社会開発協力部報告書

MINISTRY OF CONSTRUCTION
GOVERNMENT OF THE REPUBLIC OF KOREA

# PRELIMINARY FEASIBILITY REPORT
# ON
# THE LONG-TERM MULTIPURPOSE DAM SCHEMES

## (SECOND STAGE)

## VOL. 4

## ANNEXES

JULY 1979

JAPAN INTERNATIONAL COOPERATION AGENCY

# VOL. 4

# GLOSSARY

## Local Terms of Administrative Areas

| | |
|---|---|
| Do | Province |
| Gun | Subdivision of province, similar to a county |
| Myeon | Subdivision of a Gun |
| Ri | Village of community of more than one village |
| Eub | Town of the administrative level of a Myeon |
| Si | City of the administrative level of a Gun |
| Si | Special City of the administrative level of a Do |
| Gu | Subdivision of special city equivalent to Gun |
| Dong | Subdivision of Gu or Si equivalent to Myeon or Eub |
| Sa | Temple |

## Natural Features

| | |
|---|---|
| San | Mountain |
| Cheon | Small river |
| Gang | Larger river |
| Do | Island |
| Bug | North |
| Dong | East |
| Nam | South |
| Seo | West |

## Spelling of names of places, rivers, etc.

The forms of English spelling of the regions, rivers, etc. that have been adopted are those promulgated by the National Ministry of Education.

## CONVERSION FACTORS AND ABBREVIATIONS

### 1) Length

mm = millimetre
cm = centimetre
m = metre
km = kilometre

### 2) Areas

ha = $10^4 m^2$ = hectare
Pyeong = 3.31 $m^2$
danbo = 300 pyeong = 992 $m^2$
Jeongbo = 100 danbo = 0.992 ha

### 3) Volume

lit = 1,000 $cm^3$ = litre
Seok = Volume containing
100 kg unhulled rice
144 kg polished rice
105 kg barley
138 kg naked barley
141 kg polished barley
138 kg wheat
114 kg unhulled millet
124 kg polished millet
142 kg rye
135 kg corn
135 kg soybeans

### 4) Weight

mg = milligramme
g = gramme
kg = kilogramme
ton = 1,000 kg = ton
gwan = 3.75 kg
geun = 0.16 gwan = 600 g

### 5) Time

s = second
min = minute
h = hour
d = day
yr = year

### 6) Money

$ = US dollar
₩ = Won
$ = ₩ 485, 1978 price level
mill = $ $10^{-3}$

### 7) Electrical Measures

V = Volt
A = Ampere
H = Hertz (cycle)
kV = Kilovolt
W = Watt
kW = Kilowatt
MW = Megawatt
kWh = Kilowatt hour
MWh = Megawatt hour
GWh = Gigawatt hour
ohm = Resistances
mho = Micromhos = conductance

### 8) Other Measures

ppm = parts per million
% = per cent
o/oo = per thousand
PS = Horse power (75 mkg/s)
pH = scale for acidity
°C = degree centigrade
$10^3$ = thousand
$10^6$ = million
$10^9$ = billion (milliard)

### 9) Derived measures are based on the same symbols:

$m^3/s$ = cubic metre per second
ton/ha = ton per hectare
kWh/yr = kilowatt hour per year
kVA = kilovolt ampere

### 10) Technical Terms

BOD = Biochemical oxygen demand
dia. = Diametre
El. = Elevation above mean sea level
H = Height or water head
HWS = Reservoir high water surface
K = Potassium
LWS = Reservoir low water surface
N = Nitrogen
P = Phosphorus
PVC = Polyvinyl chloride
TSP = Triple superphosphate
TWS = Tailwater surface of turbine

# ABBREVIATIONS

| | | |
|---|---|---|
| ADB | Asian Development Bank | |
| ADC | Agricultural Development Corporation | |
| BOK | Bank of Korea | |
| DMZ | Demilitarized Zone | |
| EPB | Economic Planning Board | |
| FAO | Food and Agriculture Organization of the United Nations | |
| FLIA | Farm Land Improvement Association | |
| HRBS | USAID/KOWACO Han River Basin Joint Survey Team | |
| IBRD | International Bank for Reconstruction and Development | |
| IR | International Rice Research Institute | |
| ISWACO | Industrial Site and Water Resources Development Corporation | |
| JICA | Japan International Cooperation Agency | |
| KECO | Korea Electricity Company | |
| KOWACO | Korea Water Resources Development Corporation, previous name of ISWACO | |
| MAF | Ministry of Agriculture and Fisheries | |
| MOC | Ministry of Construction | |
| NACF | National Agricultural Cooperatives Federation | |
| OECF | Overseas Economic Cooperation Fund, Japan | |
| ORD | Office of Rural Development | |
| PORD | Provincial Office of Rural Development | |
| UNDP | United Nations Development Programme | |
| UNSF | United Nations Special Fund | |
| US/AID | United States Agency for International Development | |
| USDA | United States Department of Agriculture | |
| USCE | United States Corps of Engineers | |
| KOR 13 | UNDP/FAO | Soil Survey Project |
| KOR 16 | UNDP/FAO | Pre-Investment Survey of the Nagdong River Basin Project |
| KOR 72 | UNDP/FAO | Nagdong River Basin Delta Study |
| KOR 75 | UNDP/FAO | Nagdong River Basin Development Project Feasibility Study |

# ANNEX L

# GEOLOGY OF THE PROPOSED DAMSITES

TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

# GEOLOGIC LOGS

1. Bamseonggol, upstream damsite, DH1
2. Bamseonggol, downstream damsite, DH1
3. Inje, upstream damsite, DH1
4. Hongcheon damsite, DH1
5. Hongcheon damsite, DH2
6. Gujeol damsite, DH1
7. Dalcheon damsite, DH1
8. Ganhyeon damsite, DH1
9. Bonghwa, upstream damsite, DH1
10. Bonghwa, downstream damsite, DH2
11. Imha damsite, DH1
12. Hamyang damsite, DH1
13. Juam damsite, DH1

## L 1 INTRODUCTION

A preliminary geological reconnaissance was carried out on 24 proposed damsites in the first stage of the study.

For upgrading precision of the result of the above study on the selected ten dam project sites, three alternative damsites and power station sites, geological investigation including geological mapping, seismic exploration and core boring with water pressure test have been programmed in 1978.

Geological mapping and seismic exploration were carried out by JICA team, while the base map for geological mapping as well as for design work was prepared by MOC with scale of 1/1,000 to 1/2,500. Core boring with water pressure test was also executed by MOC and the result was provided to JICA Team.

All the result of the said geological investigation carried out in 1978 is described in this report.

## L 2 GEOMORPHOLOGY AND GEOLOGY OF KOREA

The Korean peninsula, 1,300 km long and 300 km wide, is located between the Yellow Sea and the East Sea at the eastern part of the Asian Continent.

The eastern coast line of the peninsula runs immediately along the skirt of steep slope of mountain range and, on the contrary, the western and southern coast line indicates curved shape having wide alluvial plains in places. It is presumed that this assymmetrical topographic shape has been caused by tilting movement, subsedence in western coast and upheaval in eastern coast, and, thus, the ridge line of watershed runs in the eastern side of the peninsula. In general, rivers running to the eastern coast are short in their stretches and steep in riverbed gradient. Long stretching rivers with gentle gradient such as the Han river, the Geum river, the Nakdong river, and the Seomjin river, discharge to the southern or western coast.

The topography of mountains along the water divide is mature, with sharp ridges and steep valley flanks, however, toward the western part of the peninsula, it becomes late mature to old stage with round ridge hill masses and with wide flat valley planes. Wide alluvial plains develop at the river mouths of great rivers in the western coast.

The standard stratigraphic unit of the Korean peninsula is shown in Table L 1, based on the 1/250,000 scale geological map compiled by the Geological and Mineralogical Institute of Korea. The lithology and major tectonic structure reflecting past geological evolutions is shown in Fig. L 1.

It is recognized that thousands million years ago, in Archaeozoic in Pre-Cambrian age folding, metamorphism and igneous activity formed highly metamorphosed gneiss and schist in Gyeonggi and Yeongnam Massif. The mechanism of them is still unclear.

In late Proterozoic age a subsidence developed between Gyeonggi and Yeongnam Massifs forming the Ogcheon Basin which is originally presumed to develop widely in the southern part of the Peninsula. Marine sediments were deposited there since onset of the subsidence till mid-Ordovisian age. At the onset of the Cambrian Period, the Ogcheon Basin became enlarged and a dominantly calcareous sequence called the Joseon Supergroup was deposited.

The sedimentation was discontinued since mid-Ordovisian probably due to marine regression.

Marine sedimentation was again renewed in late Carboniferous time after discontinuance of sedimentation since mid-Ordovisian, however, sedimentation became non-marine sequence later which together constitutes the Pyeongan Group.

Since mid-Triassic period the southern Korea peninsula were affected by warping and tilting movement called as Songrim Disturbance which resulted the Ogcheon Basin into isolated basins within the Ogcheon zone which contains the town of Daejeon now a day and extends in NE-SW direction with around 60 km in width bounded by tectonic faults in the north and the south. The non-marine sediments of the Daedong Supergroup were deposited unconformably upon older rocks in the isolated basins both within the Ogcheon zone and also scattered over the Gyeonggi Massif.

