SUMMARY

Investigations of Fill Materials near Various Damsites on Rivers in Iceland

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Scope: This report presents the preliminary findings of the author resulting from a search for suitable fill dam materials at and near various major damsites presently under consideration for development by Raforkumalastjori. The report is written prior to the availability of test results of the soils under consideration and major revisions of some statements included herein may be required when these results become available, but it is not anticipated that any major or essential revision will be required.

Available Impervious Materials

There are three sources of impervious material suitable for cores in fill dams available in Iceland. These are loessy soil, morainal, and deigulmor deposits. Each of these three materials is considered separately below.

The deigulmor deposits have been thoroughly described in the Hestvatn Geologic Report. They are present in the area of the Dynjandi Dam on the Bruara beneath 3 to 5 meters of saturated loessy soil which is high in organic content. In some areas, the deigulmor is highly pre-consolidated and is thereby rendered unsuitable as an impervious material because of the certain difficulty which would be involved in attempts to excavate it and disintegrate it for placement by normal or usual construction procedures. However, right at the Dynjandi site, on the left bank of the Bruara, exposures of the deigulmor indicate that it either has not been highly pre-consolidated or has been softened by weathering so that it is suitable for excavation and placement by usual methods using heavy equipment.

The loessy soil above the deigulmor deposit will require removal to open the borrow area. The area thus opened will also have to be drained of groundwater. The deigulmor is so impervious, probably in the range of 10^{-7} or 10^{-8} cm/sec, that it will not readily absorb or lose moisture. The chunks or pieces resulting from excavation operations will not, therefore, be subject to precise moisture control. Fortunately, samples taken of the deigulmor at the Dynjandi damsite appear to posess a natural moisture content suitable for compaction. This will not be the optimum moisture content but will be close to optimum.

A sample of the deigulmor at natural moisture content has been compacted by the Standard Proctor method in the laboratory. The compacted sample showed an excellent disintegration of the pieces of the material and the resulting mass was homogeneous and thoroughly suitable. The wet unit weight was 120 lb/cf and the estimated dry unit weight was 95 to 100 lb/cf. Since the compactive effort exerted in the Standard Proctor test simulates that which is exerted by older and smaller compaction equipment than is available today, the use of the more modern equipment should adequately assure the complete disintegration of the excavated deigulmor. Rubber-tired rollers are recommended for this crushing and compacting operation.

The depth of the loessy soil cover above the deigulmor should be determined by use of the Borro sounding equipment. The borrow area should be located where the cover is thinnest close to the damsite. A few holes should penetrate the deigulmor to establish its depth and to note any changes in character of the material with depth.

Moraine deposits are located near some of the damsites visited. This is true for the Hvitarvatn and Aboti areas and may also be true for the three dams considered in development of the Jökulsa a Fjöllum. Where better core material is not available, use may be made of the moraine. As little as 10% fines (material passing the 200 screen) renders the moraine suitable for core material as evidenced by the notable examples of Swift and Eagle Gorge dams in the United States. At least the upper 3 meters of the morainal deposits viewed in the Hvitarvatn area can be excavated by heavy equipment and quite possibly more. Compaction should be by both roller and vibratory equipment of large size and it is anticipated that the results of laboratory compaction tests will indicate that considerable moisture should be added to the moraine, on the fill, to bring it to optimum moisture content.

The permeability of the moraine will be somewhat high compared to classical impervious core materials. Consequently, when moraine is used as a core material a widening of the core is usually called for in design in order to restrict seepage losses.

Loessy soil is by far the most abundant of impervious core materials available in Iceland. It exists at the Tungufell site, near the three Jokulsa damsites and about 12 kilometers from the Burfell site in a condition suitable for use in a fill dam. Similar soils have been used in fill dams in the United States at Priest Rapids and Arkabutla Dams. The loessy soil in Iceland, however, contains some volcanic ash in most places. The maximum permissable percentage of ash content will be determined from tests already underway but is believed to be well over the percentage contained in the deposits mentioned above.

Compacted samples of the loessy soil have been viewed in the laboratory and their appearance is good from density and permeability standpoints. The ash in the loessy soil seems to lower its compacted density somewhat and heavy sheepsfoot rollers may be required for proper field compaction.

