No. 2

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

TOPICAL REPORT NO. 24

YUKON RIVER DRAINAGE BASIN
DAM SITE INVESTIGATION

SITE NO. 17

BOUNDARY DAM SITE

(MAP AND PRELIMINARY REPORT)

BY

E. B. OWEN

OTTAWA
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Boundary Dam Site

General Description

Boundary dam site is located on Yukon River immediately upstream from the International Boundary between Alaska and Yukon Territory. The International Boundary forms the western limit of the accompanying geological map. At the site Yukon River is flowing in a westerly direction. The elevation of its water surface on August 1, 1960 was approximately 865 feet above sea level.

The right abutment of the proposed dam is located in a steep bluff which rises abruptly from the right edge of the River to an elevation higher than 2,000 feet. The material exposed in this bluff from the edge of the River up to elevation 1,170 is described on the accompanying geological map.

An irregular bluff, 40 to 100 feet in height, occurs along the left edge of the River. A terrace with an extremely uneven surface extends from this bluff south for a distance of 2,000 feet to the toe of a steep bluff in which it is proposed to locate the left abutment.

The relief of the terrace is about 100 feet. Much of its unevenness is due to concentrations of large, rock blocks which appear to have been thrust upward by frost action from the underlying bedrock. These areas have been described in the accompanying geological map as felsenmeer. The results from seismic line No. 1 indicate the thickness of overburden on the terrace about 800 feet south of Yukon River varies from 62 to 65 feet. These figures are believed to be too great. The thicknesses 6 to 10 feet, obtained from seismic line No. 2, are probably more accurate.

Bedrock is extremely weathered and frequently highly sheared and altered. Extensive investigations of bedrock will have to be conducted both in the field and in the laboratory to determine if it will provide satisfactory abutment and foundation material.

There is a lack of overburden suitable for construction purposes in the area. Frozen ground was encountered in most test pits put down on the terrace south of the River. It is believed to be present beneath the entire area mapped. The area is outside the limit of the last extensive Pleistocene ice-sheet.

Unconsolidated Deposits

Five types of unconsolidated deposits have been identified in the area adjacent to Boundary dam site. These are as follows:

1. Recent Alluvium: This material varies from a soft, silty sand to a coarse gravel with boulders up to 12 inches in diameter. It is an unimportant, recent deposit formed by the present River. It extends along both sides of the River below approximate elevation 870 and forms a low bar which extends out into the River from the right bank. A small, gravel deposit occurs at the mouth of a creek which enters Yukon River about 1,000 feet upstream from the map-area.

2. Alluvium (silty sand): This material consists of a compact, fine-grained, silty sand which covers part of the terrace south of the River. Most of the swamp on the terrace is underlain by silty sand. It is a thin deposit varying in thickness from 2 to 6 feet. It usually overlies residual soil.

3. Talus: Talus is spalled material derived from bedrock exposed along a bluff. It usually occurs along the lower parts of the bluff as rock fragments ranging in size from sand to boulders several feet in diameter. Talus occurs extensively on the right abutment slope and to a lesser extent on the low bluff along the left edge of the River. The material consists of relatively small, rock fragments, many of which are schist. This talus is recent with additional material constantly being added from adjacent outcrops. An older talus occurs on and along the base of the steep bluff south of the

terrace. The rock fragments are large and consist almost entirely of greenstone. Much of the material is covered with a thick layer of moss and it is evident little has been added recently. This talus should be investigated as a possible source of riprap or rock fill.

4. Residual Soil: Residual soils are derived by weathering of the underlying bedrock. The material consists chiefly of silt and fine sand in which are scattered numerous, angular, partly weathered fragments of bedrock up to 2 inches in diameter. In some localities the clay content is appreciable. Residual soil occurs extensively on ground surface on the terrace south of the River and considerable quantities are mixed with the fine talus on the right abutment slope. It is also exposed in several recent slide scars along the left edge of the River. The thickness of the residual soil is believed to vary from 2 to 4 feet with somewhat greater thicknesses in low places where it could accumulate from adjacent bedrock exposures.

5. Felsenmeer: The term felsenmeer [1] has been used for any considerable area usually fairly level or of only gentle slope which is covered with moderate-size or large blocks of rock. A large part of the terrace south of the River is covered with Felsenmeer. It was apparently formed by upheaval and disintegration of large blocks of bedrock by frost action. The rock blocks of the Felsenmeer consist almost entirely of fairly massive greenstone. In some parts, however, there are areas up to 200 feet in length where the rock blocks consist of white quartz. The quartz was probably derived from large veins intruding the greenstone.

Bedrock

General Description

Bedrock in the area about the dam site has undergone a considerable

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[1] Sharpe, C. F. S., ;"Landslides and Related Phenomena"; No. 2 of the Columbia Geomorphic Series: 1938, p. 40.

amount of alteration and shearing. Weathering is extensive especially in the more schistose phases. South of Yukon River outcrops are scarce and bedrock is exposed only on the tops of knolls and in the bluff along the left edge of the River. Bedrock is visible in about 25 per cent of the right abutment slope.

Bedrock south of Yukon River consists of fairly massive greenstone with irregular occurrences of chlorite schist. The term greenstone is used to describe altered, volcanic or intrusive basic rocks. Their present mineralogy consists of hornblende and secondary feldspars (amphibolite) and fine-grained albite along with epidote-group minerals (saussurite).

Bedrock exposed on the right abutment slope consists of altered, igneous and sedimentary rocks in close association. These rocks are more schistose than those south of the River and the alteration of the greenstone is principally to saussurite. Thin beds of black phyllite and grey quartzite occur in the upper part of the bluff at approximate elevation 1,100 feet above sea level. These beds apparently strike in a northwest direction and dip approximately 45 degrees northeast.

The rocks occurring at Boundary site appear to be similar to those on the Alaskan side of the International Boundary which have been described by Mertie [1]. On the geological map which accompanies this preliminary report these rocks have been described as Palaeozoic (?). Crinoid stems* indicative of Palaeozoic age have been found in an exposure of limestone on Boundary Creek one mile upstream from Yukon River. This occurrence is about two miles southeast of the dam site area.

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[1] Mertie Jr., J.B.; "The Yukon-Tanana Region, Alaska"; U.S. Dept. of the Interior, Bull. 872, 1937.

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* L. H. Green, personal communication

Bedrock was more easily identified on the steep right abutment slope because the weathered material is constantly being removed resulting in the exposure of relatively fresh rock. More accurate measurements of the strike and dip of the jointing and schistosity could also be obtained.

Bedrock Structures

There are three planes of schistosity traversing bedrock in the area about the proposed dam site. The most prominent plane intersects the centre line at about 35 degrees and dips upstream at 30 degrees. Another intersects the centre line at 60 degrees and has an upstream dip of 35 degrees. The third and least pronounced plane is almost at right angles to the centre line and dips toward the right abutment at about 40 degrees.