At the climax of the movement in mid-Jurassic time, that is called Daebo Orogeny, the Ogcheon Basin were folded and metamorphosed to form the Ogcheon Fold Belt. Huge batholiths of granite and grano-diorite were intruded into the Ogcheon Belt and into the Gyeonggi and Yeongnam Massif.

After the Daebo Orogeny, a wide sedimentary basin developed in south eastern Korea where the non-marine sediments, volcanic rocks of the Gyeongsang Supergroup were deposited. The Bulgugsa Granite and acidic Plutonic rocks were intruded in places in the southern part.

Tertiary rocks, consisting of earlier non-marine, and later marine sediments of Miocene and Pliocene age were accumulated in a few small basins along the east coast.

Quarternary deposits are seen as terrace and alluvial deposits along river courses and in flat plain along sea coasts. Volcanic activity in the Quarternary was known in Jeju-do and other islands nearby.

## L 3 GENERAL DESCRIPTION OF GEOLOGICAL INVESTIGATION

### L 3.1 Investigation Performed

The quantity of the geological investigation performed in the second stage of study in 1978 is shown in Table L 2.

Three core borings in the Inje downstream site at the lower part of both banks and the riverbed, and three core borings in the Bonghwa upstream site at almost water edge of both banks and the riverbed were made by MOC in the past period. However, no accurate drilled spots of them can be identified at the sites, and obtained core materials has been missing. Only rough spot indication and geologic logs described in Korean language are available at present. No water pressure test data is attached in the description of them.

### L 3.2 Method of Investigation

#### L 3.2.1 Geological mapping

Geological mapping was carried out by using 1/1,000 to 1/2,500 scale map on the damsite and the power station site (except Bonghwa downstream power station). For the Bamseonggol (alternative), Imha and Juam damsites 1/1,000 scale maps were available, and in other dam and power station sites, 1/2,500 scale maps were used for geological mapping. These maps cover the area of the damsite as well as major appurtenant structure sites such as spillway, diversion tunnel and power house site. In addition, geological reconnaissance was made on the quarry site and re-regulating pond damsite by using 1/25,000 scale map and field measurement (see DRAWINGS).

#### L 3.2.2 Seismic exploration

Seismic exploration lines were arranged in each damsite. Two lines are placed in parallel with the dam axis, with 50 m interval and auxiliary line(s) is set perpendicular to the dam axis under the consideration of conditions of topography, surface geology as well as design of structures.

Detectors were placed at 5 m intervals to receive primary seismic wave shot at the explosion point. The obtained records were arranged in time-travel curve for analyzing thickness, structure of the velocity layers (see DRAWINGS).

### L 3.2.3 Drilling investigation

Core boring with water pressure test was executed by MOC. Prior to the operation, the technical specification of the core boring and water pressure test was discussed and agreed between MOC and JICA Team. After the boring and water pressure test was completed all data obtained were been provided to JICA Team in December, 1978. The recovered drilling core materials were inspected by JICA Team.

The water pressure test was made in the drilled hole at 5 m steps. The hole was drilled in a depth of 5 m, and then, a packer was set at the top of the drilled section and clean water was injected with the specified pressures. A volume of injected water under a given constant pressure was measured for 10 min. in each pressure stage. A series of water injection under various pressures as specified was completed, then, the hole was drilled below the tested section for obtaining the subsequent core recovery and water pressure test.

Lugeon value at the injected section was estimated by injected water volume and the given pressure as shown in Figs. L 14 to L 19.

The recovered core materials are described in this report by the observation criteria as shown in Table L 3.

### L 3.2.4 Reconnaissance of the quarry site

The quarry site was investigated based on 1/25,000 scale map in consideration of the required volume of rock materials as shown in Table L 4 for rockfill type dam construction, accessibility, overburden, rock quality, etc. within the distance of 4 km from the damsite.

### L 3.2.5 Reconnaissance of the re-regulating pond damsite

In case a re-regulating pond is deemed necessary for keeping control of water flow to the downstream, suitable damsites were investigated at the downstream of the powerstation, in connection with topographic profile, overburden and the foundation conditions.

# L 4 SPECIFIC SITE DESCRIPTION

## L 4.1 Bamseonggol, Upstream

### L 4.1.1 Outline of project

| | | |
|---|---|---|
| Location | : | See Fig. L 2 |
| Dam type | : | Rockfill |
| Dam height | : | 105 m |
| H.W.L. | : | El. 305 m |
| Power house | : | Dam and tunnel |

### L 4.1.2 Geology of damsite (DRAWING NO. 001 and Fig. L 14)

The upstream damsite is located near the uppermost stream area of the gorge streching to the downstream site. At the upstream where the dam is planned, the main stream curves and forms a wide valley of more than 10 km.

The rock is a coarse grained, hard granitic gneiss; most of rocks are fresh, however, fissures appear on many outcrops of the hillside. These fissures have not been intensively weathered.

The left abutment rises on a gentle slope for 70 m from the river side, and becomes a hillside of about 30° (1 : 1.9). The gentle slope is a river terrace covered with scree; the thickness of the overburden is estimated to be 12 m, according to core boring DH 1. By the core of this hole, it is also estimated that many of the rocks underlying the overburden deep to 19.2 m have been intensively weathered, and cracky. The core obtained in this section is a slime. A fresh, hard granitic gneiss continues from the depth of 22.2 m to the bottom of the hole. The water table in the hole is 10.6 m deep. The rock lying below a depth of 19.2 m may be impermeable.

Between the seismic Lines A-1 and A-2 lies a shallow elongate valley which is covered with scree, while on a steep slope appears many outcrops of rock.

The river terrace is cut near the outlet of the diversion tunnel, which is located about 300 m downstream of the dam axis. In this place, large boulders are distributed.

The river bed is about 80 m wide; its left abutment has a flood plane of about 30 m wide. The low water channel runs only along the right abutment. Thus, the right abutment is an undercut slope on which fresh, hard rocks are exposed. The gneissic structure of the rocks is not clear; it is rather massive and fissures are few and almost closed.

The right abutment rises on a south slope while increasing its height and width in the west-northwest. This slope is about 40° (average); the width of ridge at the high water level is about 50 m. On the river bank to the hillside, many rocks are exposed widely. The hillside near the dam axis has many reliefs, while the valley is deposited by scree. The valley is suddenly open at about 400 m downstream of the dam axis, or from the outlet of the spillway to the downstream, and the hillside slope widely covered with overburden becomes gentle. Because the tributary joins the upstream of the dam axis, the river becomes wide, and a flood plane of about 30 m wide spreads on the skirt of hill passing the riverside road.

The ratio of the valley height to the valley width at the high water level is about 1 : 4.2 near the dam axis. The right abutment rises on a very steep slope, showing an asymmetric figure on the cross section of the valley.

### L 4.1.3 Drilling investigation (DRAWING NO. 001, Fig. L 14 and GEOLOGIC LOGS)

The core borings have been made on the river terrace of a left abutment. From the topsoil of 3 m deep to a depth of 19.2 m has been excavated by means of a metal crown. Rock pieces have been obtained in some places; however slime has been lifted in most places and casing has been inserted. This implies that it would be difficult to determine whether this part has been formed by terrace sediment or a weathered rock with many fissures, but, considering from the location of the water table, a rock seems to continue from a hole depth of 12 m or deeper.

Pieces have been obtained from a depth of 19.2 to 22.2 m; fissures have been stained with limonite. A stick or piece core of fresh, hard gneiss has been obtained from the depth of 22.2 m to the bottom of the hole. The water pressure test made for rocks lying below the portion of 19.8 m deep, has obtained values of 1 Lugeon or less.

### L 4.1.4 Seismic exploration (DRAWING NOS. 001, 023 and 024)

The seismic exploration result shows the presence of three velocity layers underlying the damsite. They are interpreted as:

Interpretation of Velocity Layers,
Bamseonggol Damsite (Upstream)

| Layer | Velocity (km/sec) | Interpretation |
|---|---|---|
| I | Less than 1.0 | Overburden, severely loosened rock |
| II | 1.7 - 2.2 | Loosened or weathered rock |
| III | 4.8 - 5.2 | Fresh rock |

In addition to the above layers, a different low velocity zone with a velocity of 2.4 km/sec has been observed between 372.5 to 400 m of the Line A-2. This is located at the wing of the planned dam, the boundary between the zone and a fresh rock has not been observed clearly, however, it may be made up of loosened rocks.

### L 4.1.5 Quarry site (Fig. L 2)

The quarry site has been selected centering at a point around the high water level in the tributary which runs south and joins the main stream at the upstream of the damsite. The selected one is about 1 km north-northeast of the damsite. This quarry site does not interfere the construction although the site is located near the dam, and is capable of excavating rocks at both banks of the velley. The overburden covering the hill is thin, allowing granitic gneiss to scatter. The massive gneiss is excellent both in strength and durability.

This site is located at the valley opening south and its excavating faces may be open in the east and the west. The valley is relatively wide and water supply for work is convenient. Furthermore, the hillside slope is not so steep, and the faces are capable of being extended to the upperstream of the valley. Thus, the site has favorable construction conditions.

### L 4.1.6 Saddle area in reservoir area (Fig. L 2 and DRAWING NO. 003)

The extension of the hill feature of the left abutment forms a saddle area of about El. 310 m at about 550 m south east of the damsite. The saddle area continues considerably long; its roof width is about 50 m at the high-water level (El. 305 m). On the top of the roof exposed a granitic gneiss, while the hillside is covered with scree and the foot is covered with terrace deposit. On the gneiss distributing, fissures with steep dip strike across or diagonally the saddle ares. They seem to be loosened to the considerable depth, probably requiring an appropriate treatments for groundwater spouting.

