No. 2

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA
TOPICAL REPORT NO. 84

MACKENZIE RIVER DRAINAGE BASIN
DAM SITE INVESTIGATION

SITES NOS. 17-18

WIND RIVER AND BONNET PLUME SITES

(MAPS AND PRELIMINARY REPORT)

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WIND RIVER DAM SITE

General Description

Wind River dam site is located on Peel River immediately downstream from the junction of the Peel and Wind River. It is about 12 miles downstream from Aberdeen Falls site described in Topical Report No. 83. At the latter site it is proposed to construct a large dam, some 550 feet in height, to divert Peel River water from the Mackenzie River drainage basin through the Palmer Lake area into the Yukon River drainage basin. This water would flow northward through Eagle Plain to McDougall Pass. Here it would be used to generate a large block of hydroelectric power as it flows east through the Pass to the Mackenzie.

Wind River site should not be considered an alternate to Aberdeen Falls site. The walls of the canyon through which Peel River is flowing at Wind River site rise only about 200 feet above the river and there is no ground sufficiently high within a reasonable distance from either side of the river that would provide suitable abutments for a large dam. Consequently the proposed structure would be a low head power dam the reservoir of which would extend upstream only to the toe of the dam at Aberdeen Falls. An alternate site known as Bonnet Plume site is located about 13 miles downstream. A geological map of this site with accompanying descriptive notes is included with this report.

At Wind River site, Peel River is flowing in an easterly direction between steep, bedrock bluffs which rise abruptly from the edges of the river. The rock consists essentially of soft, black, laminated shale.

Overburden exposed along the tops of the bluffs consists chiefly of coarse-grained, well sorted gravel overlaid with a thin, irregular deposit of silt. A grain size analysis curve prepared from a representative sample of the gravel is included at the end of this report.

Unconsolidated Deposits

Four types of unconsolidated deposits were identified in the area about Wind River dam site. Three of these are included in the legend on the accompanying geological map. The fourth, which consists of yellowish brown silt, does not occur within the area covered by the map.

1. Recent alluvium (silt, sand, gravel): This material consists of silt, sand and gravel. It is exposed chiefly in a wide bar which occurs along the right side of Wind River at its junction with the Peel and continues downstream along the right side of Peel River for a distance of several hundred feet. The larger rock fragments consist of rounded boulders of sandstone and quartzite up to 18 inches in diameter. The material also contains fragments of lignite up to 24 inches in diameter.

Most of the Recent alluvium at the site is believed to have been carried down by Wind River. Upstream from its junction with the Peel the flood plain of the Wind is about 2,500 feet wide. Here the river flows in several unnavigable channels separated by extensive sand and gravel bars. The material constituting the bars is similar to that in the site area. Including the deposits of Recent alluvium in the flood plain of Wind River the quantity of material available is large. The content of

organic material in the alluvium, however, is high and considerable washing will be necessary before it could be used as aggregate.

2. Talus: Talus is material resulting from the mechanical disintegration of adjacent bedrock. At Wind River site it covers a large part of the bluff along the right side of the river. This is especially true in the downstream part where the bluff is less steep. Very little talus occurs on the bluff along the left side of the river. The talus consists of small, rock fragments ranging from sand-size particles to platy cobbles 6 inches in diameter. Most of the larger fragments consist of black argillite or sandstone. In places where bedrock consists chiefly of shale quantities of soft, black, clayey material are present.

3. Glacio-fluvial (sand, gravel): This material consists of unstratified, well sorted sandy gravel containing very little silt or clay-size particles. It is exposed in thicknesses up to 40 feet along the top of the bluff along the right side of the river in the downstream part of the site area. Here it directly overlies bedrock. Deposits of similar material up to 60 feet in thickness occur along the right side of the river about a mile downstream from the site. The cobbles and boulders present in the material consist chiefly of quartzite, sandstone and limestone. Shale, which constitutes about 5 per cent of the material, occurs chiefly in the sand-size particles.

Very little gravel is exposed along the left side of the river. The greatest thicknesses observed were about 3 feet. It invariably overlies bedrock.

Bedrock

General Description

Bedrock exposed in the walls of the canyon consist chiefly of thin-bedded, black, calcareous shale and argillite. In the lower part of the section more massive beds of fine-grained, dark grey sandstone are interbedded with the shale and argillite. These rocks are similar to those exposed in the downstream part of Aberdeen Falls site except they are thinner bedded and the dark, argillaceous limestone and chert have been replaced by the sandstone. The thickness of the sandstone beds range up to 4 feet whereas the shale and argillite strata rarely exceed 6 inches in thickness.

Bedrock exposed in the upstream part of the site consists of shale with some argillite. The underlying sandy rocks occur in the downstream part. They are common in that part of the canyon immediately downstream from the site area.