Considerable jointing is present in the rock. One prominent set intersects the centre line at 50 degrees and is almost vertical. A second set is at right angles to the other but dips downstream at approximately 60 degrees. The attitudes of both jointing and schistosity have been plotted on the accompanying geological map.

Quality of Bedrock

The considerable weathering and intense alteration and shearing of bedrock at Boundary site indicates intensive investigations will be required before a decision can be reached regarding the suitability of these rocks as abutment and foundation material. For the most part the altered, greenstone rocks appear to be fairly massive and durable. Little residual soil has been derived from them and the talus fragments are frequently large. The schists are soft and easily weathered and thus form the chief source of residual soil. They also tend to separate readily along the planes of schistosity and consequently may not be suitable as foundation or abutment material. This would be especially true in the right abutment area.

Engineering Considerations

Depth of Overburden

Overburden on the right abutment slope consists of a mixture of talus and residual soil. The greater part of the material appears to be talus and consequently it has been mapped as such. The thickness of the material is believed to be less than 10 feet throughout the entire abutment area. The thickness of the overburden covering the terrace south of the River is difficult to assess. It is believed, however, solid rock should be encountered within 15 feet of ground surface throughout the entire terrace except, perhaps, in the low swampy areas where the thickness of the drift may be somewhat greater. The depth of overburden as calculated from seismic line No. 2 (6 to 10 feet) is probably correct whereas that obtained from seismic line No. 1, (62 to 65 feet) is believed to be too great. Information is not available concerning the thickness of overburden beneath the River.

Abutments and Foundations

The schist which constitutes the greater part of the rock exposed on the right abutment slope is not believed to be satisfactory abutment or foundation material. It is a soft, easily weathered rock which tends to separate readily along the planes of schistosity. The upstream dip of the two principal planes of schistosity is favourable for construction of a dam. The altered greenstone outcropping on the terrace south of the River is more massive and may provide a satisfactory foundation for the proposed powerhouse and spillway structures and also prove suitable for the left abutment. Test borings should be put down here to determine the quality of these rocks and to investigate the presence of zones of schistose rock and the extent of weathering. The quality of the overburden underlying the

River is unknown. It is believed to consist of several feet of recent alluvium overlying glacio-fluvial sand and gravel. It is doubtful if till exists beneath the River. The high permeability of the glacio-fluvial materials will necessitate construction of a cut-off trench beneath the proposed rock-fill dam and the placing of an upstream clay blanket to control seepage.

Construction Materials

Aggregate

Except for small quantities of alluvium deposits of natural aggregate do not occur within the area mapped at the site. The nearest large deposit of gravel located upstream from the International Boundary is situated on the right side of Yukon River about six and one half miles upstream from the site. Here about 17 feet of gravel is exposed in a bluff some 45 feet in height. The gravel directly overlies bedrock and is overlain in turn by about 3 feet of silt. The material consists of a sandy gravel containing boulders up to 10 inches in diameter. Some of the larger granitic boulders are considerably weathered.

A second gravel deposit is located on the left bank of Yukon River about 13 miles upstream from the site. Here a bluff, 50 feet in height, consists entirely of well graded, fine, sandy gravel overlain by about 3 feet of silt. The pebbles and cobbles are well rounded with a maximum diameter of 4 inches. Many similar deposits of gravel overlain by minor thicknesses of silt are located along both sides of Yukon River upstream as far as Forty Mile River. In most instances they are easily accessible by River which at the present time provides the only means of haulage to the site.

The presence of well rounded boulders in the talus on the north abutment slope suggests gravel may occur at a higher elevation on the slope north of the map-area. Several test pits were dug in this area and a small deposit

of silty, sandy gravel was found extending 600 feet east from the International Boundary from a point 300 feet north of Yukon River. The deposit is not extensive but because of its proximity to the site it is suggested more test pitting should be done in this area. Much of the area is covered with a thin deposit of fine, silty sand which would have to be removed before the underlying gravel could be used. Grain size analyses curves for samples from seven potential aggregate deposits are included at the end of this report.

Impervious Material

Suitable material in sufficient quantities for the impervious core of the proposed rock-fill dam was not found in the site area. The silt occurring on the terrace south of the River is a thin deposit and does not exist in sufficient quantity to be useful. Similar silts overlie many of the gravel deposits along the River. One occurrence, apparently thicker than the rest, is located one-quarter mile southwest of Yukon River and about three and a half miles upstream from the site. Here about 20 feet of silt is exposed along a small creek. The material consists of a brown silt containing a small quantity of fine sand. Its dry strength is low. A sample (No. 29) of the material was sent to the Soils Laboratory of the Water Resources Branch in Vancouver where a grain size analysis curve was produced. The curve is included at the end of this report. The permeability of this material was computed in the field to be in the order of 10^{-7} cm. per sec. If properly compacted the silt could probably be used as impervious material for the core of an earth-fill dam. Similar material was used at the Whitehorse Rapids Dam on Yukon River a short distance above Whitehorse.

According to Terzaghi [1] ice lenses several feet in thickness have been found in silts located in permafrost regions. This is due to an

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[1] Terzaghi, K.; Permafrost; Contributions to Soil Mechanics, 1941-1953; Boston Soc. of Civil Eng.; 1953, p.331.

accumulation of frozen water contained in the material. As permanently frozen ground probably underlies the dam site area it is believed consideration should be given to this problem before the silt is used as core material. Ice lenses were not noted in any of the silt deposits examined. This may be due to the proximity of Yukon River or because the test pits were not sufficiently deep.

Pervious Material

Pervious material required for the proposed dam can be obtained from the gravel deposits described under the "aggregate" heading.

Riprap and Rock Fill

Durability tests should be conducted on representative samples of the rock occurring at Boundary site to determine if it would provide satisfactory riprap or rock fill. The large proportion of schist exposed on the right abutment suggests much of this rock would not be suitable. The altered greenstone outcropping on the terrace south of the River may provide satisfactory material. The areas of felsenmeer are possible sources of rock fill. The rock blocks usually consist of altered greenstone and are frequently large. Similarly the talus occurring in the south part of the area mapped may provide suitable rock fill. The talus on the right abutment slope consists generally of finer material and is a doubtful source.

Surface Water

At the time of the investigation (August 6, 1960) three small creeks were flowing across the terrace south of the River. Considerable surface water was also present especially in the vicinity of a small pond in the southwest part of the map-area. Two of the creeks joined to flow west across the International Boundary and the third drained east toward Yukon River.

Ground Water

There is little information concerning ground-water conditions in the area about the proposed dam site. The presence of frozen ground beneath the terrace south of the River suggests a perched water table may exist in this area. Seepages of ground water do not occur in the steep, right abutment slope. The brown staining associated with the weathered rock on this slope is the probable result of small quantities of surface water percolating downward through the rock during the spring run-off. Accurate information regarding the water table can only be obtained by installing several ground-water observation holes. The presence of frozen ground throughout the site area would add considerably to the cost of such a program.

