieve size. For these purposes the sample is divided at the No. 4 sieve into coarse and fine fractions. Sample No. 4 was analysed as potential aggregate and sample No. 5 as potential impervious material.

Description of Potential Aggregate for the following Grain Size Analysis Curve

Sample Number	Location	Field Description of Material	Field Description of Overburden	Thickness of Deposit	Volume (Estimated)	Remarks
4	Bluff on right side of Rat River; 400 feet west of right abutment	Well graded, sandy gravel; very little silt or clay; stratified; numerous rounded to subrounded boulders up to 18 inches Cobble and Boulder Lithology Sandstone - 70% Quartzite - 20% Shale - 5% Granite - 4% Gneiss - 1%	None	125 feet	60,000 cubic yards	Easily accessible; overlies bedrock

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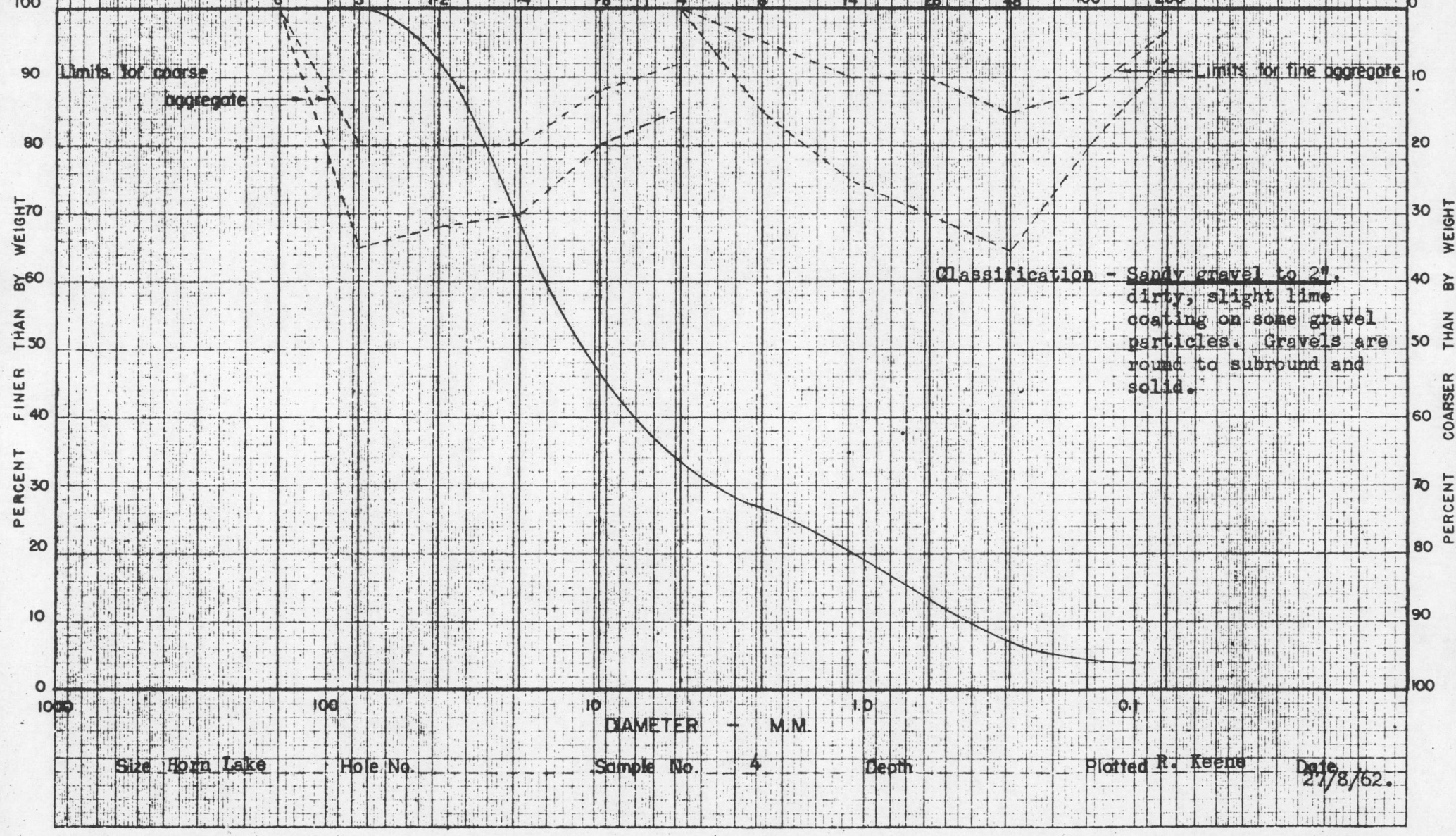
GRAIN SIZE ANALYSIS For CONCRETE AGGREGATE RECONNAISSANCE



Classification - Sandy gravel to 2", dirty, slight lime coating on some gravel particles. Gravels are round to subround and solid.