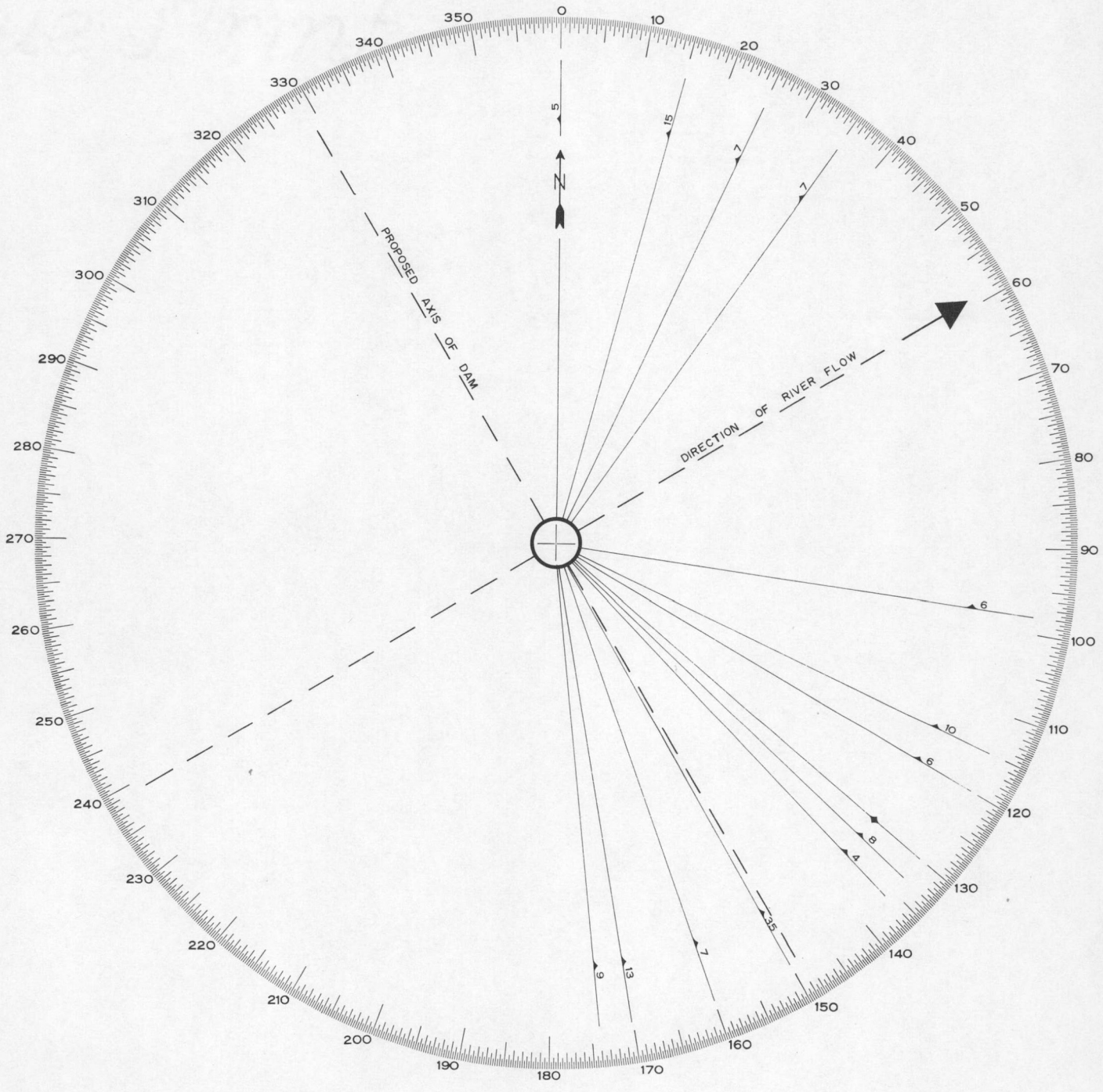
Weathering in these rocks is confined chiefly to the shale which disintegrates into a black, clayey material containing small, angular fragments of bedrock.

Bedrock Structures

In general the dip of the bedding varies from 4 to 15 degrees upstream or into the right abutment. This can be seen in photograph G. S. C. 44-7-62 which is included at the end of this report. In places, however, minor undulations in the strata have resulted in low angle downstream dips.

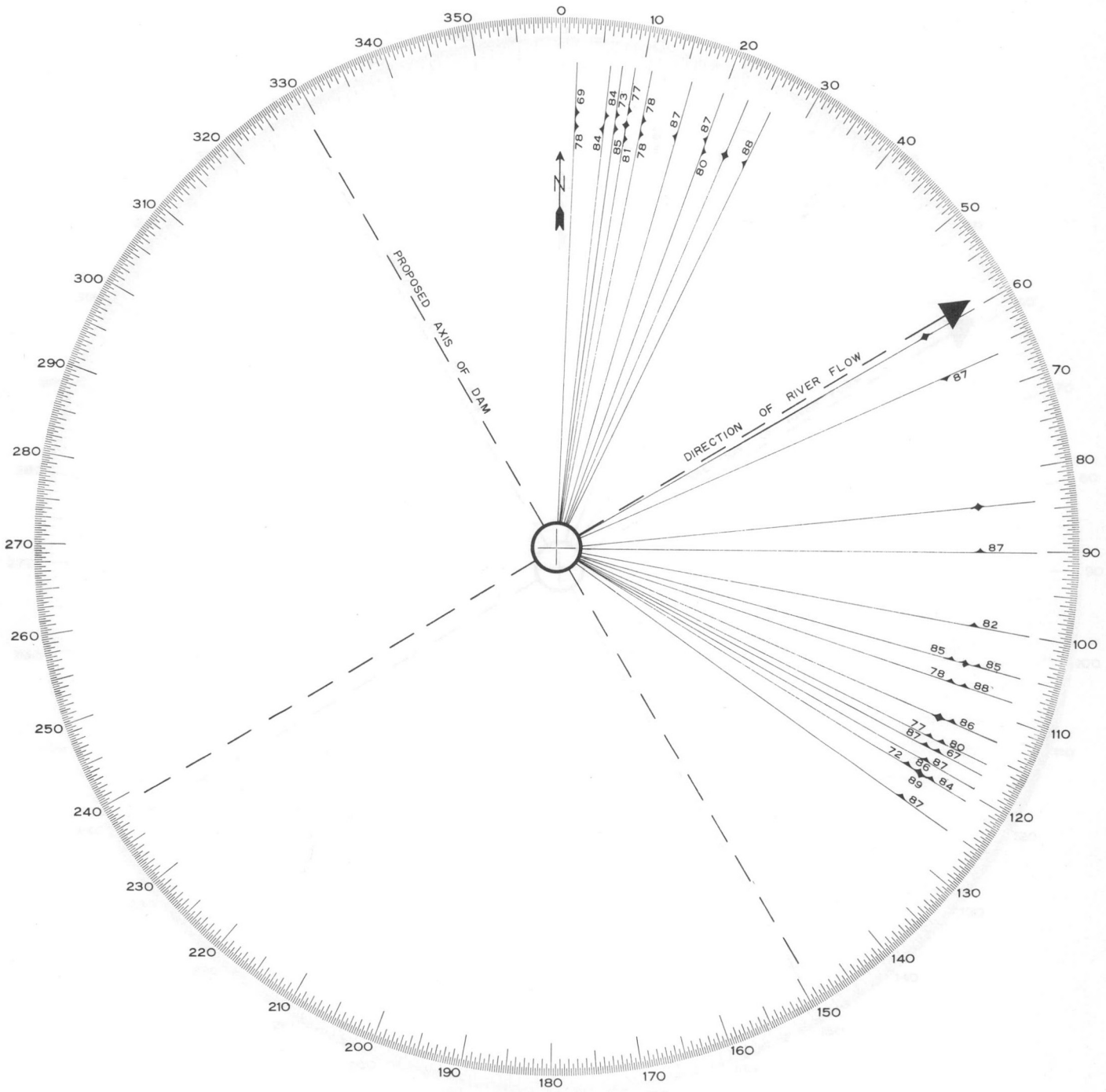
There are two prominent joint sets which intersect one another at angles between 60 and 80 degrees. One set which closely parallels the bedding dips steeply downstream or into the left abutment. The other set also dips downstream at high angles or into the right abutment. Many of the flat, vertical faces in the rock exposed in the walls of the canyon are joint planes from which rock fragments have fallen. The spacing of the joint fractures varies from a few inches to 4 feet or more. They are usually tight except in the upper 3 to 4 feet where they may be open as much as 3 inches.