Frozen Ground

'Frozen ground was encountered in several localities south of the River; both on the terrace and on that part of the steep slope south of the terrace which is included in the map-area. It invariably occurred beneath an insulating layer of mass or decayed vegetation and varied in depths from 8 to 42 inches beneath ground surface (August 3, 1960). It is believed frozen ground exists beneath the entire site area.

Further Investigations - Conclusions

It should be remembered the present geological investigation of the proposed Boundary dam site is a preliminary one designed to furnish the engineers with as much information as possible before any money is spent on expensive engineering investigations both in the field and in the laboratory. As a result of this geological investigation, the following conclusions and suggestions concerning any future work in the site area are made:

1. Bedrock in the site area is badly weathered and intensively altered and sheared. Consequently detailed information concerning the quality of bedrock underlying the proposed rock-fill dam, the spillway and powerhouse structures, and in the two abutment areas, are required.

2. Information is not available concerning the quality and quantity of overburden beneath the present River. Consequently test borings should be put down across the River to take soil samples, conduct permeability tests and to determine the elevations of bedrock surface.

3. There is a lack of construction materials, i.e. aggregate, impervious material and rock fill in the area. Consequently the gravels and silts occurring upstream along Yukon River and bedrock at the site should all be investigated regarding their suitability as construction materials.

Chemical Analyses of Yukon River Water

During the 1960 field season samples of Yukon River water were taken at the International Boundary and above and below the junction of Forty Mile River and Yukon River. The samples were analysed for their mineral content by the Industrial Waters Section, Mines Branch, Department of Mines and Technical Surveys, Ottawa. The results of the analyses are included on the following page. For comparison an analysis made of Yukon River water at Eagle, Alaska, some 20 miles below Boundary dam site, by the United States Geological Survey has been included. The results indicate the water in Yukon River is medium hard but not highly mineralized. The low mineral content may be due in part in the lack of circulating ground water resulting from the permanently frozen condition of the ground. A large part of the mineral content of most streams is contributed by ground water. There is a

progressive increase downstream in the mineral content of Yukon River water; the water at the International Boundary is about twice as hard as that above the mouth of Pelly River.

The reported value of the turbidity should be considered only as indicative. Flash floods may cause a rapid increase in the sediment load. A proper sediment study, therefore, requires regular sampling, often in the case of flash flooding, at hourly intervals.

Chemical Analyses of Yukon River Water
(parts per million

Location	Date	River Discharge	pH	SiO_2	Ca	Mg	Na	K	Fe	CO_3	HCO_3	SO_4	Cl	F	Turbidity	Total Hardness as $CaCO_3$
At Yukon -Alaska boundary; centre of River	Aug. 9, 1960	High	7.7	5.8	31.0	8.6	2.0	1.1	3.2	0.0	105	25.8	0.8	0.12	55	113
Four miles below Forty Mile River; centre of River	Aug. 10, 1960	Medium High	7.9	5.9	30.4	8.5	2.1	1.2	9.3	0.0	104	25.7	1.0	0.12	290	111
One mile above Forty Mile River; centre of River	Aug. 10, 1960	Medium High	7.8	6.0	34.6	8.8	2.0	1.2	9.3	0.0	117	25.8	0.6	0.11	280	123
At Eagle Alaska*	July 8, 1915	Medium	-	9.6	27	6.2	-	-	.10	Tr	98	16	Tr	-	-	-

* Dole, R.B., and Chambers, A.A.; 'Chemical Charactor of some Surface Waters in Alaska' U.S. Geol. Surv., W.S.P. 418-420, 1917, p. 102.

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. Each 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 each sample.

(c) Curves showing 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.

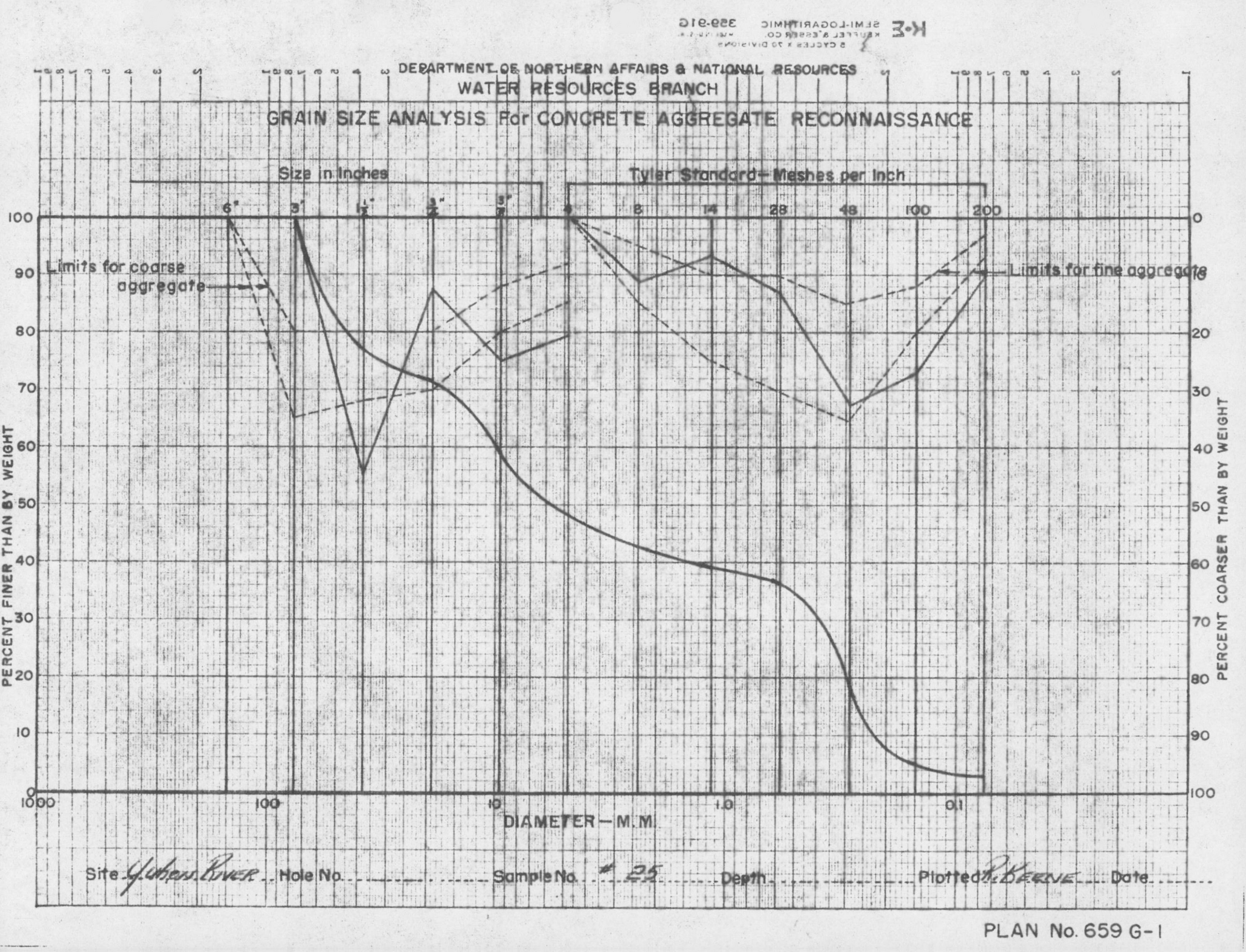
One sample (No. 29) was analysed as potential impervious material; the remainder as potential aggregate.