All the loessy soil deposits viewed were too dry for proper field compaction. Moisture will have to be added and this should be done at the borrow area to minimize loss due to blowing in transport. Either ponding, ditching, or sprinkling will work well although ponding of water over portions of borrow areas and excavation by dozer and shovel mixing the dry and wet loess probably assures the best moisture control.

Available Shell Materials

There are at least one of three primary shell materials available near most of the damsites visited. These are sand (usually wind blown), sand and gravel (from eskers or outwash plains, or river deposits), and rockfill. Moraine may also be used as shell material.

For the various sites, the various materials available are listed below:

Jökulsa a Fjöllum Development

Skarthsa and Mithfell-Lambafjoll Dams	Wind blown sand and rockfill, perhaps some moraine
Selfoss Dam	Sand and gravel from eskers, Rockfill, perhaps some moraine

Hvita Development

Dynjandi Dam	Sand and gravel from outwash deposits near Mosfell

Tungufell Dam	Rockfill
Aboti Dam	Rockfill and moraine
Hvitarvatn and Jokulfjall Dams	Morain and sand and gravel from Jokulfall river bed
Thjorsa Development	
Burfell	Sand in delta deposit west of Burfell and rockfill

The appropriate use of the various materials will depend on the economics related to Icelandic wage rates and to foundation conditions at the various sites. This will require comparative analyses of alternates. Most of the obvious alternates have been presented in sketch form prior to submission of this report and these should serve as a basis for initiation of the studies.

It should be mentioned that placement and compaction of pervious materials should be accomplished with the materials thoroughly saturated. Sand should be compacted with vibratory equipment. One pass of tractors over sand and gravel is sufficient for compaction of this material. Rockfill needs only to be dumped and sluiced. The rock of rockfill should be of sound and durable quality. One portion of the core of clay stone from Hole 5 at Burfell was obviously not of this quality. Care, therefore, must be exercised in estimating the portion of required rock excavation which can be used as rockfill.

Summary

In most cases, the available soils in Iceland permit a wide range of choices of fill dam design. Use of these natural building materials in an ingenious manner should result often in sizable economies and will enhance the overall development of the hydro-electric resources of the nation. The author is pleased to have taken a small part in such a vigorous and all-encompassing program.

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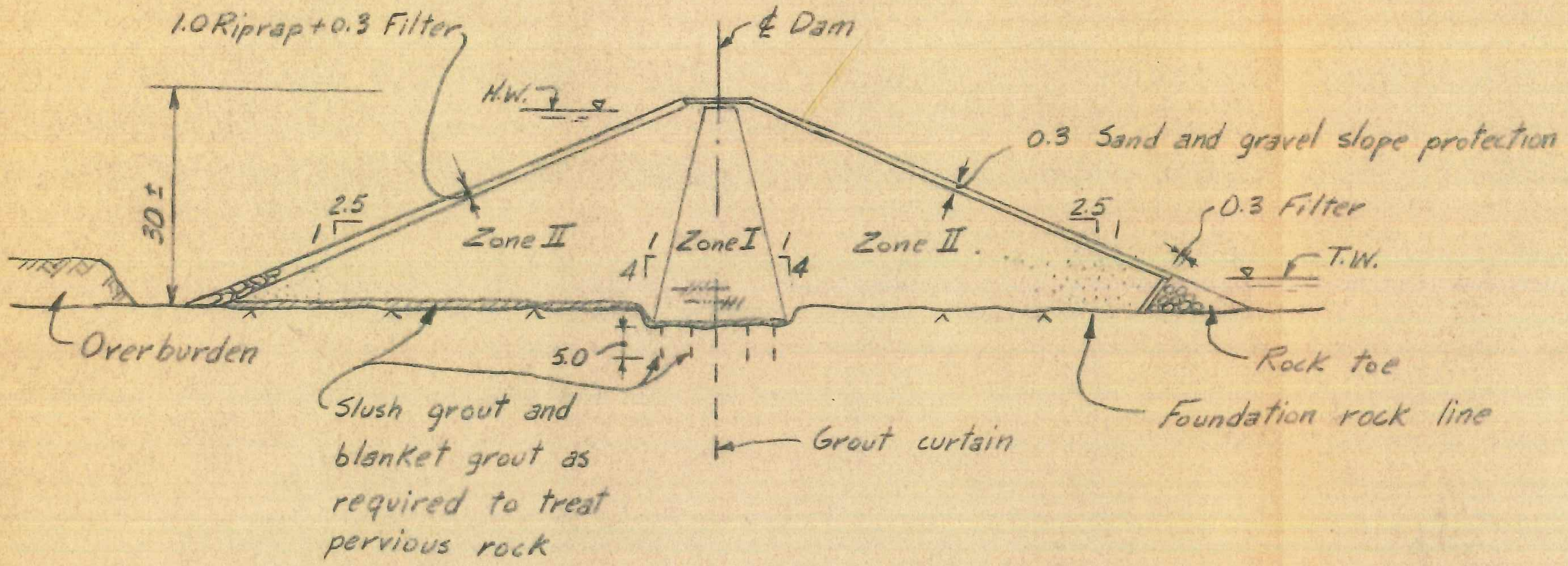
JOKULSA A FJOLLUM DEVELOPMENT