Faulting is not common in the site area. Only one of the three faults depicted on the accompanying fault rosette for Wind River site occur within the area. The remaining two are located a few hundred feet downstream. All the faults are normal. The vertical displacement varies from a few feet to 75 feet. In all instances they are continuous across the canyon. The average width of the zones of broken rock associated with the faulting is about 10 feet. The quantity of gouge varies from about 1 inch in the harder rocks to 3 or more inches in places where the shear plane intersects shale beds. Minor slickensiding exists along the bedding and joint planes indicating some movement has also occurred along these surfaces.



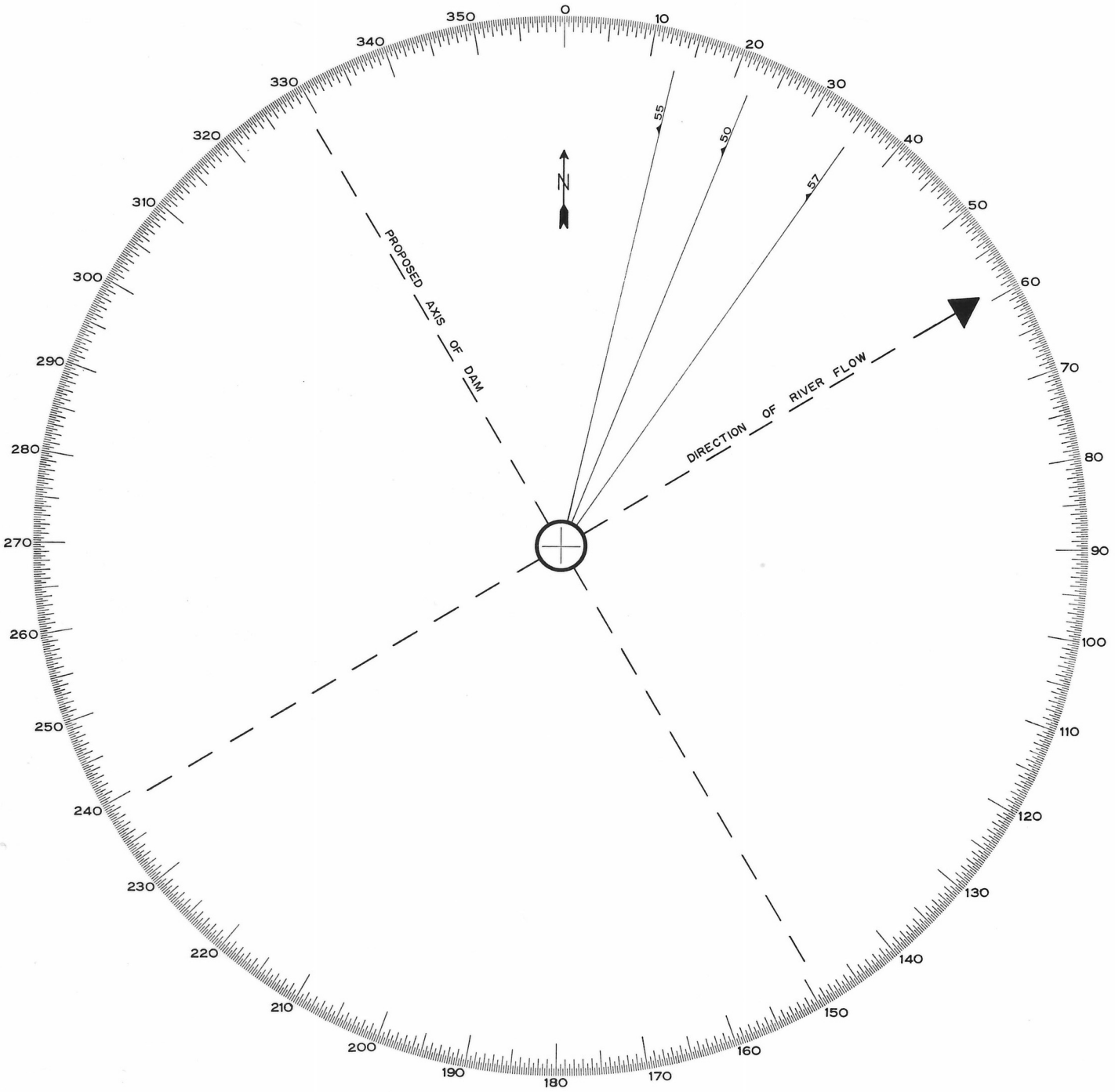
BEDDING ROSETTE

The above illustration presents diagrammatically the direction and dip of bedding in bedrock exposed at Wind River site