Description of Potential Aggregate for the following Grain Size Analyses Curves

Sample Number	Location	Field Description of Material	Field Description of Overburden	Thickness of Deposit	Areal Extent (estimated)	Accessibility
25	Left side of Yukon River, 18.5 miles upstream from site	Fine, sandy gravel; very little weathering; rounded cobbles up to 4 inches	10 feet of fine, silty sand	40 feet	-	By Yukon River
26	Right side of Yukon River, 15 miles upstream from site	Medium, sandy gravel; very little weathering; well rounded cobbles to 6 inches	5 feet of silt over 6 feet of sand	25 feet	=	"
27	Left side of Yukon River, 13 miles upstream from site	Well graded, fine , sandy gravel; well rounded cobbles to 4 inches	3 feet of silt	50 feet	-	"
28	Right side of Yukon River, 6.5 miles upstream from site	Sandy gravel directly overlying bedrock; boulders up to 10 inches; many of the larger, granitic boulders are badly weathered	3 feet of silt	17 feet	-	"
30	300 feet north of Yukon River and 620 feet east of International Boundary on small terrace	Well graded, fine sandy gravel; rounded weathered cobbles to 4 inches	None	-	-	Immediately north of site area; easily accessible

Description of Potential Aggregate for the following Grain Size Analyses Curves

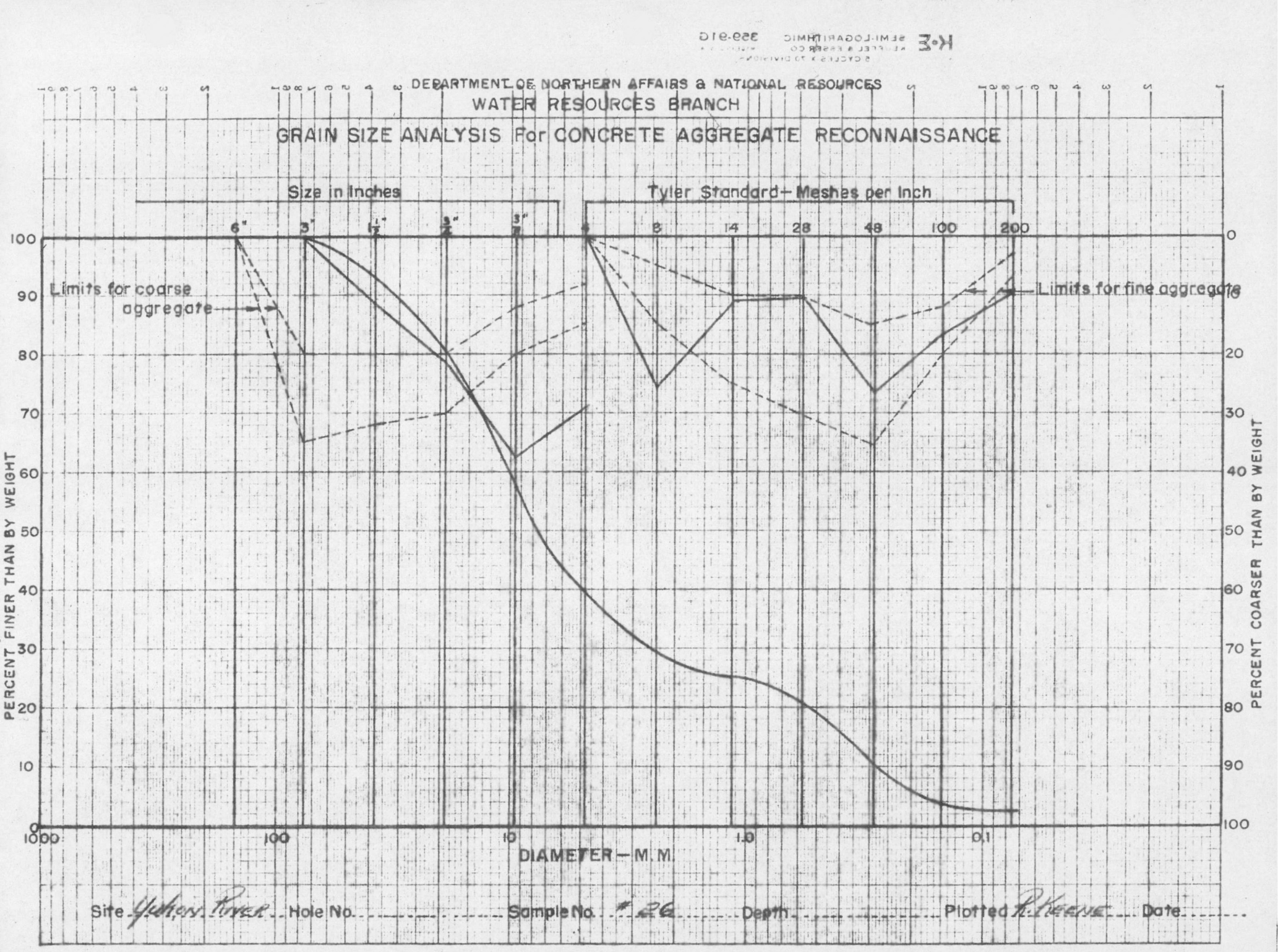
Sample Number	Location	Field Description of Material	Field Description of Overburden	Thickness of Deposit	Areal Extent (estimated)	Accessibility
31	On International Boundary $\frac{1}{4}$ mile north of Yukon River	Silt with a few weathered, angular rock fragments up to 1/8 inch and a small number of rounded, weathered granitic boulders up to 6 inches; material is typical of upland slope soil	None	-	-	Immediately north of site area; easily accessible
32	In Alaska, left bank of Yukon River, 8 miles downstream from International Boundary	Roughly stratified, fine, sandy gravel; rounded cobbles up to 8 inches	5 feet of sandy silt	30 feet	-	By Yukon River