### L 4.1.7 Geology of appurtenant structures

#### (1) Diversion tunnel (DRAWING NO. 001)

Two parallel diversion tunnels have been planned at the left abutment. It is expected that hard, massive granitic gneiss are excavated in the most part of the tunnels. The geology of the tunnels is excellent, with no problem about tunnel diameter and interval between the tunnels. Since there are many fissures on the rock near the tunnel inlet, caution must be taken to keep stability of the slope near the tunnel inlet. Boulders deposit near the tunnel outlet. It is suggested that this deposit will be excavated and removed for the construction.

#### (2) Spillway (DRAWING NO. 001)

The spillway will be made at the right bank. The right bank rises up a steep cliff, the hillside slope of the chute will be high, requiring design and construction taking stability of the slope into account. The surface of near the outlet is covered with overburden. The foundation depth may be determined in further investigation.

### (3) Powerhouse (Fig. L 2 and DRAWING NO. 003)

The powerhouse is planned to be constructed about 1.8 km downstream the alternative damsite. Large boulders are accumulated at the foot of hillsides and streams near the powerhouse site. There are rocks with fissures and tumbled blocks. The planned powerhouse site seems to be appropriate, but the depth of foundation has not been determined. A further investigation is necessary.

## L 4.2 Bamseonggol, Downstream

The downstream damsite seems to be located at part of a large-scale rockslides zone. A wide gentle slope extends centering around the place about 1 km south-southeast the damsite. The valley originating from the gentle slope is covered with collapsed rock blocks. The head of the valley changes to the gentle slope and there are swamps on the gentle slope which have been made by collapsed materials. On the foot of both banks, large boulders have been collapsed and accumulated. The rocks on the hillside are loosened, and have been formed by a large block detached from a bed rock. On the other hand, there are exposed, fresh firm biotite gneiss on the river channel.

There is also saddle area at a location about 500 m east from the damsite. The height of its top is about 320 m in elevation. Completely weathered small outcrops of gneiss scarecely exit on the saddle area. The slopes are widely covered with thick overburden, requiring appropriate countermeasures for stored water spouting. The physical limit of reservoir high water surface will be at El. 300 m. The location of the site is shown in Fig. L 2.

### L 4.2.1 Geology of damsite (DRAWING NOS. 002 and 003)

The valley at the damsite has the left slope with an inclination of about 20° and the right slope with an inclination of about 40° lying across a river channel of about 30 m wide. The ratio of the valley height to the valley width at the high water level (El. 300 m) is 1 : 3.7.

The hillside of the left abutment is covered with overburden from El. 280 m downward; there are few rock exposures and detached rocks. The detached rocks are also distributed on the hillside higher than 280 m in elevation and the slope is gradually steep toward the top. The foot with a gentle slope seems to be formed as the result of that the river terrace has been covered with scree. Large boulders are distributed on it. These boulders are biotite gneiss, some of which have slickensides presumably formed by mountain slides attributable to fault.

The sand and gravel are accumulated on the river channel; however it seems to be thin. The narrow outcrops of rocks stretched along the right river side are fresh, firm biotite gneiss. Generally, the spacing of a fissure is close, and most of dip is steep.

The slope of the right abutment is made of gneiss which covered with thin overburden. Generally, there are many loosened or detached rocks. On the foot of the hill slope, large boulders are distributed.

### L 4.2.2 Drilling investigation (DRAWING NO. 002, Fig. L 14 and GEOLOGIC LOGS)

One core boring has been made on the gentle slope of a left mountain foot by excavating 40 m deep. Surface soil and soil with debris lie from the surface to the depth of 6.1 m. The small amount of biotite gneiss core has been taken from the depth of 6.1 m or more, some of which have slicken-sides. The water table lies at a depth of 13.6 m, being at almost same elevation as the water table in the main stream. Therefore, it would be difficult to say the core is formed by a bed rock or by detached rocks. Since the water pressure test has been made from the depth of 23.2 m or more showing its Lugeon's values of 9 to 19, and slime has been obtained from the depth of 6.1 to 15 m the bed rock distributed presumable 15 m deep. The depth to 4.7 km/sec layer in seismic wave velocity is about 19 m in the core boring spot.

### L 4.2.3 Seismic exploration (DRAWING NOS. 004, 025 and 026)

The seismic exploration result shows the presence of three velocity layers underlying the damsite. They are interpreted as:

Interpretation of Velocity Layers,
Bamseonggol Damsite (Downstream)

| Layer | Velocity (km/sec) | Interpretation |
|---|---|---|
| I | Less than 1.1 | Overburden, severely loosened rock |
| II | 2.0 - 2.1 | Detached rock, loosened rock, weathered rock |
| III | 2.7 - 4.1 | Fresh rock (somewhat cracky) |

In addition to the above layers, some different low velocity zones shown in PROFILE A-A have been observed. These low velocity zones are estimated to be formed by cracky rocks.

The comparison between the exploration result at the downstream and that of upperstream reveals that the velocity of seismic wave at the downstream is slower than that at the upstream and that there are more low velocity layers in the downstream than in the upstream, moreover the 2.1 km/sec layer is thicker at the downstream than at the upstream, although there is no difference in rock type between two sites.

This suggests that the rocks at the downstream are loosened to a considerable depth and have more fissures.

### L 4.2.4 Comments

(1) The downstream site located at part of a wide rockslides area is not suitable for damsite of a high dam.

(2) The upstream damsite has not such unfavorable geologic conditions as the downstream damsite has. The foundation of the core of the planned fill dam will be provided inthe 2.0 km/sec (or more) layer (DRAWING NOS. 025 and 026) and the foundation of the shell zone will be on the upper part of the 2.0 km/sec layer. Lugeon's value of 1 or less obtained by the water pressure test would show the foundation rock is generally excellent in water-tightness.

(3) Most of the diversion tunnels of the upstream scheme route is formed by firm, hard gneiss with few fissures. Consideration on the slope stability at the inlet and the excavation of boulders at the outlet are suggested for the construction.

(4) The powerhouse site for the upsteam dam is planned to be constructed at more stable location in surrounding area. Further investigatiion is required for the site of the surge tank, penstock line powerhouse, to determine the foundation depth.

(5) An appropriate treatment is required for a saddle area centering about 550 m southeast the damsite in order to prevent stored water spouting.

(6) Rock material is capable of being obtained from the location centering around 1 km north the damsite. This location has favorable construction conditions in addition to that fresh firm gneiss is capable of readily obtained. Moreover, filter materials are provided by river gravel widely distributed at the upstream damsite.

## L 4.3 Inje, Upstream

### L 4.3.1 Outline of project

Location : See Fig. L 3
Dam type : Concrete gravity dam
Dam height : 128 m
H.W.L. : El. 344 m
Powerhouse : Dam and tunnel

### L 4.3.2 Geology of damsite (DRAWING NO. 004)

The river forms rapids at the upstream from the survey point 9 and at the downstream from the survey point 13. It is 30 to 40 m in width during a period of drought. Both abutments are very steep and the ratio of valley height to valley width is about 1 : 3.6 at the planned high water level (El. 344.00 m).

At the left abutment, rocks crop out continuously along the river side and the hillside is covered with thin scree. At an area from 260 to 280 m in elevation, loosened rock masses and large detached rocks are scattered. Most part of the river bed is covered with thin gravel deposit. The river side has rock outcrops. The right abutment is formed by a steep rocky mass but shallow valleys at the upstream and downstream side of the planned dam are deposited by debris.

The damsite is composed of a hard, firm and coarse grained granite having cracks ordinary in intervals of 30 to 80 cm. The outcrops are fresh though surface portion is loosened and locally has some open cracks because of a steep topographic feature. The drilling investigation and observation at the face of the quarry along the right abutment road suggest that the extent of relaxation is approximately 5 m deep at a lower portion of hillside. Both abutments have cracks with a gentle dip toward the mainstream. Large boulders lying from the left abutment foot to river brink will be those coming from the steep slope.

Considering a steep topographic feature, flood condition and existence of satisfactorily firm rock bed, a concrete dam is recommended for the planned type.

### L 4.3.3 Drilling investigation (DRAWING NO. 004, Figs. L 14, 15 and GEOLOGIC LOGS)

One vertical core boring with a hole length of 40 m has been made at the crossing of Line A-1 and the road of the right abutment. In this boring, granite has been reached below 1 m thick soil and debris. Rock has weathered and is cracky up to a depth of 3.6 m; it becomes fresh and hard from a depth of 4.9 m or more. The core recovery is 100 % in most parts excluding cracky parts. R.Q.D. is 100 % in most sections; it is more than 50 % in general excluding cracky parts. Rocks are excellent.

The water table is at a depth of 17.9 m. The water pressure test result which was obtained from a depth of 16.5 m to deeper shows that most of rocks may be assumed to be impervious.

### L 4.3.4 Seismic exploration (DRAWING NOS. 004, 027, 028 and 029)

The seismic exploration result shows the presence of four velocity layers underlying the damsite. They are interpreted as:

Interpretation of Velocity Layers,
Inje Damsite (Upstream)

| Layer | Velocity (km/sec) | Interpretation |
|---|---|---|
| I | Less than 0.3 | Soil and debris |
| II | 1.6 | Severely loosended rock, weathered rock |
| III | 3.0 | Partially cracked rock |
| IV | 4.5 | Fresh and firm rock |

Two and four low velocity zones have been detected on Lines A-1 and A-2, respectively; however, no low velocity zone has been detected on Lines B-1 and B-2. There is only one low velocity zone with a width of 17.5 m along Line A-1 (about El. 270 m) at the left abutment. All other low velocity zones lie at an elevation of 270 m or higher.