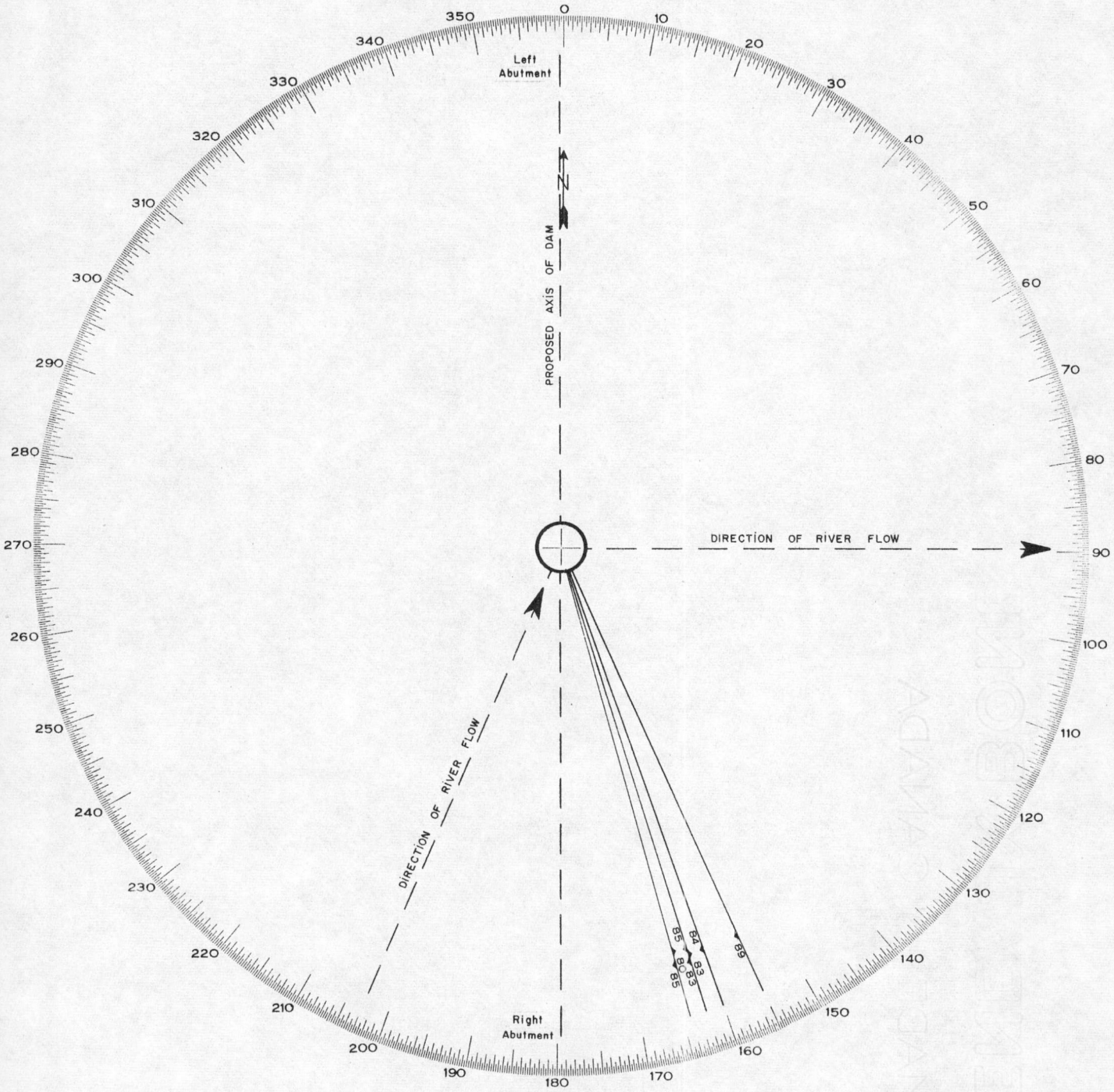
JOINT ROSETTE

The above illustration presents diagrammatically the direction and dip of jointing in bedrock exposed at Wind River site



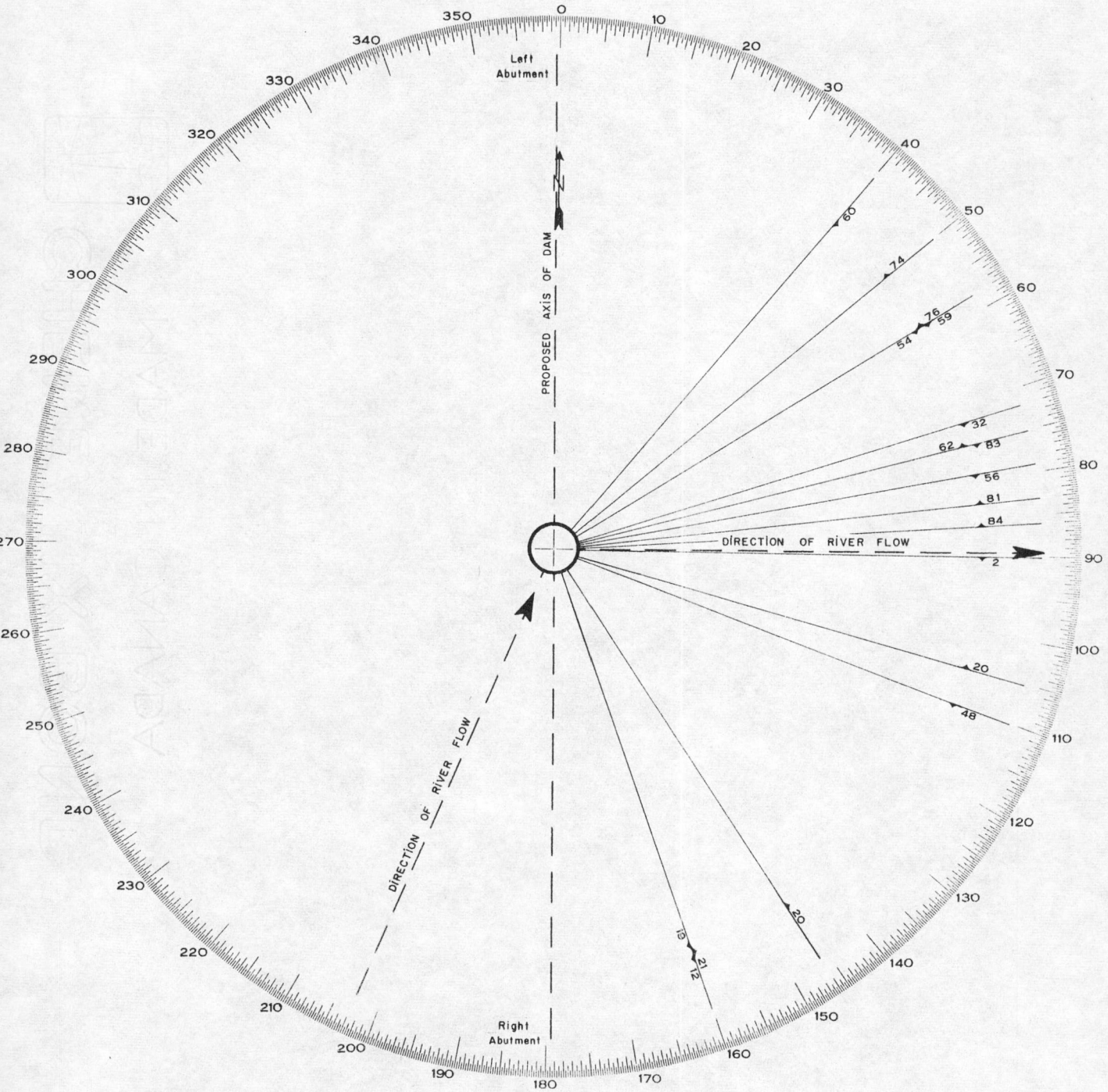
FAULT ROSETTE

The above illustration presents diagrammatically the direction and dip of faulting in bedrock exposed at Wind River site