DEPARTMENT OF NORTHERN AFFAIRS & NATIONAL RESOURCES
WATER RESOURCES BRANCH
GRAIN SIZE ANALYSIS For CONCRETE AGGREGATE RECONNAISSANCE
Size in Inches
6"
3"
1½"
¾"
⅜"
Tyler Standard - Meshes per Inch
4
8
14
28
48
100
200
Limits for coarse aggregate
Limits for fine aggregate
PERCENT FINER THAN BY WEIGHT
PERCENT COARSER THAN BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
1000
100
10
1.0
0.1
DIAMETER - M.M.
Site Yukon River
Hole No.
Sample No. # 25
Depth
Plotted R. DERVE
Date
PLAN No. 659 G-1

DEPARTMENT OF NORTHERN AFFAIRS & NATIONAL RESOURCES

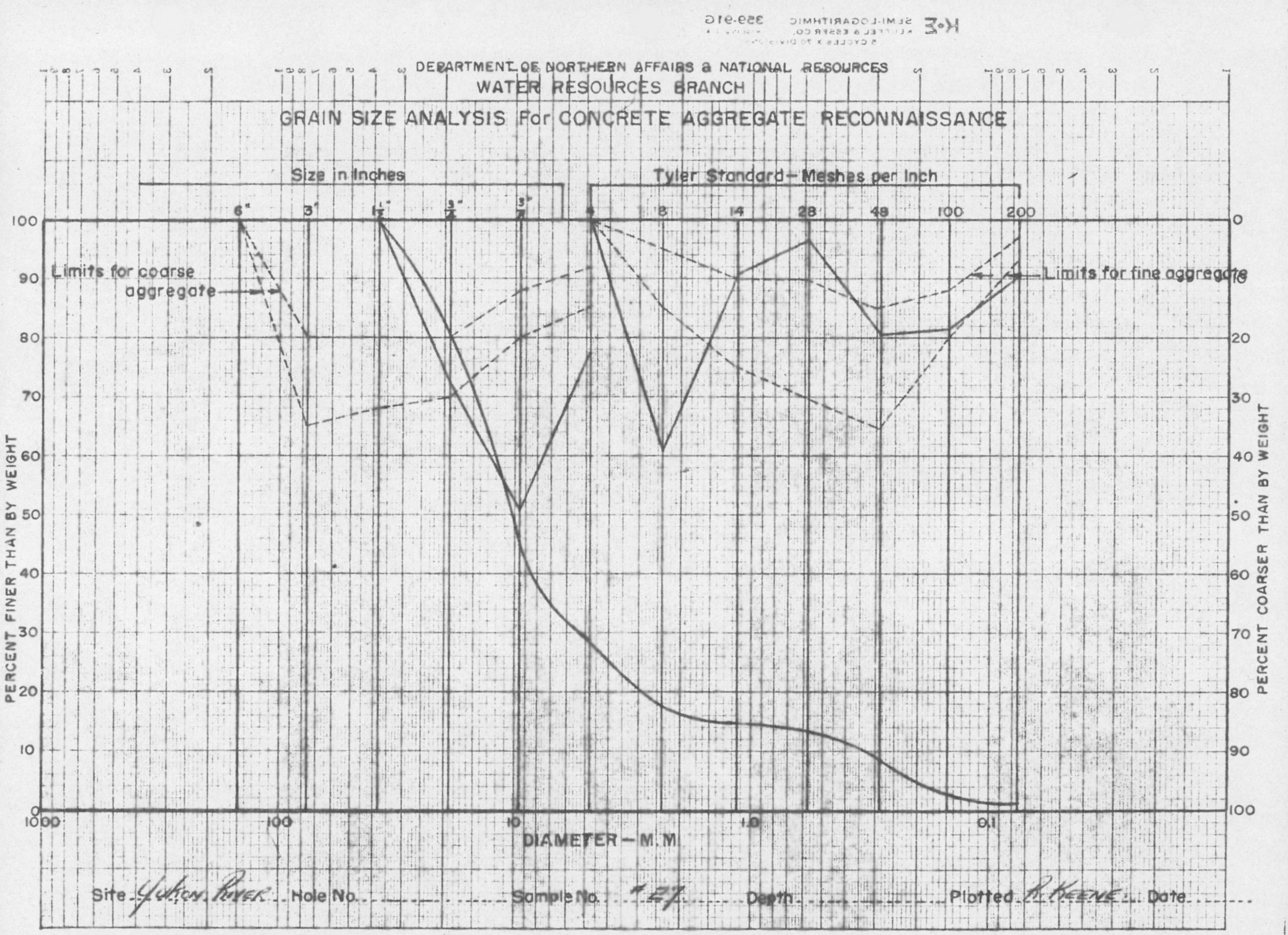
WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS For CONCRETE AGGREGATE RECONNAISSANCE