SKARTHSA AND MITHFELL-LAMBAFJOLL DAMS

ALTERNATE I

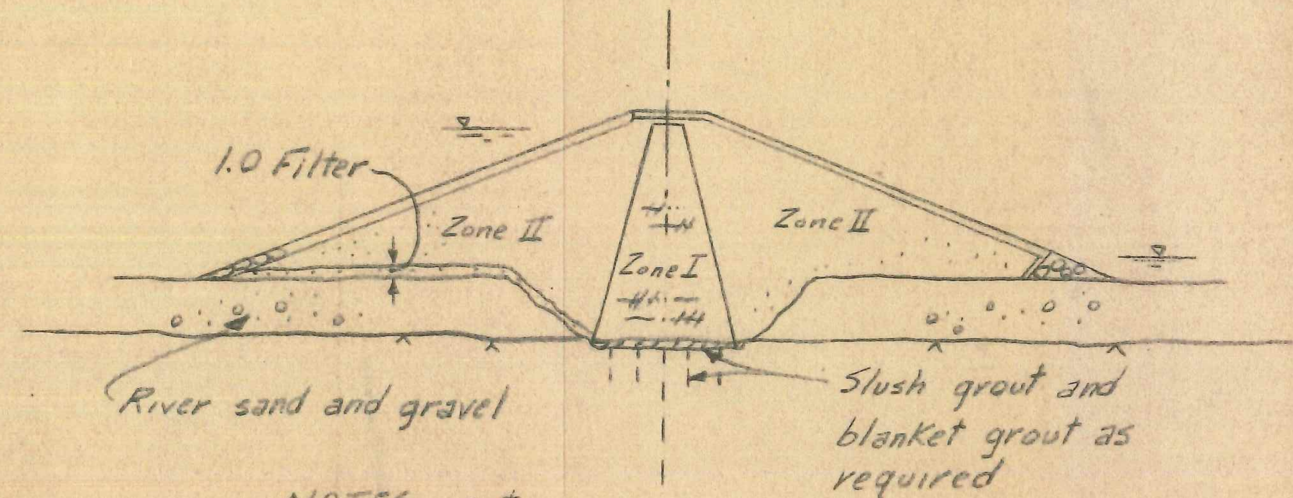
DAM ON BEDROCK



ALTERNATE II

DAM ON OVERBURDEN

Same as Alternate I except as noted



NOTES

1. Zone I is loess (sandy silt), assumed soil characteristics are $\phi = 20°$, $c = 0$, $k = 10^{-5}$ cm/sec
2. Spread Zone I material in 0.3 lifts and compact with sheepsfoot roller
3. Access must be gained to the East side of the Jokulsa to assure availability of sufficient quantity of loess
4. Zone II is wind blown sand or river sand, assumed soil characteristics are $\phi = 28°$, $c = 0$, $k = 10^{-2}$ cm/sec.

NOTES, cont.