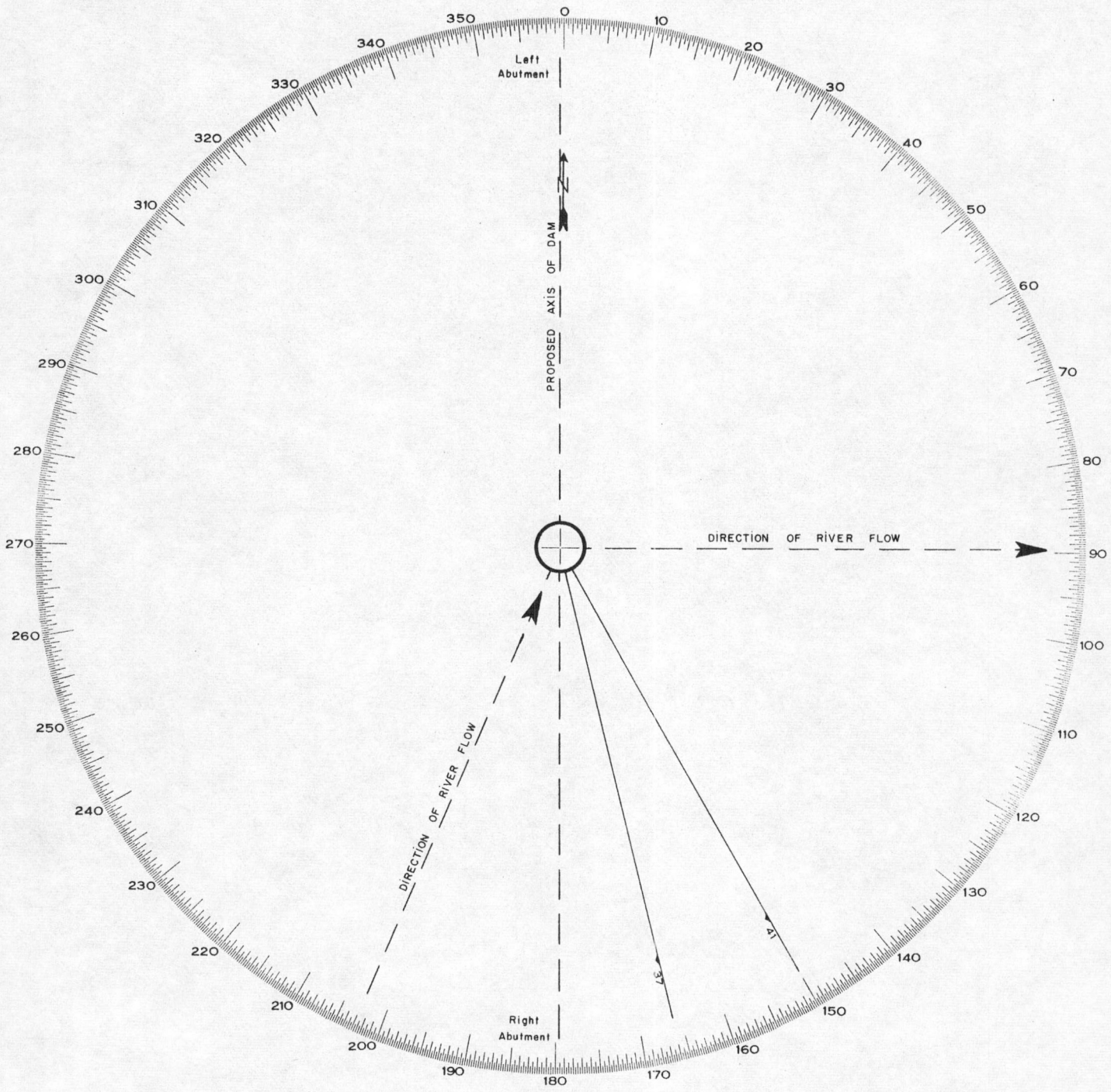
BEDDING ROSETTE

The above illustration presents diagrammatically the direction and dip of bedding in bedrock exposed at Bonnet Plume site



JOINT ROSETTE

The above illustration presents diagrammatically the direction and dip of jointing in bedrock exposed at Bonnet Plume site



FAULT ROSETTE

The above illustration presents diagrammatically the direction and dip of faulting in bedrock exposed at Bonnet Plume site

Quality of Bedrock

Bedrock in the site area is believed to be sufficiently competent to provide suitable foundation and abutment material for a low head power dam. The dips of the strata are close to horizontal with the result the rock will be at its maximum strength to resist the load of the dam structures. The most competent rock at the site is the sandstone which is interbedded with the shale in the downstream part. The association of shale and sandstone frequently affects the properties of these two rock types by permitting access of water to their contacts. However, the permeability of the rocks at Wind River site is believed to be low and they should provide excellent foundations for a dam.

Engineering Considerations

Depth of Overburden

Relatively little overburden exists at Wind River site. The talus which occurs chiefly along the right wall of the canyon is thin and nowhere is greater than 10 feet in thickness. The deposits of silt, sand and gravel exposed along the tops of the canyon walls vary in thickness from 3 feet on the left side to 40 feet in the downstream part of the right side.

There is no evidence as to the thickness of overburden beneath the river. For the purposes of design it is suggested the figures 40 to 45 feet be used as an average depth to the top of bedrock from the surface of the river. Bedrock will probably be at its lowest elevation beneath the left side of the river. Here the canyon wall frequently descends almost vertically into the river and there is no evidence it suddenly levels out.