Site Yukon River Hole No. Sample No. 126 Depth Plotted R. Greene Date

PLAN No. 659 G-1

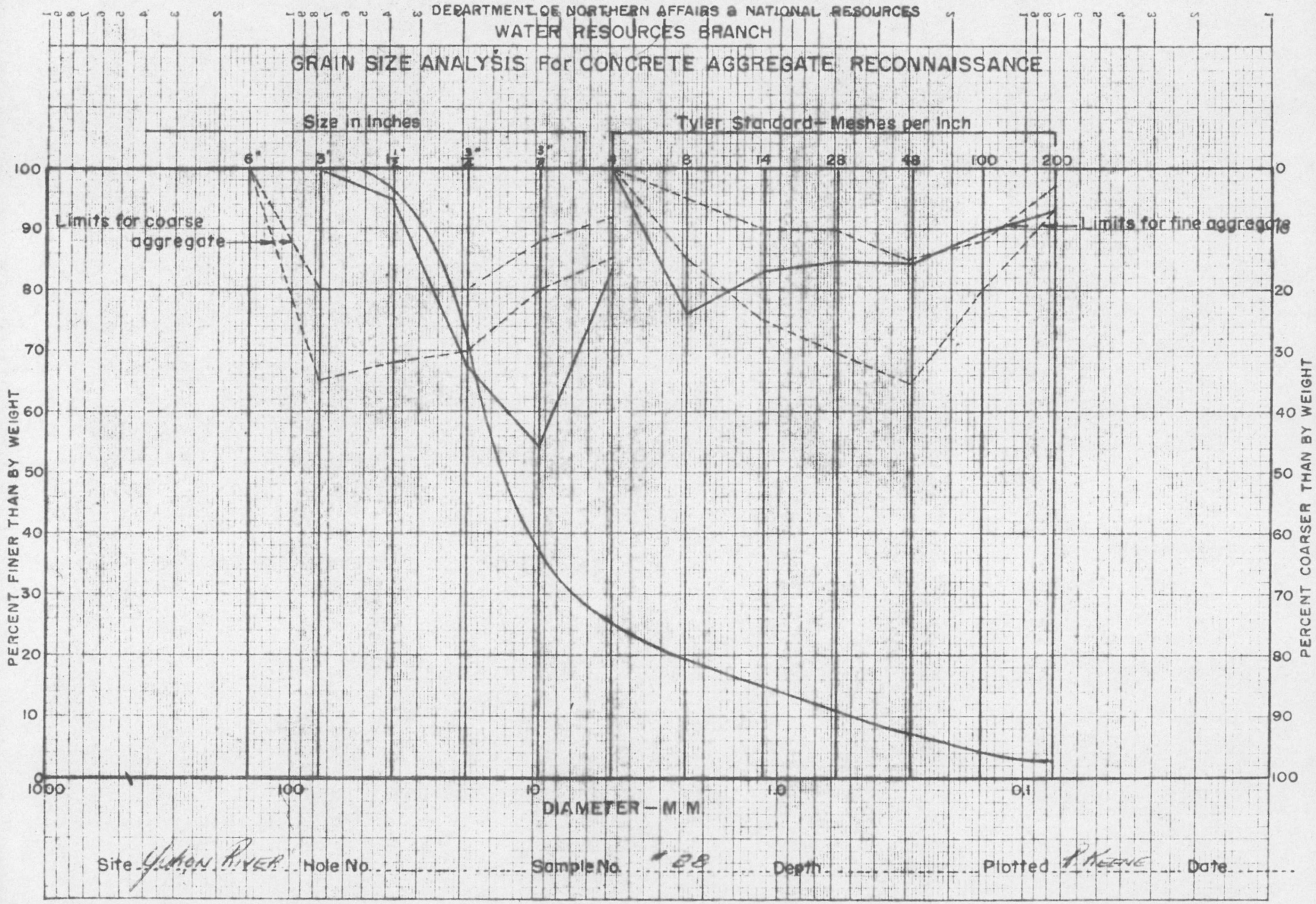


PLAN No. 659 G-1

DEPARTMENT OF NORTHERN AFFAIRS & NATIONAL RESOURCES

WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS For CONCRETE AGGREGATE RECONNAISSANCE



Site Yukon River Hole No. ..... Sample No. 28 Depth ..... Plotted T. Keeve Date .....

PLAN No. 659 G-1

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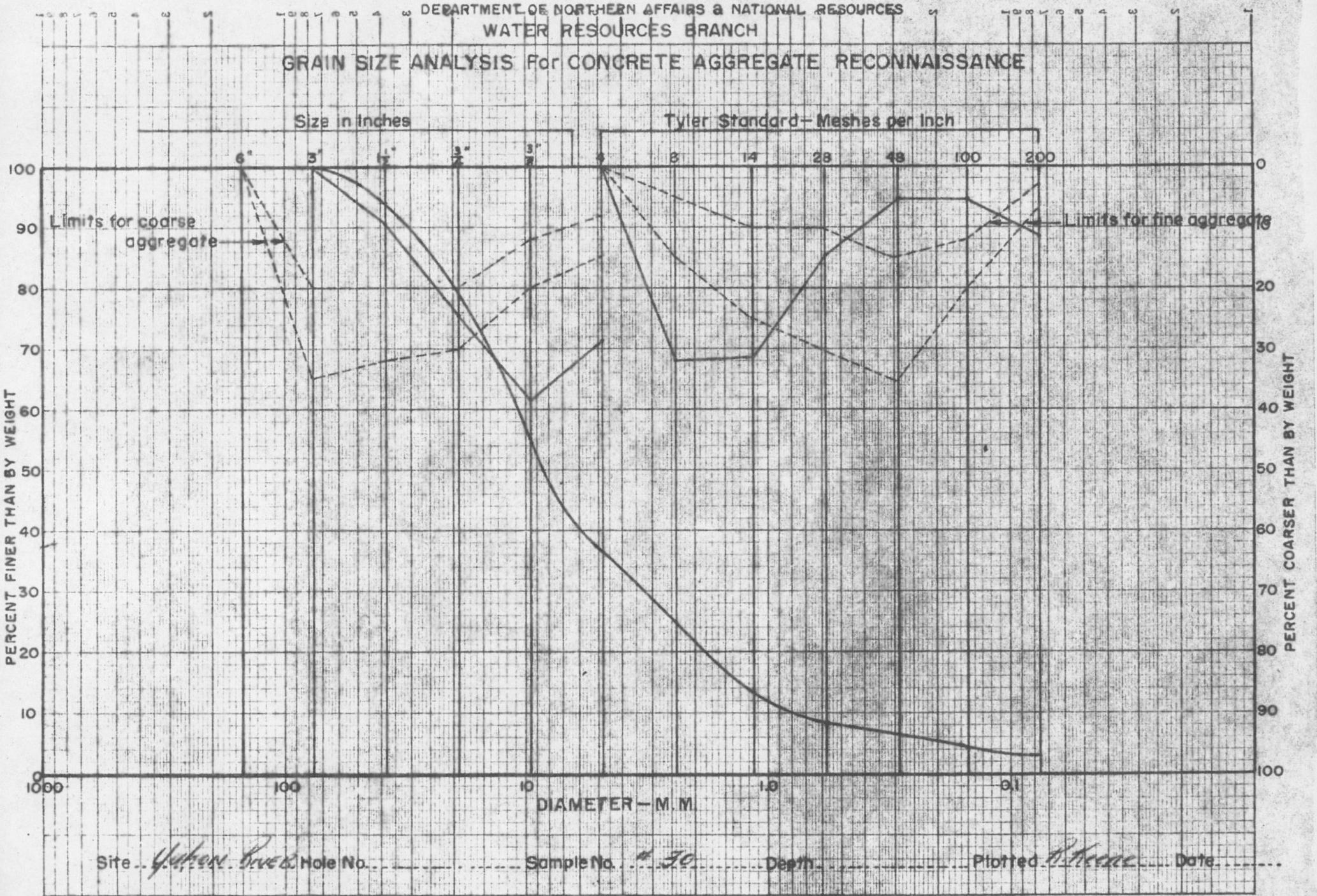
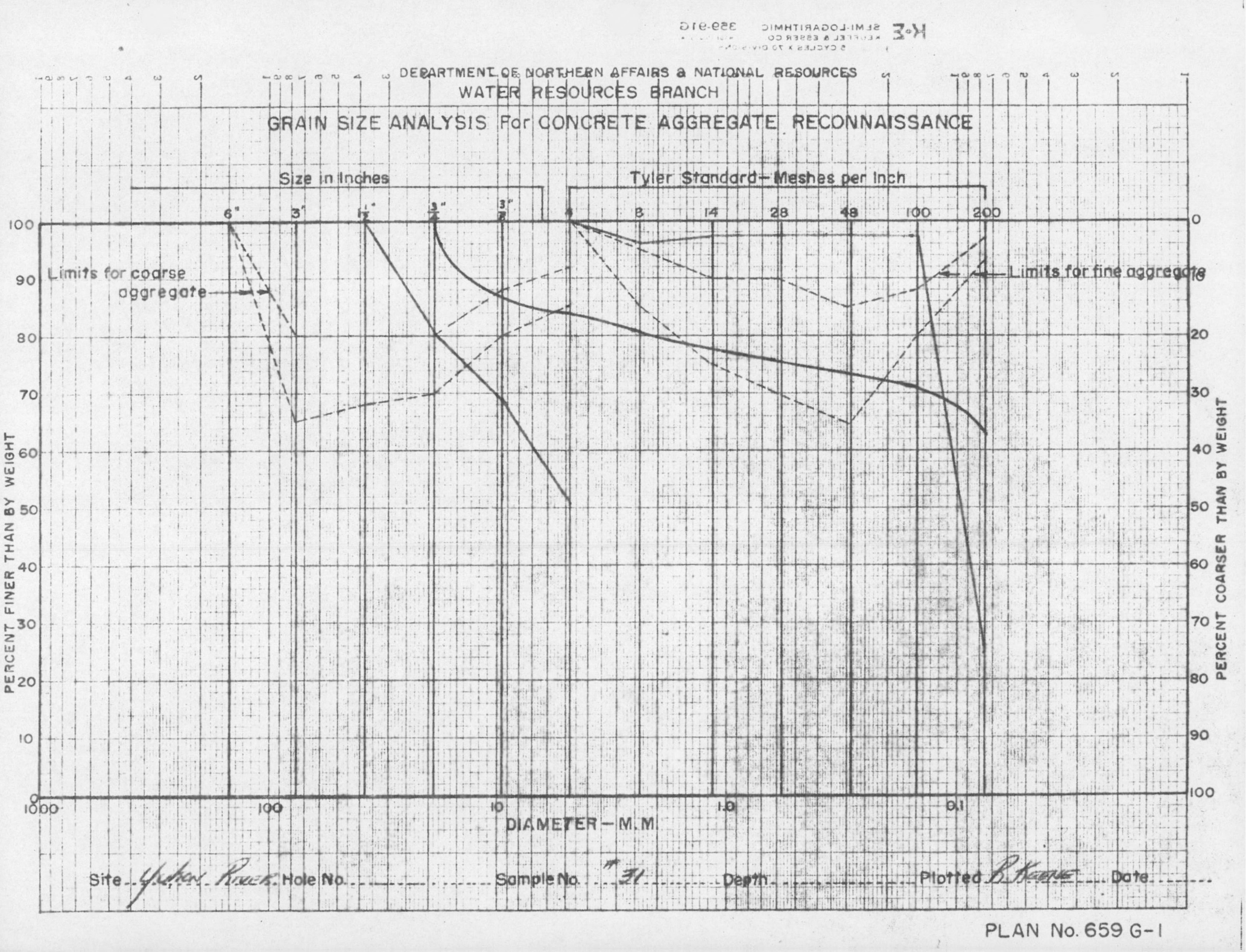
WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS For CONCRETE AGGREGATE RECONNAISSANCE