Size Horn Lake Hole No. Sample No. 4 Depth Plotted R. Keene Date 27/8/62.

Description of Potential Impervious Material for the following Grain Size Analysis Curve

Sample Number	Location	Field Description of Material	Field Description of Overburden	Thickness of Deposit	Areal Extent (Estimated)	Remarks
5	Left abutment bluff; approximate elevation 900; 3 feet beneath ground surface; immediately above frost line.	Sandy, clayey silt; grey, stratified; no pebbles	None	3 + feet	Unlimited	Fluid when thawed

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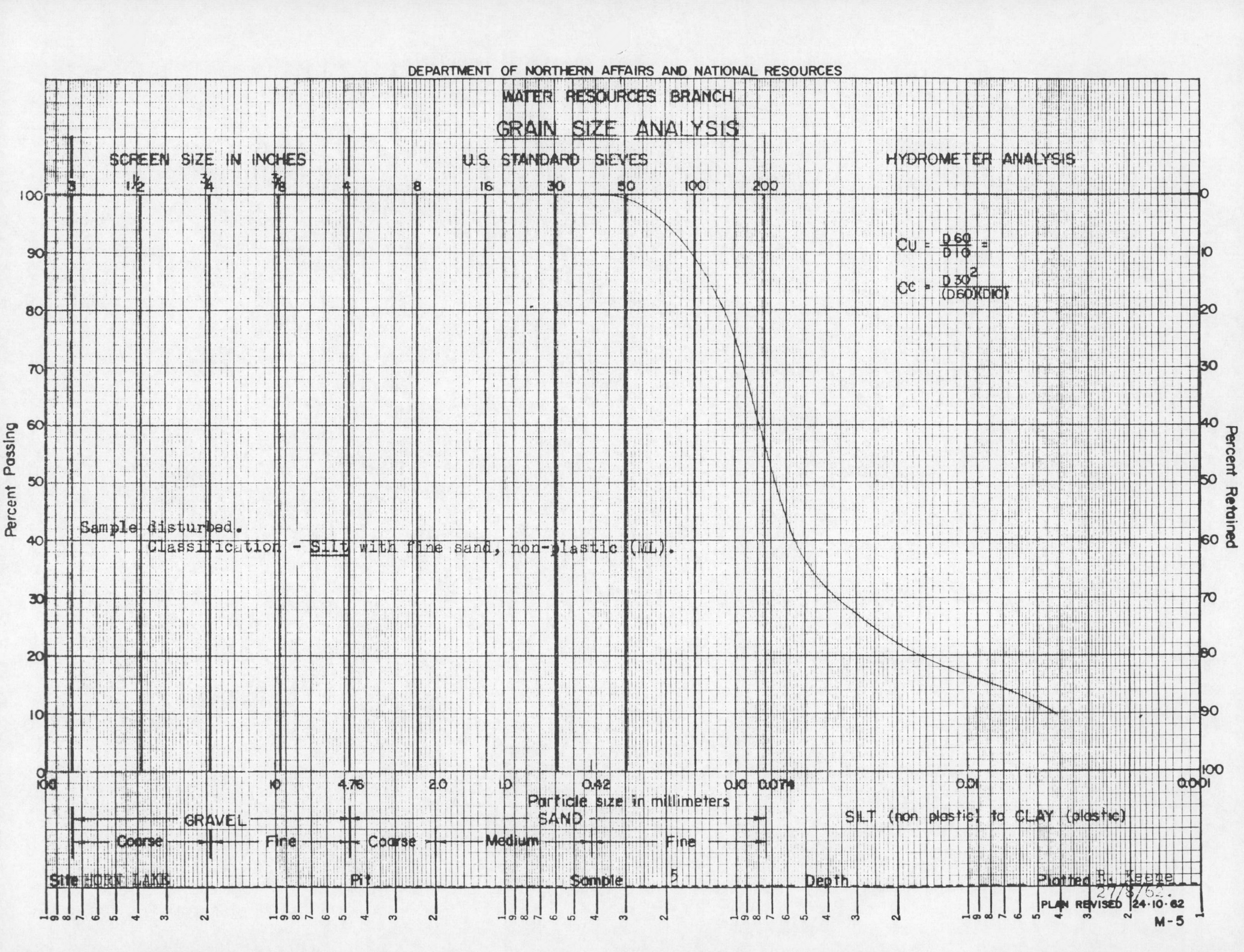
WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS



PLAN REVISED 24-10-62

M-5

Plate 1

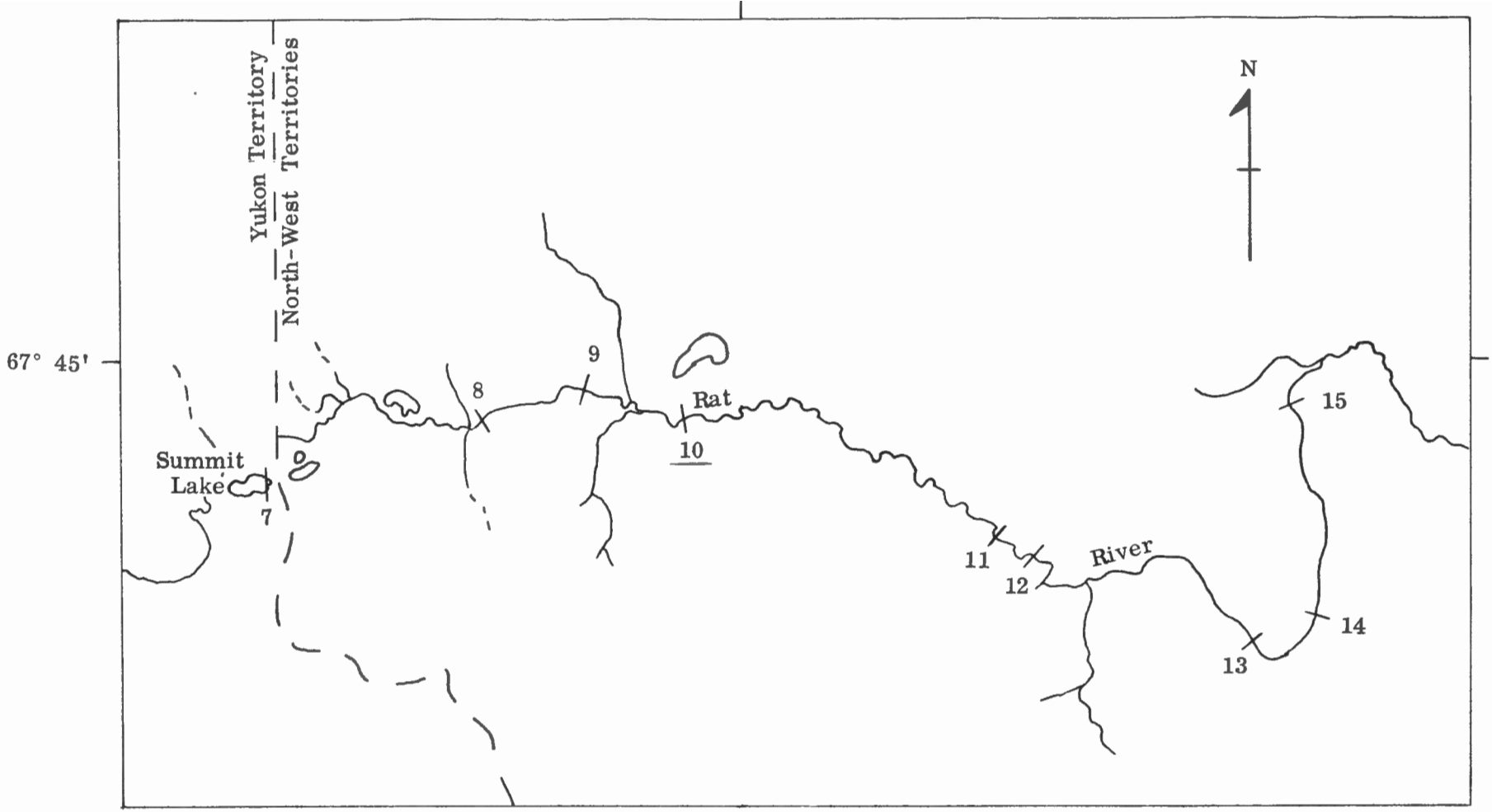
Right abutment, Horn Lake dam site, Rat River in foreground.

G. S. C. 14-3-62

Plate 2

View north along centre line; bluff with terraces is left abutment.

G. S. C. 15-6-62



LOCATION OF PROPOSED DAM SITES
MACKENZIE RIVER DRAINAGE BASIN
Scale: 1 inch to 4 miles (approx.)

Site No.	Name	Site No.	Name	Site No.	Name
7 -	Summit Lake	10 -	Horn Lake	13 -	Barrier
8 -	Fish Creek	11 -	Rat Canyon (Upper)	14 -	Longstick
9 -	Bear Creek	12 -	Rat Canyon (Lower)	15 -	Delta