Proposed Location of the Dam

The result of the investigation indicates the downstream part of the site area would be the best location for the dam. Here the lower part of bedrock exposed in the canyon walls consists of relatively massive sandstone strata interbedded with shale and argillite. These rocks would form the lower part of the abutments as well as the foundations for the proposed dam structures.

The height of the dam is limited by the elevation of bedrock surface exposed in the canyon walls. Along the left side of the canyon this is about 830 feet above sea-level and, although not as well exposed, is believed to exist at about the same elevation on the right side. It might be possible to increase the height of the dam by construction of dikes. This would not be a problem at the left end of the dam as overburden here above the canyon wall is thin and it would not be difficult to construct the dike on bedrock. Overburden at the right end of the dam would consist of about 40 feet of permeable sand and gravel. Special treatment would be required in this area to prevent seepage of reservoir water beneath the dike. A cut-off trench back-filled with impervious material would probably be the most effective means. The sand and gravel from the excavation could doubtless be used in other parts of the project.

Abutments and Foundations

Bedrock in the area suggested for the site of the dam is believed competent and should provide suitable foundation and abutment material. Bedrock beneath the river consists of interbedded shales, argillites and sandstone.

It is upon these rocks the main structures of the dam will be founded. Here the overburden is probably about 25 feet thick. It is doubtful if the rock surface is highly weathered and consequently only a small quantity of rock will have to be removed before fresh, solid rock against which concrete or dike material can be placed will be encountered. To secure a better bond between concrete and rock it would be better if the floor of the excavation was located on a sandstone bed.

Structural conditions in the canyon walls may produce stream-ward movement during excavation. This may occur along the right wall of the canyon if during construction of the right abutment the excavation cuts are steeper than the dip of the strata. The joint fractures in the prominent set which closely parallels the canyon walls may also open up for a considerable distance back from the abutment. This latter movement could result in leakage around the ends of the dam and also reduce the resistance of the rock to horizontal forces. An investigation should be carried out to determine the rate of deterioration of the shale which will occur in the upper parts of the abutments. If it is rapid, precautions will have to be taken to protect the freshly exposed rock face until concrete can be placed against it. Any proposed diversion tunnel can be located in either abutment as bedrock conditions are similar on both sides of the canyon. The rocks at Wind River site are relatively insoluble and it is doubtful if solution channels or extensive fissures exist in them. Grouting will be necessary to seal narrow seams along the jointing and bedding as well as larger fractures in the fault zones.

The presence of springs and seepages in the vicinity of some of the faults indicate these structures act as aquifers.

Construction Materials

Aggregate

The quantity of natural aggregate available in the site area along with that occurring immediately downstream and in the flood plain of Wind River may be sufficient to satisfy the requirements of the project. A grain size analysis curve obtained from a representative sample of the material is included at the end of this report along with a description of the material.

Extensive deposits of similar gravel covered with a thin layer of silt occur in the area between Wind and Bonnet Plume Rivers about 6 miles south of the site. These deposits are easily accessible and would be an excellent source of natural aggregate. Like most natural aggregates, however, the material would have to be washed, screened and reblended to produce a properly graded aggregate.

It is doubtful if bedrock at the site could be crushed to produce satisfactory aggregate. The quantity of shale present, which is deleterious in aggregate, is too high.

Impervious Material

Impervious material suitable for the core of an earth dam does not occur in the site area. A deposit of tough, dense till located along the left (west) side of Wind River about 10 miles upstream from its mouth should be investigated as a potential source of material. A test pitting program will be required here to determine the quantity and quality of material available.

Pervious Material

Large quantities of material suitable for the pervious shells, filters or drains of an earth dam could be obtained from the gravel deposits described under the aggregate heading. The gravel would have to be screened and reblended to produce properly sized material.

Riprap and Rock Fill

The relatively thin-bedded sedimentary rocks exposed at the site are not believed suitable as a source of riprap or rock fill. As bedrock for many miles around the site consists of similar rocks a problem of obtaining suitable material exists. It is suggested the dolomitic rocks exposed in the vicinity of Mt. Deception be examined as a potential source of material. This area is about 16 miles southwest of the site.

Groundwater

Numerous small springs occur at the base of both walls of the canyon usually in the vicinity of a fault zone. The temperature of the water was 42 degrees fahrenheit. The presence of the springs is an indication the fault zones are aquifers and should be investigated whenever they occur in the abutments or foundations. Their presence could result in considerable leakage from the reservoir. There is no evidence of solution by percolating groundwater in bedrock exposed at the site.

Frozen Ground

There is no evidence of frozen ground in either wall of the canyon. A few shallow test pits were dug on the terrace above the right wall in an attempt to investigate the extent of the gravel deposit (August 14, 1962).

The pits penetrated about 2 feet of the yellowish brown silt which overlies the gravel. Frozen ground was not encountered in any of the pits. The terrace above the left wall of the canyon was not investigated. It is possible the ground encountered by the test pits was dry frozen ground, i.e. ground with a temperature below 0°C. but containing no ice as a cementing substance.

Comparison between Wind River and Bonnet Plume sites

The results of the investigation indicate that, geologically, Wind River and Bonnet Plume sites are similar. One exception, however, is the difference in the attitudes of the bedrock strata. At Wind River site the dip of the beds is relatively horizontal. It varies from 4 to 15 degrees either in an upstream direction or into the right abutment. At Bonnet Plume site the beds are vertical or dip steeply downstream. As horizontally bedded rocks, in general, provide the most competent foundation material it is believed the Wind River site is the most satisfactory of the two.

The following are comparisons between some of the more important features at the sites:

1. Topography: The topography at the two sites is similar. At each site Peel River is flowing through a relatively narrow, steep-walled canyon the walls of which are bedrock covered in places with a thin deposit of talus derived from the adjacent rock.

2. Overburden: Overburden at the two sites is the same. It consists chiefly of small deposits of Recent alluvium located beneath Peel River and in fairly extensive bars situated immediately downstream from

the mouths of Wind and Bonnet Plume Rivers. Most of the material was probably carried down by the two tributary streams. The talus, in general, consists of small, platy rock fragments which have little use as a construction material. At both sites bedrock is overlaid by varying thicknesses of coarse-grained, glacio-fluvial gravel which, if sufficient quantities are available, has a potential use as coarse aggregate.