5. Spread Zone II material in 0.3 lifts and compact with vibratory compactors
6. Some weathered morain may be encountered at the sites. It may be used in Zone II nearest the center core

Scale: 1 cm = 10 meter

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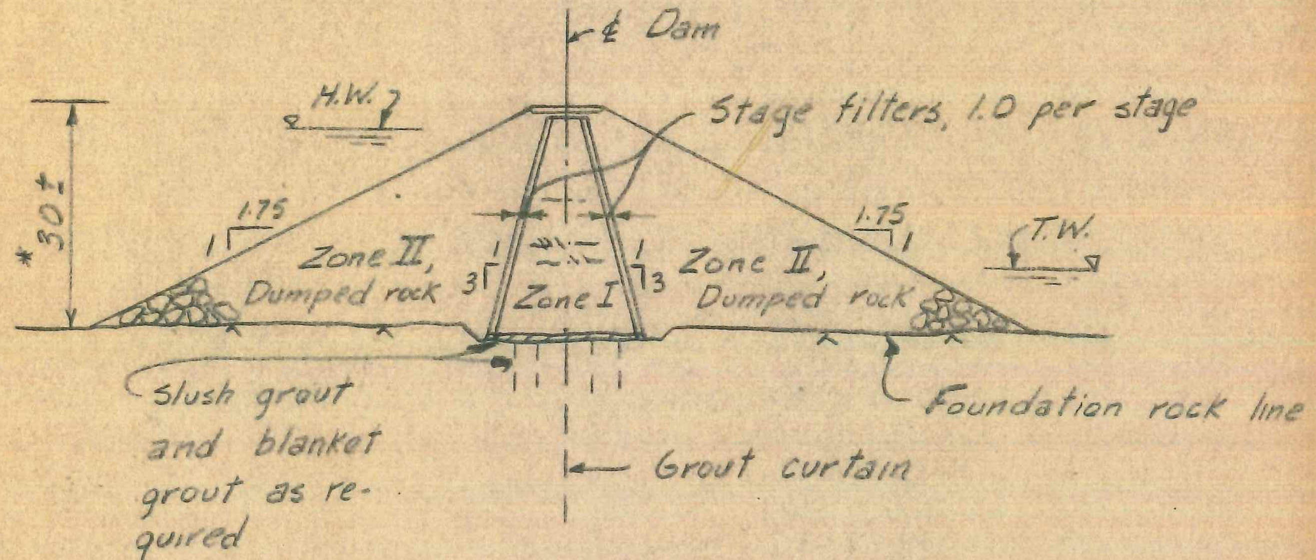
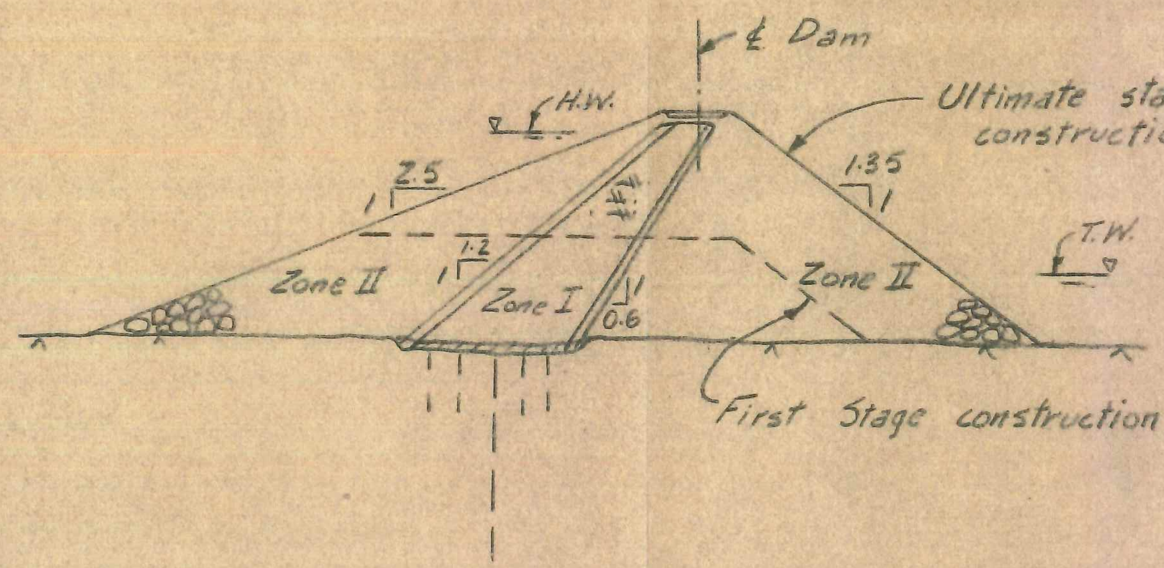
JOKULSA A FJOLLUM DEVELOPMENT
SELFOSS DAM
and
HVITA DEVELOPMENT
TUNGUFELL DAM