Most of these low velocity zones are 10 to 30 m wide along the seismic line having a velocity of 2.0 to 3.5 km/sec. It could not be determined if these lone low velocity zones were resulted from the topographic reason or concentrated fissures. Some of them will need test excavation before construction.

### L 4.3.5 Quarry site (Fig. L 3)

Survey was made only for the right abutment taking account of transportation conditions of rock and the fact that there is no flat area suitable for work in the main stream in valley. A quarry site has been set in a hilly area in an valley which joins the mainstream about 1.3 km upstream the damsite (Site A).

This hill area is covered with thin overburden and has a wide distribution of fresh rock outcrops. Its face will be opened in the west. Valley gradient is not so steep and roads could be constructed on hillsides of both banks. Furthermore, a working space will be enough since the face will be located at the crossing of the two valleys. The site is formed by hard granite which partially contains gneiss. These granite and gneiss have similar rock characters to each other and are excellent in strength and durability.

Besides the above quarry site, a hilly area of a valley joining the mainstream at about 1.5 km downstream of the damsite is also proposed. This area (Site B) has simliar construction conditions as quarry site A despite its face will be toward the northeast. This site is covered with thin overburden, and formed by granite. This granite is also excellent in quality as rock material. The quarry site B could be utilized also for the downstream site being located at about 3 km from the downstream damsite.

### L 4.3.6 Geology of appurtenant structure sites

#### (1) Diversion tunnel (DRAWING NO. 004)

A diversion tunnel is planned at the left abutment. A geological survey of the diversion tunnel shows that the tunnel will run across hard and firm granite. However, in some sections, the cracks strike in parallel to the direction of the tunnel and dip about 15° toward the mainstream, requiring a protection of walls during excavation. The inlet is planned at a skirt of a very steep rocky slope. In the vicinity of the outlet, the coverage of tunnel is not thick, and overburden is distributed at the end of the outlet.

#### (2) Powerhouse (Fig. L 3 and DRAWING NO. 006)

The powerhouse is planned at a skirt of a thin ridge projected into Soyanggang reservoir from the southeast. The ridge where the penstock and surge tank are planned is covered by highly decomposed granitic gneiss. Presumedly 20 m thick. This fact will be taken into account in the design and construction of the penstock and surge tank. The geological mapping detected a fault with a fructured zone about 5 m wide (strike: N30°E; vertical dip) at El. 470 m on the ridge. To the intake side of the fault, hard granitic gneiss is distributed though having open cracks. The fault will cross the headrace tunnel but rocks adjacent to the fault are assumed to be hard and firm.

## L 4.4 Inje, Downstream

### L 4.4.1 Outline of project

Location : See Fig. L 3
Dam type : Concrete gravity dam
Dam height : 150.00 m
H.W.L. : El. 341.00 m
Powerhouse : Dam and tunnel

### L 4.4.2 Geology of damsite (DRAWING NO. 005)

The dam axis will run across a location 35 m downstream of the gauging station and stretch to the ridge projected out from the both abutments. At the axis, the river is about 40 m in width. The ratio of valley height to valley width at the high water level is about 1 : 3.7. The valley has such a topographic feature as steep gradient from the river bed (El. about 210 m) to middle portion of hillside (El. 320 m) at both abutments followed by rather gentle slopes at an elevation of 320 m or more.

The mainstream becomes rapid; its river gravel is thin. Rocks crop out continuously at both banks, and a large amount of boulders tumbled from hillsides are distributed along both river sides.

The mountains at both banks are thick enough for dam construction. They are covered with thin overburden and have widely exposed rocks. Like the upstream damsite, this site is formed with hard, firm granite; however, rocks underlying near the surface are loosened. This requires that a care is to be taken in dam design.

Water seeps through cracks at a hillside on right abutment road (a location about 30 m upstream of the dam axis). Its temperature suggests that water comes out via a shallow part near the surface.

Interpretation of Velocity Layers,
Inje Downstream Damsite

| Layer | Velocity (km/sec) | Interpretation |
|---|---|---|
| I | Less than 0.5 | Topsoil, debris |
| II | 1.2 - 1.6 | Severely loosened rock, weathered rock |
| III | 2.8 - 3.3 | Somewhat loosened rock, slightly weathered rock |
| IV | 5.6 | Fresh, hard and firm rock |

The velocity of seismic wave in rock is faster at the downstream site than at the upstream site. This may be attributed to that the rock character is more excellent at the former than at the latter.

There is one low velocity zone clearly detected at Lines A-1 and A-2, respectively. Both zones run along a skirt of the right abutment. The zones along these exploration lines are 15 m and 12.5 m in width, respectively. A detailed investigation is required to confirm their characters.

Besides the above zones, another low velocity zone (about 2.2 km/sec and 25 m wide) runs in the vicinity of the end of the upstream of Line B, though not clearly detected. This zone is located fairly far from the dam axis.

### L 4.4.4 Quarry site (Fig. L 3)

Refer to L 4.3.

### L 4.4.5 Geology of appurtenant structure sites

(1) Diversion tunnel (DRAWING NO. 005)

Both the inlet and outlet are planned at a skirt of a steep valley wall of the mainstream.

(2) Powerhouse (Fig. L 3 and DRAWING NO. 006)

Refer to L 4.3.6 (2).

### L 4.4.6 Comments

(1) A fill dam is not recommended for both upstream and downstream damsites, from the viewpoint of topographic condition and construction of a large capacity spillway. This may also be said by the fact that both damsites and their vicinity are very steep, providing unfavorable conditions of material transportation.

(2) The base rock of the both abutments are fresh, hard granite excellent in strength and watertightness. The superficial rock, however, is steep and loosened and some cracks dip gently toward the river side, needing attention to slope protection during construction.

(3) Considering that the dam will be high concrete type, the foundation excavation line is assumed to be at the lower end of Layer III of seismic exploration in lower part of the abutment and is assumed to be at the upper end of Layer III in higher part.

(4) At the both upstream and downstream sites, diversion tunnel constructed by excavating hard and firm granite. It is possible that cracks gently leaning toward the river side continue for a considerably long section. An appropriate consideration is required in excavation. Some slope protection will be necessary at portals of both the inlet and outlet. The coverage is thin and debris deposits lie in the vicinity of the outlet of the upstream damsite, needing a detailed investigation of its character.

(5) The surface of the ridge where the penstock and surge tank are planned, is formed by decomposed granitic gneiss. Its thickness is assumed as 20 m. Further investigations of the thickness and rock character will be needed for stability and design of structures.

(6) Taking account of change in dam type into a rockfill dam, a quarry site has been selected both at the upstream and at the downstream scheme. Both quarry sites have been located only on the right bank of the mainstream considering topographic conditions for

a transportation road. Both quarry sites have satisfactory rock characteristics, and excellent construction conditions. Rock materials of both quarry sites could be used for concrete aggregate. Moreover, the rock has not so strong crushing resistance, so it could be used for sand production with low cost.

(7) There is no significant difference in geologic condition between the upstream and the downstream damsite. The dam volume of the upstream damsite (1,688 x $10^3$ $m^3$) is smaller than that of the downstream damsite (2,587 x $10^3$ $m^3$). The headrace tunnel length of the upstream damsite (about 5,250 m), however, is longer than that of the downstream damsite (about 2,800 m). Both damsites should be compared and studied from engineering and economic standpoints.

## L 4.5 Hogncheon

### L 4.5.1 Outline of project

| | | |
|---|---|---|
| Location | : | See Fig. L 4 |
| Dam type | : | Concrete gravity |
| Dam height | : | 80 m |
| H.W.L. | : | El. 120 m |
| Powerhouse | : | Attached to dam |

### L 4.5.2 Geology of damsite (DRAWING NO. 007)

The dam axis, on the left abutment, runs across the east slope of the ridge projected to north-northeast, while on the right abutment, passes the end of the ridge projected to south. The distance between both ridges is about 280 m at river bed point. Between two ridges, the mainstream forms a gorge; the valley becomes wide suddenly at the upstream and downstream of the gorge. The river channel is about 120 m in width at the dam axis. A sand beach has been formed at the right bank. At the dam axis section, the right abutment is steeper than the left abutment, forming an asymmetric feature of valley. The ratio of valley height to valley width at the high water level (El. 120 m) is about 1 : 5.

The damsite is formed by quartzite, schists and their alternation. Quartzite widely distributed at the left abutment locally intercalated forms an alternation with schists. The schist formation consisting of a small part of chlorite shist and a large part of sandstone schist is distributed from a river bed to the whole area of the right abutment.

Hard, firm and milk white or light gray quartzite forms a valley wall and very steep slope at a hillside. Hard, compact schist forms a steep valley wall in the south, while weathered schists form friable rock layer at high level parts of both abutment.

At the right bank, narrow quartz vein (about 70 cm wide at the dam axis) intrudes almost in parallel to the river channel, with a dip of 70° toward left bank. It contacts closely with mother rocks. The overburden covering these basements is several to 10 m in thickness at hillsides. Talus deposits consisting of boulders are distributed at the left abutment. The average river gravel thickness seems to be about 5 m or so.