3. Bedrock: Bedrock exposed at the two sites is similar. It consists chiefly of soft, black thin-bedded shale. At Wind River site inter-beds of argillite and sandstone are associated with the shale whereas at Bonnet Plume site the second most common rock is a dark, argillaceous limestone.

4. Bedrock Structures: With the exception of the bedding bedrock structures at the two sites are similar. Jointing consists chiefly of two steeply dipping sets which intersect roughly at right angles. At both sites one set closely parallels the canyon walls. Faulting is not common but the faults that are present are sufficiently large that they usually can be traced for several hundred feet. At Wind River site the faults are, in general, normal whereas at Bonnet Plume site they are usually thrust faults. At both sites small seepages of groundwater frequently occur along the base of the canyon wall close to the faults.

5. Construction Materials: It is doubtful if sufficient quantities of suitable construction materials can be obtained from either overburden or bedrock occurring at the sites. As the sites are only 12 miles apart the same sources of material could be used to supply either site providing such material could be found.

Conclusions

The results of the investigation indicate that although Bonnet Plume and Wind River sites are similar in many respects the latter site will probably provide more satisfactory foundation and abutment materials. However, if a dam is constructed at Wind River site the water from Bonnet Plume River, a major tributary of the Peel, will be lost. Also the elevation of the water in Peel River at Bonnet Plume site is some 134 feet lower than at Wind River site. The engineering implications of these facts which imply more hydroelectric power could be generated at Bonnet Plume site is beyond the scope of this report.

Chemical Analysis of Peel River Water

On August 8, 1962 a sample of Peel River water was taken from the centre of the river at a point about 19 miles upstream from the site. The sample was analysed for its mineral content by the Industrial Waters Section, Mines Branch, Department of Mines and Technical Surveys, Ottawa. The results of the analysis are included in the report on Aberdeen Falls dam site (Topical Report No. 83, site No. 16).

Grain Size Analysis Curve

The grain size analysis curve for potential aggregate included in this report was prepared in the soils laboratory of the Water Resources Branch in Vancouver. The grain size sheet shows the following information:

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

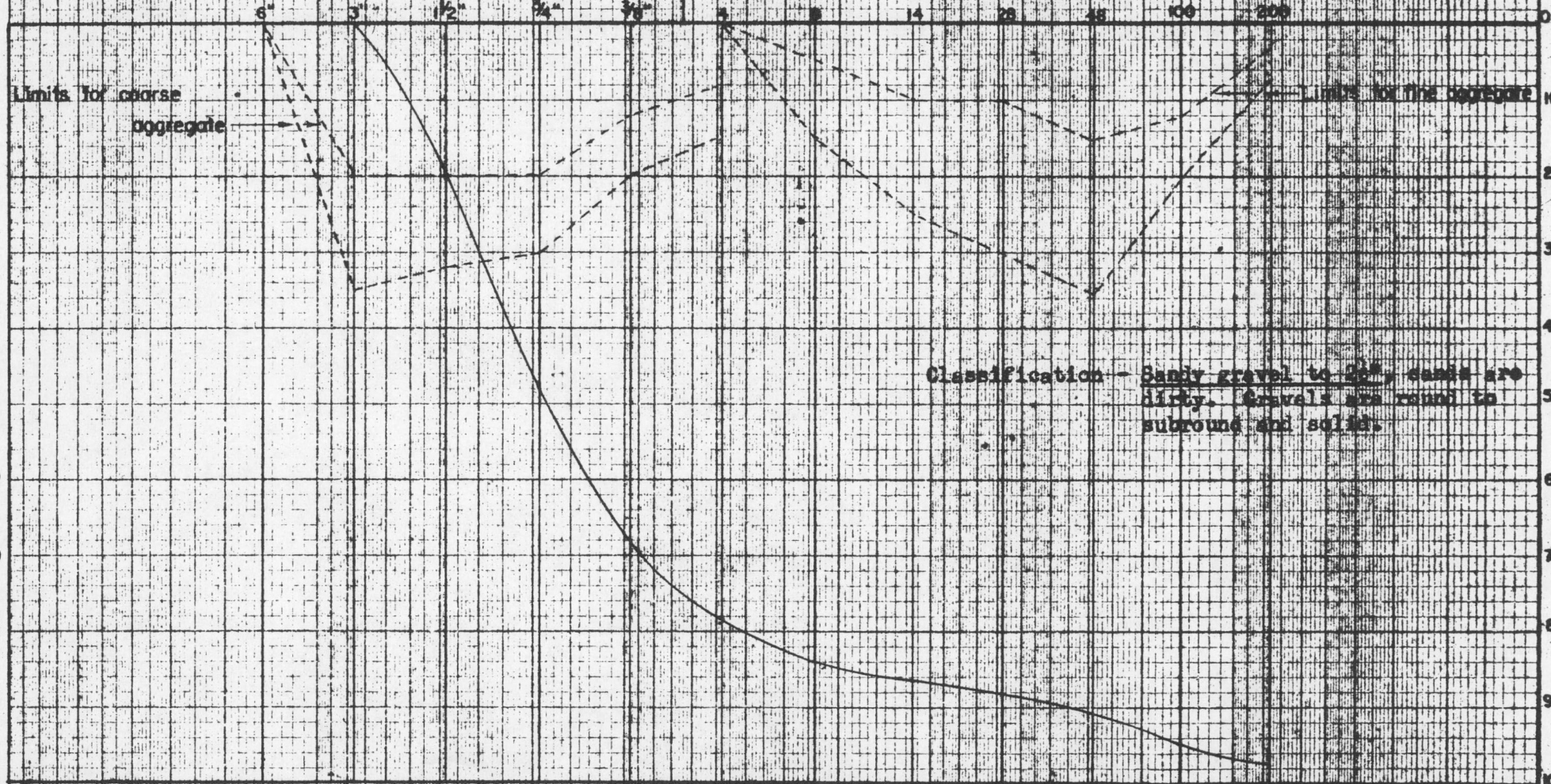
(b) A cumulative grain size curve for the sample.

(c) A curve showing individual percentages for 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.

DEPARTMENT OF NORTHERN AFFAIRS & NATIONAL RESOURCES

WATER RESOURCES BRANCH

GRAIN SIZE ANALYSIS For CONCRETE AGGREGATE RECONNAISSANCE



Size Wind River Hole No. Sample No. 16 Depth Plotted R. Keene Date 27/8/62.