Site Yukon River Hole No. Sample No. # 30 Depth Plotted [illegible] Date

PLAN No. 659 G-1


DEPARTMENT OF NORTHERN AFFAIRS & NATIONAL RESOURCES
WATER RESOURCES BRANCH
GRAIN SIZE ANALYSIS For CONCRETE AGGREGATE RECONNAISSANCE
Size in Inches
Tyler Standard – Meshes per Inch
6"
3"
1½"
¾"
⅜"
4
8
14
28
48
100
200
Limits for coarse aggregate
Limits for fine aggregate
PERCENT FINER THAN BY WEIGHT
PERCENT COARSER THAN BY WEIGHT
100
90
80
70
60
50
40
30
20
10
0
1000
100
10
1.0
0.1
DIAMETER – M.M.
Site Yukon River Hole No. Sample No. 31 Depth Plotted B. Keane Date
PLAN No. 659 G-1

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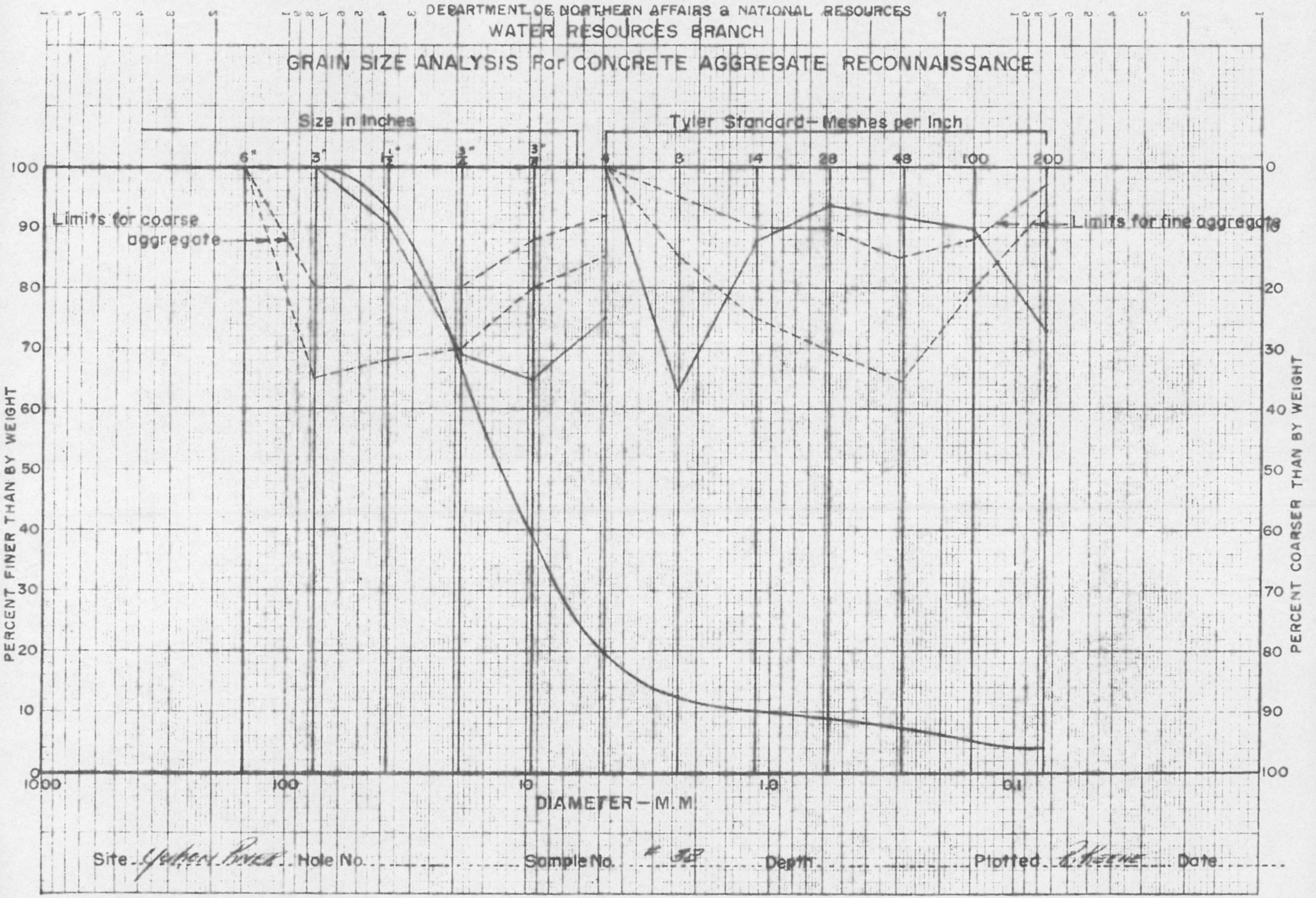
WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS For CONCRETE AGGREGATE RECONNAISSANCE