At this damsite, Fault A was assumed and Fault B was imagined. Presence of Fault A was assumed connecting its outcrop which was found at the top of projected ridge on the left abutment (El. 120 m), and a low velocity zone resulted from the seismic exploration. In the outcrop, the quartzite schist alternation was crossed by Fault A of a strike of N20°W and dip of 70°NE. The shear zone is about 8 m in width. The ridge top has been eroded along the strike of the fault forming a peculiar feature of a wedge-type section. The shear zone is well compacted and clay formation is insignificant.

Presence of Fault B was imagined based on the results of core boring DH 1 and the location of low velocity zones analyzed from the seismic exploration. This fault seems to separate quartzite distributed at the left abutment and schists distributed at the right abutment. At a location that has been assumed as a fault by core boring, core recovery is very poor and lifted core have slikensides and are mylonitized. Lugeon values are 7 at a depth of 15 m or less and 0.7 to 3 at a depth of more than 15 m, indicating that the fault is well compacted.

### L 4.5.3 Drilling investigation (DRAWING NO. 007, Figs. L 15, 16 and GEOLOGIC LOGS)

Core borings DH 1 and DH 2 have been made at the left bank of Line A-1 and at the crossing of Lines A-2 and B on the right bank, respectively. The length of hole is 40 m in both core borings.

In core boring DH 1, a rock has been drilled under river gravel 1.5 m deep. Up to a depth of 28.5 m, core recovery was very poor; especially, slime has been detected up to a depth of 10 m. A rarely obtained piece is mylonitic or has slickenslides, presumably indicating that the zone is crushed. The water pressure test result shows that Lugeon values are 7 at a depth of up to 15 m and 3.0 to 0.7 at a depth of more than 15 m, indicating that the zone is well compacted. R.Q.D. is 35 % to 60 % from 28.5 to 34 m deep, and 85 % from deeper than 34 m. The water pressure test shows that Lugeon's value is 0.7. The core is fragmental from 30 to 32 m deep, and cracks have been stained.

In core boring DH 2, schists have been drilled under river gravel about 5 m in depth. Rocks becomes fresh, firm and hard from 6.0 m. The core recovery is almost 100 %. R.Q.D. ranges 20 % to 90 % (average 50 %); however, R.Q.D. becomes apt to low toward deeper. The water pressure test result showed that Lugeon value ranges from 4.6 (max.) to 0.3 (min.), being large for a rock underlying deeply. Above Lugeon values and R.Q.D. are indicating that there exists cracky rocks at some intervals.

### L 4.5.4 Seismic exploration (DRAWING NOS. 007, 032 and 033)

The seismic exploration result shows the presence of four velocity layeres underlying the damsite. They are interpreted as:

Interpretation of Velocity Layers,
Hongcheon Damsite

| Layer | Velocity (km/sec) | Interpretation |
|---|---|---|
| I | Less than 1.0 | Scree, river gravel, talus deposit |
| II | 1.9 | Severely loosened rock, weathered rock |
| III | 3.5 | Cracky rock, somewhat weathered rock |
| IV | 4.3 to 4.7 | Fresh, hard and firm rock |

From the macroscopic viewpoint, the velocity layer in fresh rock has a velocity of 4.5 km/sec at the left abutment (quartzite), 4.7 km/sec at the river bed (schists) and 4.3 km/sec at the right abutment (schists). In addition to the above velocity layers, two low velocity zones have been analyzed on Lines A-1 and A-2 at the right abutment, one zone at the river bed, and another zone at a vicinity 160 m downstream of the crossing of Lines B and A-2. One of low velocity zones of the right abutment and the low velocity zone of the river bed have been assumed as part of Faults A and B, respectively.

### L 4.5.5 Quarry site (Fig. L 4)

Although the damsite has unfavorable topographic conditions for construction of a fill dam, quarry site (Site A) has been surveyed considering a possible change in dam type. The quarry site has been selected at the left bank of the mainstream taking transportation condition into account. The site is in a highland (El. 319.9 m) located about 2.5 km upstream of the damsite. The area formed by quartzite is covered with very thin overburden; its steep slope toward the mainstream allows rocks to widely crop out. Between the steep slope and the mainstream, there exists a fairly wide plane, providing favorable conditions for working. From the viewpoint of quarrying conditions, however, this quarry site is not so favorable because quartzite is so hard and firm possibly as producing over sized material and the slope is very steep.

The highland area (Site B) about 200 m in elevation located about 3 km (air line) south-southeast of the damsite is formed by gneiss and schists capable of being used for good quality rock materials. The transportation distance will be more than 4 km.

### L 4.5.6 Geology of appurtenant structure sites

#### (1) Diversion tunnel (DRAWING NO. 007)

A diversion tunnel is planned across a projected ridge of the right abutment. The inlet is to be constructed directly at a very steep rocky slope, while the outlet is to be constructed at a skirt of the west slope of the ridge. This outlet joins the mainstream at an openchannel.

The tunnel will be found on fresh, hard and firm schists. The strikes of cracks are almost perpendicular with the driving direction of the tunnel, and dips are mostly steep, providing favorable geologic conditions which enable driving of a tunnel with a large diameter.

The thickness of river gravel distributed at the open channel is about 5 m. Further investigation is necessary for permeability of the coffer dam foundation.

(2) Powerhouse (DRAWING NO. 007)

The powerhouse is planned in river channel attached to the dam. The outcrops of sandstone schist are scattered in a vicinity of the powerhouse. The results of core borings and seismic exploration indicate that the powerhouse site is covered with thin river sand under which fresh, hard and firm schists are expected to lie.

### L 4.5.7 Comments

(1) The topographic feature of the damsite is suitable for a concrete gravity dam rather than a filldam.

(2) The foundation of the left bank of the damsite is mainly formed by quartzite, while that of the right bank is formed by schists. The quartzite is very hard and firm, however, its superficial part has many cracks. The major part of schists is formed by hard, firm sandstone schist and chlorite schist which is more or less softer than sandstone schist. All fresh rocks have satisfactory bearing capacity and watertightness for the dam.

(3) The results of geological mapping and drilling investigation suggest that overburden, scree, river gravel, talus deposits including large boulders, loosened rocks and weathered rocks to be removed during excavation will be in the vicinity of lower end of a low velocity layer (1.9 km/sec).

Also, the outcrop status at the assumed Fault A of the left bank and the results of drilling investigation in the river channel suggest that the presumed Faults A and B are compact; especially, Fault B has a Lugeon's value of less than 7. Fault A possibly runs across the dam wing, requiring a study of treatment method by digging a test adit and by performing a drilling investigation. Fault B also requires a study for treatment by performing a drilling investigation and test grouting.

(4) The diversion tunnel is planned at the right bank taking topographic features into account. The rock character of the tunnel route has not problem for excavation of a tunnel about 15 m in diameter.

(5) The powerhouse is planned in the river channel with a thin sand layer under which firm schists suitable for the powerhouse foundation are expected to lie.

(6) Aggregates for concrete dam will be readily provided by river gravel widely extending in the vicinity of damsite. However, rock materials provided by the quarry site 3 km upstream of the damsite are too hard, firm and massive, and the land is steeply sloped. Another quarry site providing a good quality of gneiss and schists is fairly far from the damsite.

## L 4.6 Gujeol

### L 4.6.1 Outline of project

| | | |
|---|---|---|
| Location | : | See Fig. L 5 |
| Dam type | : | Rockfill |
| Dam height | : | 68 m |
| H.W.L. | : | El. 748 m |
| Powerhouse | : | Diversion plan (Proposed); Dam and tunnel<br>Songcheon plan (Alternative); Dam and tunnel |

### L 4.6.2 Geology of damsite (DRAWING NO. 008)

The valley at the dam axis has such an asymmetric feature as that the right abutment with a 45° slope is faced with the left abutment with a 30° slope across a mainstream with a width of about 30 m. The left bank becomes very gentle from elevation of 800 m or more (above sea), restricting the dam height. The ratio of the valley height to the valley width at the high water level is about 1 : 4.

The damsite is formed by very hard and firm rocks. Its bedding is not clear; there may be an anticline running along the mountain foot of the left bank in parallel with the river channel and a syncline structure running through the middle part of the left hill side. Some cracks have a dip of about 20° in the direction of the downstream, while many cracks have a dip of more than 40° in diverse directions.

The overburden covering the basement includes scree, talus deposit, rockfalls deposit, river gravel, fan deposit and terrace deposit. Scree and talus deposit are widely distributed on the left abutment, while they are locally as well as thinly distributed on the right abutment. Presumably, a narrow terrace underlies the left abutment talus deposit along the foot of hill side. Debris formed by large boulders is accumulated from the outlets of the diversion tunnel to that of the spillway. The thin river gravel contains large boulders. The fan deposit is distributed along the upstream of the left bank, while the terrace deposit is distributed along the mainstream upward the right bank where an upper coffer dam is planned.

### L 4.6.3 Drilling investigation (DRAWING NO. 008, Fig. L 16 and GEOLOGIC LOGS)

The core boring DH 1 has been made vertically down to 30 m at the crossing of the Lines A-1 and B of the seismic exploration.

The boring has reached sandstones under the debris with a thickness of 3 m; however, the superficial parts of the sandstones do not allow the core to be obtained, and casing has been inserted to 6 m deep. At the depth of up to 9 m, rocks have been weathered, cracked and stained to brown. At the depth of 9 m or more, rocks become fresh, gray or dark gray and hard. R.Q.D. is zero at the part from 17.5 to 24 m. The water table in the hole is 8 m deep. Permeability is reduced as depth increases; it is less than 1 Lugeon at a depth of 20 m or more.