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	Areal Extent (Estimated)	Remarks
16	Right side of Peel River; 15 feet below top of bluff directly above station G-2; 3 feet beneath ground surface	Coarse-grained, sandy gravel; poorly graded; low silt content; unstratified; numerous boulders up to 12 inches; rock fragments are chiefly sandstone, limestone, and quartzite, about 5 per cent are shale.	3 feet of silt	40 feet	Length: 1,600 feet, Average thickness: 25 feet, Width: 100+ feet	Gravel directly overlies bedrock; extensive deposit of similar gravel along right side of river about one mile downstream

Plate 1

Left abutment, Wind River site; the vertical height height of the bluff is about 180 feet.

G. S. C. 44-7-62

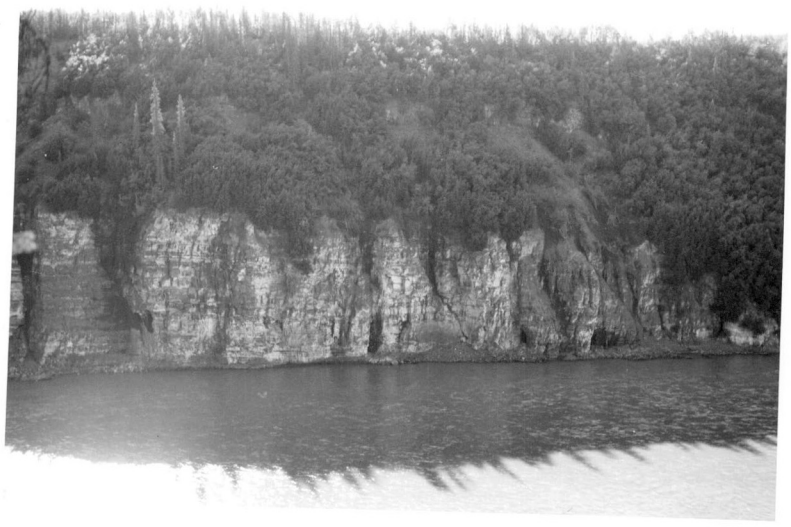
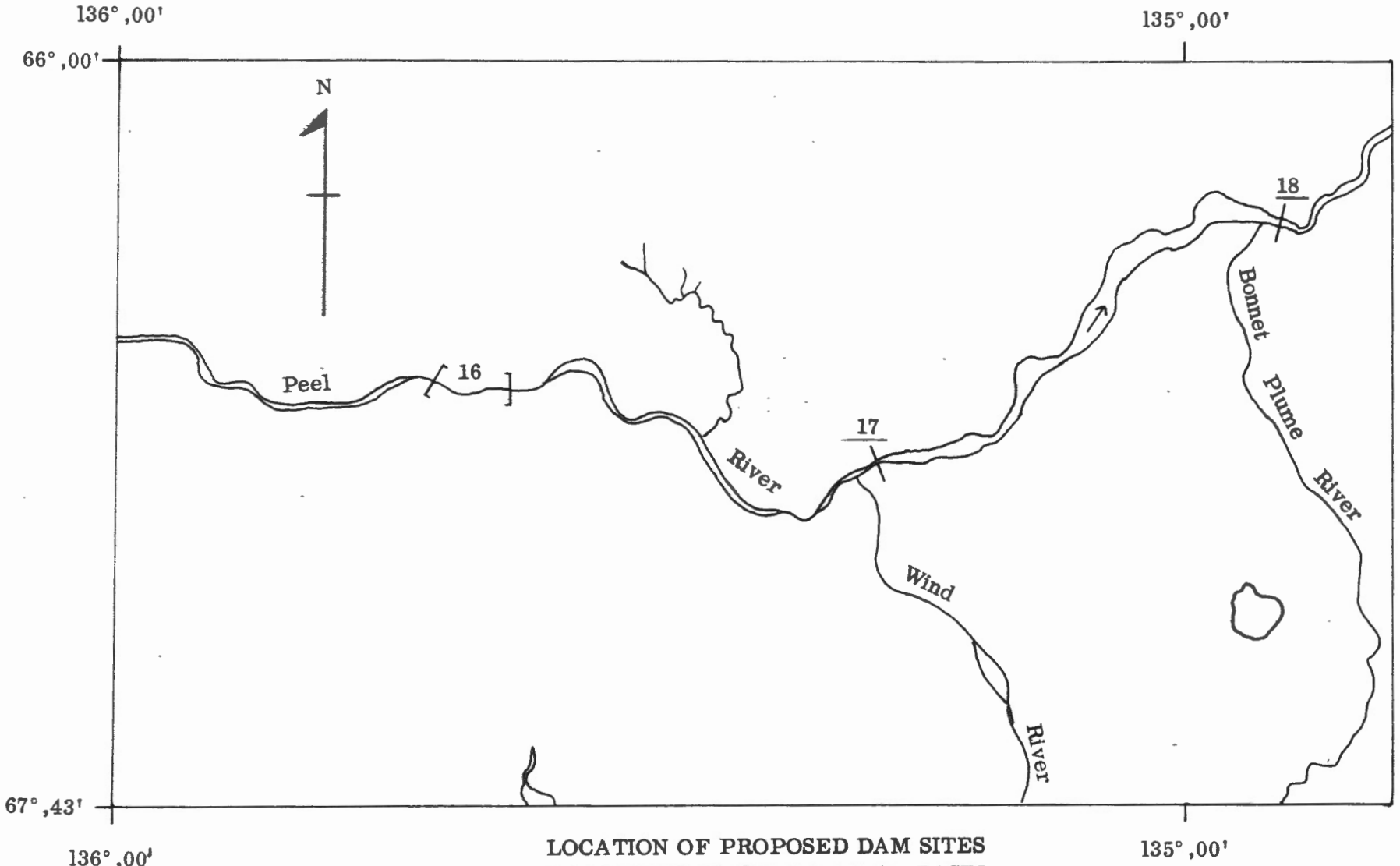


Plate 2

Right abutment, Wind River site; the upper part concealed by vegetation is covered with a thin mixture of talus, silt, sand and gravel.

G. S. C. 46-5-62



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

Site No.	Name
16 -	Aberdeen Falls
17 -	Wind River
18 -	Bonnet Plume