Site Yukon River Hole No. Sample No. 4 Depth Plotted K. Keene Date

PLAN No. 659 G-1

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

Sample Number	Location	Field Description of Material	Field Description of Overburden	Thickness of Deposit	Areal Extent (estimated)	Permeability* (cm. per sec.)
29	¼ mile southwest of Yukon River; 3½ miles above site; exposed along small creek	Brown silt; minor sand; low dry strength	None	20 feet	small	10^{-7}

* Permeability computed in the field using a Soiltest permeameter, Model K-620

DEPARTMENT OF NORTHERN AFFAIRS & NATIONAL RESOURCES

WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS

SCREEN SIZES IN INCHES | U.S. STANDARD SIEVES | HYDROMETER ANALYSIS

3" 1½ ¾ ⅜ #4 #8 #16 #30 #50 #100 #200

$$Cu = \frac{D60}{D10} =$$

$$Cc = \frac{D30^2}{(D60)(D10)}$$

Percent Passing: 100 90 80 70 60 50 40 30 20 10 0

Percent Retained: 0 10 20 30 40 50 60 70 80 90 100

100 10 4.76 2.0 1.0 0.42 0.10 0.074 0.01 0.001

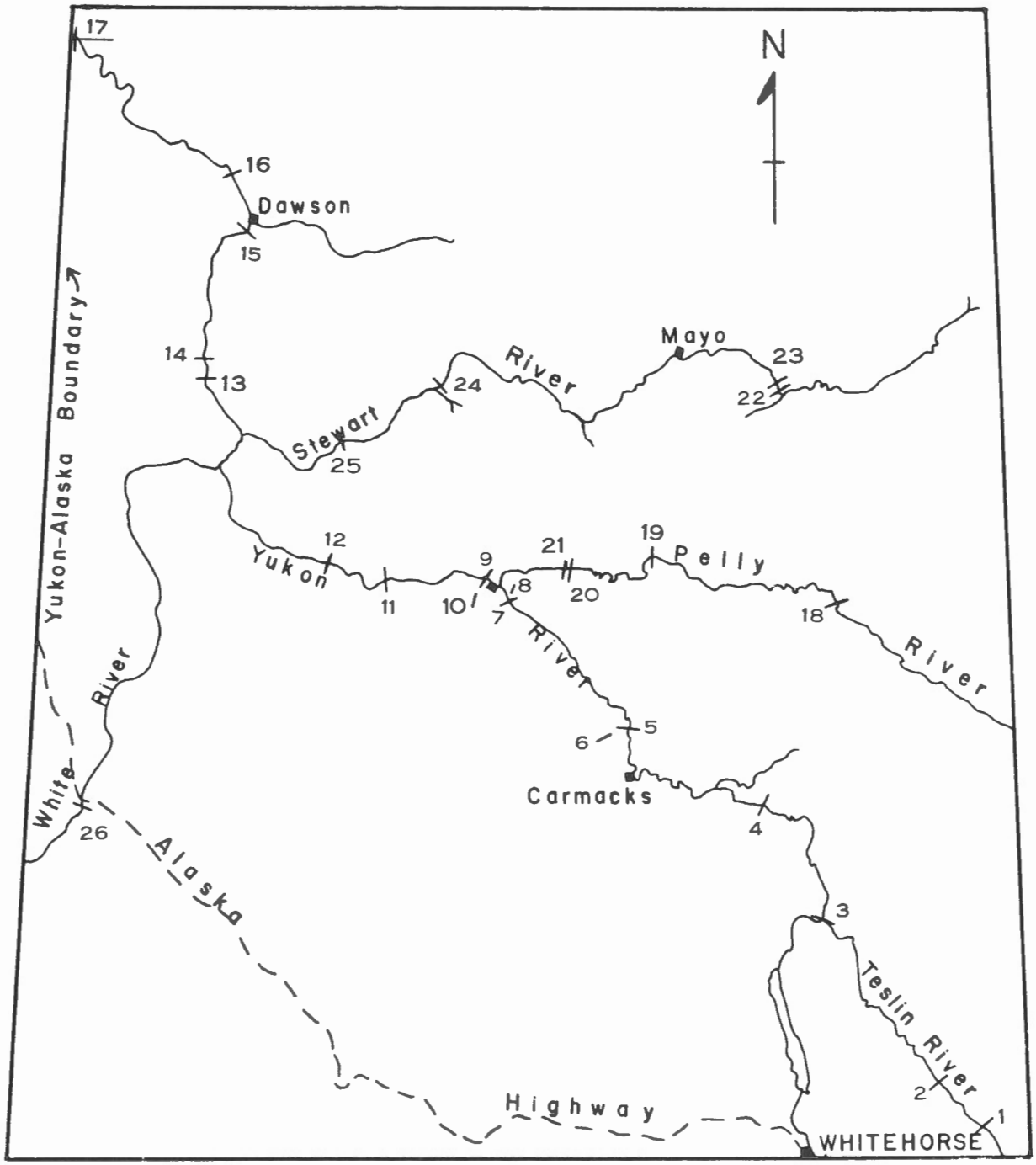
Particle Size in Millimeters

GRAVEL — SAND — SILT (Non Plastic) to CLAY (Plastic)

Coarse — Fine — Coarse — Medium — Fine

Site YUKON RIVER Pit Sample #29 Depth Plotted R. Mathews

PLAN _____



LOCATION OF PROPOSED DAM SITES
YUKON RIVER DRAINAGE BASIN
Scale: 1 inch = 40 miles

Site No.	Name	Site No.	Name	Site No.	Name
1	Swift River	10	Fort Selkirk Draw	19	Granite Canyon
2	Northwest Power	11	Selwyn	20	Gerc
3	Hootalinqua	12	Britannia	21	Bradens Canyon
4	Big Salmon	13	Ogilvie no.1	22	Five Mile Rapids
5	Five Finger Rapids	14	Ogilvie no.2	23	Fraser Falls
6	Five Finger Draw	15	Upper Dawson	24	Independence
7	Wolverine	16	Lower Dawson	25	Porcupine
8	Wolverine Draw	17	Boundary	26	Lower Canyon
9	Fort Selkirk	18	Detour		