### L 4.6.4 Seismic exploration (DRAWING NOS. 008 and 034)

The seismic exploration result shows the presence of three velocity layers underlying the damsite. They are interpreted as:

Interpretation of Velocity Layers,
Gujeol Damsite

| Layer | Velocity (km/sec) | | Interpretation |
|---|---|---|---|
| I | Left bank : | less than 1.0 | Overburden, severely loosened and weathered rock |
| | Right bank : | 0.3 - 1.4 | Topsoil, scree, loosened and weathered rock |
| II | | 2.0 | Cracky rock, weathered rock |
| III | | 3.5 | Fresh rock |

In addition to the above velocity layers, low velocity zones have been analyzed at the mountain foot of the left bank of Line A-1, at the flank of the left bank and at the vicinity of about 730 m in elevation of the right bank on Line A-2. Besides these, the area of low velocity is located on Line B about 100 m from the crossing of Lines A-2 and B. The width of low velocity zones is fairly wide on these lines, presumably showing an area where rocks are cracked.

### L 4.6.5 Quarry site (Fig. L 5)

The quarry site has been selected at a tributary valley of the left bank joining the mainstream at a point of about 300 m upstream of the dam axis. This site is formed by fresh, hard rocks covered with thin overburden. The valley width is not so wide, requiring a handling of running water for quarrying. However, the site is very near from the damsite.

### L 4.6.6 Geology of appurtenant structure sites

#### (1) Diversion tunnel (DRAWING NO. 008)

The diversion tunnel will be made by excavating hard rocks. These rocks have many cracks some of which run in parallel to the tunnel route. At a vicinity of the portal of the inlet or outlet, some cracks are open; care will be needed not to allow blocks to tumble down in the vicinity of the inlet and outlet during construction.

(2) Spillway (DRAWING NO. 008)

The spillway will be made also at the left abutment. The foreset part and chute part of the spillway will be placed on sandstones. Since the excavated surface of a traffic wall of the mountain side rises up fairly high, care will be needed not to allow rocks to fall and slide along the slope during construction.

(3) Intake (Fig. L 5 DRAWING NOS. 008 and 009)

Diversion plan (DRAWING NO. 009)

The intake is planned at the outcrops of fresh, and hard sandstones located at the left bank about 1.5 km away from the damsite. Many cracks distributed in rocks are almost vertical; some of which have a gentle dip (10° to 20°) in the direction of the mainstream.

Songcheon plan (DRAWING NO. 008)

The intake is planned at the outcrops of hard sandstones located at the right bank of the damsite. The vicinity of the area has very steep landforms. Rocks are somewhat loosened and cracks are open. Although such features do not extend beyond the superficial area, some slope protection will be required during construction of the portal of tunnel.

(4) Powerhouse (Figs. L 6, 7, DRAWING NOS. 010 and 011)

Diversion plan (Fig. 6 and DRAWING NO. 010)

The powerhouse is planned at about 12 km in the north-east direction of the damsite. The headrace tunnel will be constructed in the hill masses and a sharp edged ridge of sandstone, granite, slate and quartzite in various series of geologic formation. The rocks along the tunnel route are commonly well cemented and little water seepage is expected to occur. The penstock and the surge tank will be laid on a sharp edged steep ridge formed of quartzite, sandstone and slate of the Yeongweol, Hongcheon and Gobangsan series with bedding plane of around N35° W60°E. The skirt of the ridge slope is formed of piedmont fan complex made of talus deposits covering probably the alternation of sand stone, quartzite and slate of the Gobangsan series. Deep excavation will be needed for foundation of the powerhouse.

Songcheon plan (Fig. L 7 and DRAWING NO. 011)

The powerhouse is planned about 14 km downstream in the south of the damsite. The headrace tunnel will be in the hill masses formed of the alternation of cemented slate, and sandstones of Yeoryang, Nagam and Gobangsan series. The penstock and the surge tank may be laid on a firm rocky ridge; however, slumps are developed on the steep slope, especially in the eastern part. Further study is required to fix the route of the penstock.

The bedding plane of the alternation near the powerhouse is commonly N4° to 25°E, 50° to 60°W in strike and dip, respectively and gradually changing to N54°W 20°E in the downstream. Accordingly, syncline axis occurs near a bridge where minor sheared zones are seen in the slaty rock. Firm sandstone beds are developed in the upstream of the syncline axis.

### (5) Re-regulating pond damsite (Fig. L 7 and DRAWING NO. 020)

The re-regulating pond damsite has been selected about 2 km downstream of the proposed powerhouse as shown in Fig. L 7. The left abutment consists of steep cliff of outcropping hard sandstone of the Gobangsan Group. The riverbed is 75 m in width having gravel probably on the base rock of that sandstone.

The right abutment is presently a bank of a railway with about 10 m high above the riverbed banked on the same sandstone.

### L 4.6.7 Comments

(1) The left abutment of the damsite has a gentle slope at an elevation of about 800 m or more.

(2) The talus deposit is distributed on the foot of the mountain of the left abutment, while the slope of the right abutment is steep and rocks are widely cropped out on it. The basement sandstones are somewhat loosened and deep sandstones are fresh and hard. The water pressure test made in the core boring DH 1 shows 3 Lugeons at a depth from 15 to 20 m and less than 1 Lugeon at a depth of 20 m or more. The bed rock has a low permeability.

(3) The excavation line of the dam foundation will be located in a middle of a velocity layer of 2.0 km/sec (seismic exploration) at a core part, and the foundation of rockfill part will be obtainable by removing unstable overburden. The low velocity zone analyzed by the Line A-1 is 12 m wide on the line and is located at the cutoff part of the dam, requiring further studies.

(4) Fresh and hard sandstones are provided from a mountain located at 1 km (distance in a straight line) upstream of the damsite as rock materials.

(5) The foundation of the surge tank and the powerhouse shall be detected by core borings in both schemes. Further investigation will be required to determine the final location of penstock.

## L 4.7 Dalcheon

### L 4.7.1 Outline of project

Location : See Fig. L 8
Dam type : Concrete gravity
Dam height : 55 m
H.W.L. : El. 117 m
Power station : Attached to the dam

### L 4.7.2 Geology of damsite (DRAWING NO. 012)

The damsite is placed at a narrow river stretch between hill masses of both banks formed of granite and schist probably of the Yeongweol Group.

The left abutment rises on a steep slope of granite which has irregular cracks on its outcropping surface, and partly weathered to arkosic sand. Schist masses are seen irregularly as xenolith in granite mass. Soils occur in places on the slope. Debris develop at the foot of the skirt of the slope. The overburden seems thin, probably 3 m or less.

At the riverbed gravel overlies probably granite and schist with thickness of a few meters. The core boring indicates about 2 m thick gravel bed covering sandstone schist and biotite schist here.

The right abutment slope is less steep and rather thick deposits of weathered materials cover the base rock of granite and schist. Granite develops from the river side to El. 135 m, that is almost the height of the crest of the dam, and above that elevation schist of phyllite occurs with schistosity of N60° to 85°E, 60° to 80°N in general.

According to the result of the seismic exploration, weathered granite will be present with thickness of around 5 m on the left bank slope, and the upper part of the right abutment beneath the overburden. Then, cracky rock and fresh rock develops in descending order.

### L 4.7.3 Drilling investigation (Fig. L 16 and GEOLOGIC LOGS)

A core boring was made to a depth of 40 m on the riverbed at the intersection of Lines A-1 and B-1. The core boring indicates that alluvial deposits of gravel with 2 m thickness overlies the base rock of the alternation of sandstone schist and biotite schist with intruded aplite veins.

The upper part of the base rock is slightly weathered and the fresh hard base rock appears below 5 m in depth. The permeability of the fresh rock is less than 30 Lugeon. Cracks and joints seem to have neither stains nor clayey materials, therefore, the base rock can be improved on its permeability by grouting treatment and will provide a good foundation for a concrete gravity dam.

### L 4.7.4 Seismic exploration (DRAWING NOS. 035 and 036)

The seismic exploration shows five velocity layers which are interpreted as below.

Interpretation of Velocity Layers,
Dalcheon Damsite

| Layer | Velocity (km/sec) | Interpretation |
|---|---|---|
| I | 0.2 - 0.4 | Soil, very loose debris |
| II | 0.6 - 0.8 | Soil and very loose debris at the upper part of the right bank slope, very weathered base rock in both banks, gravel bed in river bed |
| III | 1.3 - 1.5 | Weathered or very cracky rock |
| IV | 2.2 - 2.4 | Cracky rock |
| V | 5.5 | Fresh rock |

It is supposed at this moment that Layers I, II, III and IV will be removed by the construction of the concrete gravity dam. The Layer V will provide an appropriate foundation after grouting treatment.

The Layer III will be used for the foundation for a cofferdam.

No low velocity section is found in the fresh bed rock, that means, an intensive sheared zone will not be expected along the seismic exploration lines.

### L 4.7.5 Quarry site

In case the dam type would be changed into rockfill type, a quarry site can be opened about 1,500 m upstream of the damsite in the right bank where hard biotite schist can be obtained for rock materials.