ALTERNATE I
VERTICAL CORE ROCKFILL



* 15 ± for Tungefell

ALTERNATE II
SLOPING CORE ROCKFILL FOR STAGE DEVELOPMENT



NOTES

1. Zone I material is loess, assumed soil characteristics are $\phi = 20°$, $c = 0$, $k = 10^{-5}$ cm/sec.
2. Spread Zone I material in 0.3 lifts and compact with sheepsfoot roller.
3. Dumped rock is spoil from tunnel excavation, assumed $\phi = 40°$; dump and sluice with 2-4 cu.m. of water per cu.meter of rock
4. Some morainal deposits may be encountered close to

NOTES, cont.

the site. Because of the shorter haul, they may be less expensive than rock from furthest portions of tunnel. Moraine may be used in Zone II nearest the center core.

Scale: 1 cm = 10meters

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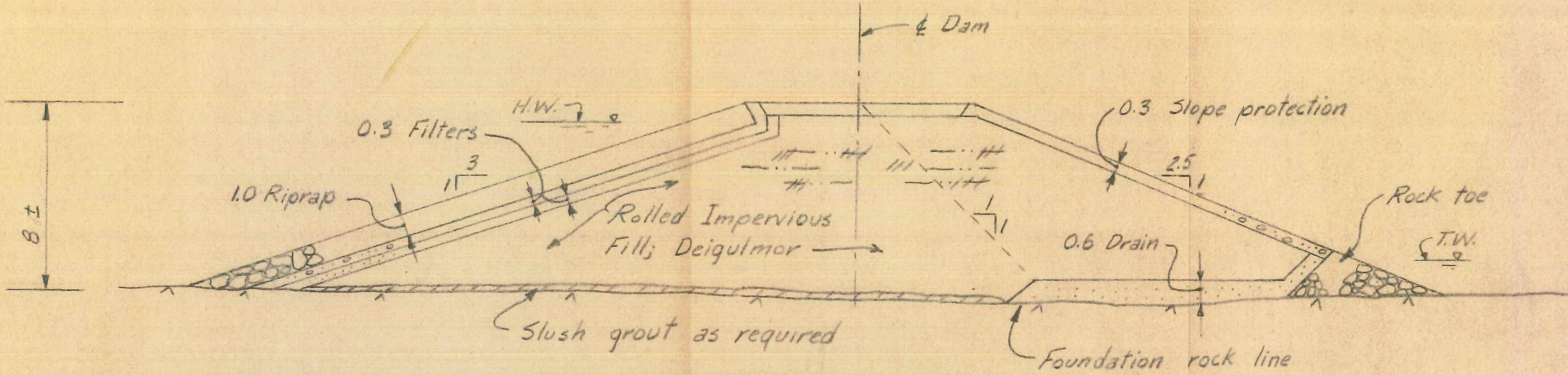
HVITA DEVELOPMENT

DYNJANDI DAM



Scale: 1 cm = 2 meters

NOTES

1. A test embankment should be constructed of the deigulmor soil to determine the most suitable type of compaction equipment to be used. Heavy rubber-tired rollers may be best. The most practicable moisture content attainable should also be determined during the test.