### L 4.7.6 Geology of appurtenant structure sites

#### (1) Diversion tunnel

A diversion tunnel will be placed at the left bank. The tunnel route will be almost in a firm granite mass without intense fault. However, as the outlet will be located at the slope of weathered granite covered with overburden of debris, careful treatment will be needed here.

#### (2) Power house

The powerhouse will be located at the right bank, immediately downstream of the dam where firm foundation of granite is expected after shallow excavation of soil and debris.

#### (3) Re-regulating pond damsite (DRAWING NO. 020)

Three alternatives are considered at the downstream of the damsite around 2,000 m, 2,800 m and 3,300 m, respectively as shown in Fig. L 8. The upstream one and the middle stream one have almost same width of around 160 m in each.

The upstream site (A) has steep cliff of outcropping schist of the Yeongwoel Group on both banks for 10 m or more from the gravelly riverbed.

The middle site (B) is underlain by schist of the Yeongwoel Group. The left abutment is formed of a ridge of weathered rock in the upper part and talus deposit in the lower part. The riverbed is covered with gravel. The right abutment rises on a steep cliff of outcropping schist.

The downstream site (C) has 220 m width. The left abutment rises on a talus deposit and weathered schist. The riverbed is covered with gravel. The excavation will be the largest among three sites even though the right bank is formed of the fresh granite.

The upstream site (A) seems to require less excavation of gravel and talus deposit though dam height may be a little higher than the middle one.

### L 4.7.7 Comments

(1) The fresh granite and schist will provide suitable foundation for the concrete gravity dam as well as the rockfill dam at the proposed site.

(2) The thickness of overburden and weathered part of the rock shall be surveyed by means of core boring with water pressure test and adits excavation.

(3) The characteristics of cracky zone shall be confirmed by in situ rock shearing tests as well as core borings with water pressure tests in order to confirm the foundation of the concrete gravity dam.

(4) Routine geological investigation shall be adapted to the appurtenant structure sites, generally, by means of core borings.

## L 4.8 Ganhyeon

### L 4.8.1 Outline of project

Location : See Fig. L 9
Dam type : Concrete gravity
Dam height : 46.4 m
H.W.L. : El. 111.4 m
Powerhouse : Attached to the dam

### L 4.8.2 Geology of damsite (DRAWING NO. 013)

The dam is planned at the middle of the gorge extending about 800 m where the river is about 100 m wide. The ratio of the dam height to the valley width at the high water level is about 1 : 2.8. The slope of the right abutment is steeper than that of the left abutment, forming somewhat asymmetric bilge feature on the section of valley.

The damsite is formed by green, fine grained, very hard quartz porphyry and some fresh rocks crop out along the valley. The porphyry contacts with granite at 250 m downstream of the dam axis. This granite is locally mylonitized but firm, and narrowly distributes. The contact between the granite and the porphyry is clear at part of the right bank, measuring a direction of N70°E, 65°NW; however, its feature is rather irregular and either of them gradually changes to the other frequently.

At the upstream of the dam axis of the left abutment lies a wide valley with tumbled large boulders. The dam abutment has a slope of about 30° up to 100 m in elevation. The slope becomes more gentle at an area between 100 and 110 m, then reaches the roof top at about 150 m in elevation. The slope rises up steeply at some places between 110 to 150 m in elevation. This gentle slope developes in parallel with the river course about 300 m downstream, giving an impression that it is a river terrace formed along with the gentle dipping joint system.

Cracks run across the mainstream; many of which dip steepy upstream, while some of which dip gently to the mainstream or the mountain side.

The flat river bed is covered with thin river gravel and distributed with fresh rocks widely.

At the right abutment, an about 40° steep slope continues along with a narrow plane in parallel with the river channel, and fresh rocks are widely cropped out. Because of the steep slope, surface rocks are loosened slightly.

The damsite has no fault: It has been selected at the location where a diversion tunnel can be shortened by taking advantage of favorable topographic conditions.

### L 4.8.3 Drilling investigation (DRAWING NO. 013, Fig. L 17 and GEOLOGIC LOGS)

The core boring has been made at the crossing of two seismic lines A-1 and B-1 at the left river side by drilling 20 m vertically. Quartz porphyry is reached under a sand layer of 1 m thick or less; fresh hard rocks are reached at a depth of 2 m or more. There are many cracks at this portion. R.Q.D. ranges from 20 % to 40 %, while Lugeon value is 0.5 or less. Casing has been inserted only in the sand layer portion, showing that cracks have clung. The planned dam can be constructed on the favorable foundation by removing the overburden and loosened rocks.

### L 4.8.4 Seismic exploration (DRAWING NOS. 013 and 037)

The seismic exploration result shows the presence of three velocity layers underlying the damsite. They are interpreted as:

Interpretation of Velocity Layers,
Ganhyeon Damsite

| Layer | Velocity (km/sec) | Interpretation |
|---|---|---|
| I | Less than 1.0 | Overburden, decomposed rock |
| II | 2.0 | Loosened or weathered rock |
| III | 3.5 - 4.5 | Fresh rock |

In addition to the above velocity layers, low velocity zones have been observed at an area with an elevation of 115 m on the right abutment of Line A-1 and at a skirt of the left abutment of Line A-2. The low velocity zone at A-1 has a velocity of 2.0 km/sec and a width of about 6 m, while that at A-2 has a width of about 10 m, but its velocity is uncertain. The former seems to show an effect of steep landform and the latter seems to show the distribution of boulders deposit. Further investigation is required on these zones at a next step.

### L 4.8.5 Quarry site (Fig. L 9)

In modification of dam type, i.e. a rockfill dam or a combination of a concrete dam and a rockfill dam, rock materials are provided by the hillside of a tributary joining the mainstream at about 500 m in bee line downstream of the damsite. This wide tributary has a gentle gradient; fresh, hard granite and quartz porphyry with medium-space cracks are widely cropped out. Filter materials are provided by river gravel widely deposited on the mainstream.

### L 4.8.6 Geology of appurtenant structure site

#### (1) Diversion tunnel (DRAWING NO. 013)

One diversion tunnel is planned at the left abutment. The tunnel site takes advantage of favorable topographic conditions, and reduction in rock excavation is planned. The rocks at the tunnel route are quartz porphyry having a few gentle-dip cracks running in parallel to the tunnel route and many steep-dip cracks running almost perpendicular to the tunnel route.

Since boulders are widely distributed in the vicinity of portals of both the inlet and the outlet, removal of them is suggested.

#### (2) Powerhouse (DRAWING NO. 013)

The powerhouse is planned at the left abutment just downstream of the dam. The foundation of the powerhouse will be settled on a firm quartz porphyry. The overburden and boulder deposits on the location of tailrace are not so thick.

#### (3) Re-regulating pond dam (Fig. L 9 and DRAWING NO. 021)

The regulating pond dam is planned at location B, C and D as well as location A, 1.8 km south-east of the damsite, where the mainstream running from the south-east changes its route to the south-southwest. The former three location have been compared.

At location B, the river is wide and its right abutment is a valley wall where outcrops are widely distributed. On the other hand, its left abutment widely distributes thick overburden. At location C about 400 m upstream of the location D, the left abutment has widely rock exposures and its valley wall is very steep, while the right abutment up to 20 m high above the river bed is formed by terrace. At location D about 350 m upstream of the railway bridge, valley walls of both abutments formed by rocks are very steep.

Location A is a proposed location for the re-regulating pond dam. At this location, the left abutment has peculiar topographic features with many mountain folds. However, the location seems to be free from water leakage from the reservoir of the planned dam 22.7 m high (H.W.L. : El. 83.40 m). The river gravel at the location is about several meters thick.

### L 4.8.7 Comments

(1) The dam and the powerhouse are planned taking advantage of favorable topographic conditions. Their basements are formed by hard, firm quartz porphyry. Since the overburden is thin, the foundation of structures will be obtained by removing detached stones. Overburden is not thick both on the left abutment terrace and river bed; there will be no significant trough at the river channel. The rocks has a Lugeon's value of less than 0.5; those distributed in deeper part are regarded as impervious.

(2) Low velocity zones have been observed by the seismic exploration at a location 120 m in elevation of the right bank of Line A-1 and at the left bank of Line A-2. The former location is a change point of topography where a steep slope begins. On the other hand, the latter seems to be reflected by deposit of large boulders. No low velocity zone has been detected at Line B-1.

Velocity of seismic wave of bed rock is 3.5 km/sec at the left abutment, 4.5 km/sec at the river bed, and 4.0 km/sec at the right abutment, respectively.

The low velocity zone underlying the damsite seems to have many but not so wide cracks, indicating that it is capable of being repaired by grouting.

(3) Concrete materials are provided by river deposits widely distributed in the vicinity of the damsite. A sufficient amount of good quality rock materials are provided in the vicinity of the damsite even though the dam type is changed to a rockfill dam. The quarrying is capable of being chosen at many areas of face.

Furthermore, the working area is wide and has excellent quarrying conditions.

(4) Location A at the uppermost stream has been selected from the investigation for the re-regulating pond damsite among four sites. On the steep valleys of both abutments at this location crop out rock beds widely. Mountain folds are complicatedly engraved and rock beds are somewhat loosened. This does not mean, however, that water leakage occurs at a dam about 23 m high (F.W.L. : 83.40 m). The river gravel is about several meters in thickness.

### L 4.9 Bonghwa, Upstream

The major problem is seen on the thick debris at steep slope on the right bank of this site. If the right abutment is deemed to be stable after deep excavation of the existing intensely cracked zone in the future stage, the dam construction will be possible, but if the rock masses, the bedding plane of which is rather concordant with the slope, would move progressively after excavation, the dam building will be difficult. The location of the site is shown in Fig. L 10.