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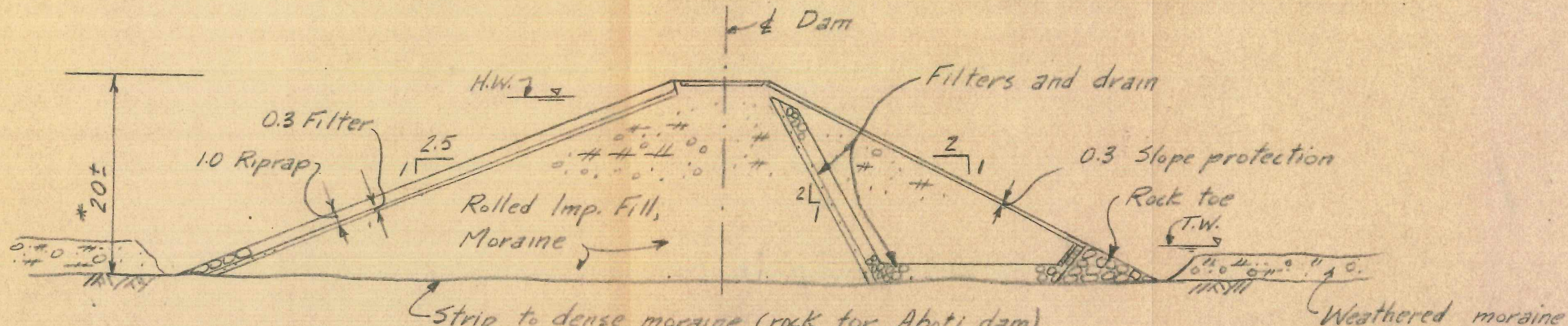
HVITA DEVELOPMENT

HVITARVATN, JOKULFJALL, AND ABOTI DAMS



* 8± for Aboti

NOTES

1. Assumed soil characteristics for moraine; $\phi = 30°$, $c = 0$, $K = 10^{-4}$ cm/sec.
2. Remove cobbles larger than 6" dia. by scarifying each lift
3. Spread moraine in 0.3 lifts, compact with heaviest available combination roller-vibratory compactors
4. All moraine shall contain 10% or more material passing #200 screen
5. See page 5 for alternate for Aboti Dam

Scale: 1 cm = 5 meters

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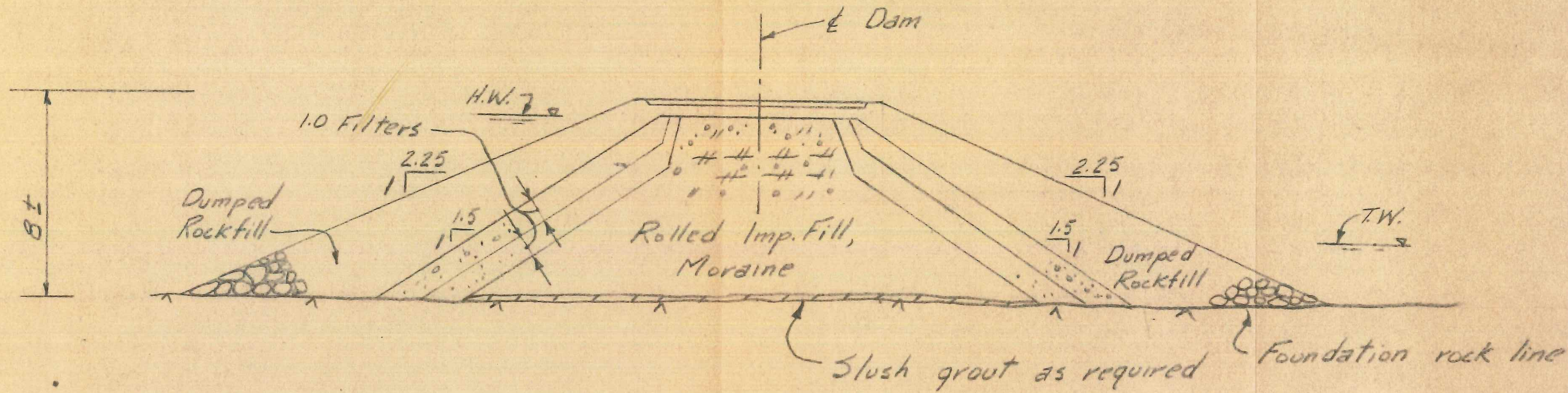
HVITA DEVELOPMENT

ABOTI DAM

ALTERNATE II



NOTES

1. Rockfill is obtained from required excavation, see page 2 for pertinent notes
2. See page 4 for notes regarding moraine

Scale: 1 cm = 2 meters