#### L 4.9.1 Geology of damsite (DRAWING NO. 014)

The damsite comprises the alternation of well cemented greenish sandstone, conglomerate and slate of the Silla Group of Cretaceous era. Bedding plane is N80°W, 20°S in the upstream of the damsite, gradually changing its strike at the damsite showing N30° to 70°E, 3° to 10°S and N55°E, 15°S in the downstream

The left abutment rises on a very steep cliff of outcropping rock with more than 60° slope angle. The dip angle of the bedding plane is against cliff slope. The outcrop shows widely spaced joints and some minor sheared zones and, in general, firm foundation will appear after shallow excavation of cracky zone of the rock. Minor fault occurs on the left bank slope with around 3 m wide sheared zone running N25°E, 10°S. The riverbed is covered with gravel, but, at the immediate downstream of the assumed dam axis, rocky floor is seen at the left side of the river course. According to the result of the seismic exploration, gravel and cracky zone of the rock will overlie firm fresh rock of the alternation of sandstone, conglomerate and slate with thickness of a few meters at around the dam axis.

The right abutment rises on a steep slope, formed mostly of slumping rock block, from the river side to El. 270 m and, then upward, become gentle slope where weathered sandstone is present beneath soil. Minor outcrops of intensely cracked sandstone appear in places along the skirt of the steep slope. The presence of thick debris, slumping rock block and intensely cracked outcrops may suggest a land slide occurring along the steep slope, specially below El. 250 m. The result of the seismic exploration indicates that soft rocks showing seismic velocity less than 1.2 km/sec have a thickness of more than 20 m and the underlying cracky zone, a thickness of around 25 m on the fresh rock. This cracky zone is also confirmed by the core boring as mentioned below. Thus, the excavation for the foundation of the impervious core zone of the dam will be deep even though some part of the cracky zone is applicable for foundation after grout treatment.

### L 4.9.2 Drilling investigation (GEOLOGIC LOGS)

A core boring is carried out on Line A-1 on the right bank slope around 10 m apart from the intersection of Line B-2 toward the river.

The soil consisting of silt and clay covers the base rock of the alternation of slate, sandstone and conglomerate with thickness of 3.8 m.

The base rock, however, is very cracky as known by poor recovery rate of boring core throughout the drilled hole. Recovered pieces of rock are slightly weathered even in considerable depth and brownish clayey materials are seen below 30 m in depth. Escape of drilling water was often observed and jamming trouble happened at the depth of 48.80 m during the drilling operation. No water table was detected to the bottom of the borehole.

It is quite doubtful to prepare the foundation on such cracky rocks to the depth of 50 m investigated by the core boring. The foundation might be obtained at much deeper part of the bed rock.

### L 4.9.3 Seismic exploration (DRAWING NOS. 038 and 039)

Seismic exploration indicates five velocity layers which are interpreted as below.

Interpretation of Velocity Layers,
Bonghwa (upstream) Damsite

| Layer | Velocity (km/sec) | Interpretation |
|---|---|---|
| I | 0.2 - 0.3 | Soil, very loose debris |
| II | 0.5 - 0.6 | Loose debris, intensely weathered rock |
| III | 1.0 - 1.2 | River bed gravel, weathered rock |
| IV | 2.0 - 2.2<br>2.3 - 2.5 | Cracky rock |
| V | 4.7 - 5.0 | Fresh rock |

On the right bank, soft rocks of Layers I, II and III showing seismic velocity less than 1.2 km/sec have a thickness of more than 20 m, and the underlying cracky zone of Layer IV showing seismic velocity as much as 2.0 to 2.5 km/sec has a thickness of around 25 m on the fresh rock.

Presence of some sheared zones under the right bank is suggested by low velocity sections observed in the velocity Layer V. These low velocity sections should be carefully examined in the further study stage.

### L 4.9.4 Quarry site

Quarry site for rock materials can be opened at rocky slope on the right bank, about 1,000 m upstream of the damsite. A northern cliff, formed of well cemented sandstone showing bedding plane N80°W 20°S, is easy in accessibility.

### L 4.9.5 Comments

(1) It is sure at this moment that Bonghwa downstream site is better than Bonghwa upstream site from the geological view point for dam construction.

(2) The riverbed shall be studied with core drilling and the left abutment shall be investigated with core borings and adits for confirming the firm foundation.

(3) Other appurtenant structures and the quarry site will require detail study by means of core borings for confirming the firm foundation and available quantity of rock materials, respectively.

## L 4.10 Bonghwa, Downstream

### L 4.10.1 Outline of project

| | | |
|---|---|---|
| Location | : | See Fig. L 10 |
| Dam type | : | Concrete gravity |
| Dam height | : | 128 m |
| H.W.L. | : | El. 297 m |
| Power station | : | Dam and tunnel |

### L 4.10.2 Geology of damsite (DRAWING NO. 015)

The damsite is formed of the alternation of well cemented sandstone, conglomerate and slate of the Silla Group of Cretaceous era. Bedding plane is generally N10° to 30°E, 8° to 12°S. Two minor faults crossing the riverbed almost parallel with the dam axis are seen up and down stream of the damsite and a fault with about 3 m sheared zone running along bedding plane is observed at the left bank of the upstream of the dam axis.

The left abutment rises on a rather steep slope with around 35° covered with talus deposits from the water edge to El. 250 m and, then a steep cliff occurs upward. Deposits of large blocks of tumbling rock is developed at the skirt portion of the left abutment. The talus deposits including such tumbling blocks will be 5 m in thickness according to the result of seismic exploration. Cracky zone of the base rock of the alternation occurs beneath the talus deposits with thickness of 6 to 12 m, covering the fresh base rock.

The river course is underlain by gravel, cracky zone of the base rock and base rock in descending order. Gravel bed is thin, probably 1 to 2 m in thickness and in places, rocky floor crops out specially at the left side of the river course. Thickness of the cracky zone is around 5 m.

The right abutment rises on a steep slope from river side to El. 250 m and, then upward, on a gentle slope.

The slope is covered with thin soil and talus deposits. Outcrops of conglomerate appear in places. Weathered zone will be 5 m thickness beneath the soil and talus deposits. Cracky zone is developed beneath the weathered zone. Its thickness increases from 5 to 20 m upward suggested by the result of the seismic exploration.

Fresh rock with slight weathering will provide an appropriate foundation for the concrete gravity dam after grouting treatment throughout the damsite even though minor faults occur here.

However, leakage through the right abutment must be studied carefully because of short distance between the reservoir and a tributary located immediately downstream of the damsite on the right bank.

### L 4.10.3 Drilling investigation (Fig. L 18 and GEOLOGIC LOGS)

A core boring was made on Line A-1 on a foot path on the left bank.

Talus deposits of boulder with sand clay covers the base rock of conglomerate with thickness of 4.9 m.

The base rock, consisting of conglomerate, sandstone and slate is weathered at its top portion and gradually less deteriorated downward.

To a depth of 11 m the rock is weathered and very cracky, but, below 11 m rock pieces become hard though slightly weathered in some of rock forming minerals and joint cracks occur in rather wide interval having almost clean surface but rarely stained.

Below 19.8 m the rock becomes almost fresh even though colour of some part of sandstone shows slight deterioration.

Water pressure test indicates that the rock mass has less than 10 Lugeons on its permeability below 12 m in depth.

As far as the observation of the recovered core of the borehole, the rock below 19.8 meters in depth will be used for the foundation of the concrete gravity dam after grouting treatment.

### L 4.10.4 Seismic exploration (DRAWING NOS. 040 and 041)

Seismic exploration at the damsite shows five velocity layers. The interpretation corresponding to the geology is shown in below.

Interpretation of Velocity Layers,
Bonghwa (downstream) Damsite

| Layer | Velocity layers (km/sec) | Interpretation |
|---|---|---|
| I | 0.2 - 0.3 | Soil very loose debris |
| II | 0.6 - 0.8 | Debris weathered rock |
| III | 1.2 - 1.3 | Debris (tumbling block) at the left bank and very cracky rock at the right bank |
| IV | 2.2 - 2.5 | Cracky rock |
| V | 4.7 - 5.0 | Fresh base rock |

The velocity of Layers I, II, III and IV will be removed for preparing the foundation of the concrete gravity dam. The Layer V will be an appropriate foundation after grouting treatment. A low velocity part suggesting presence of sheared zone is observed in the fresh rock at round El. 200 m at the left bank slope. This low velocity section should be carefully examined in the further study stage.

### L 4.10.5 Quarry Site

Two quarry sites are considered at a hillside around 500 m upstream of the left bank, and at a hillside around 1,500 m upstream of the right bank. Both quarry sites will provide good rock materials of well cemented sandstone and conglomerate. The former one will need an access road with hair pin curves on a steep slope to get the quarry site. The latter one takes a rather long range, however, in case a relocated road is placed at the right bank, this may be more beneficail than the former. The selection of the quarry site will depend on the planning of a road including relocation programme.

### L 4.10.6 Geology of Appurtenant Structure

#### (1) Diversion tunnel

A diversion tunnel will be made on the left bank. The tunnel route will pass through well cemented sandstone and conglomerate, however, it may encounter a sheared zone which is suggested by the seismic exploration. The inlet will be made at a cliff of outcropping sandstone. As the outlet will be placed on the slope formed of talus deposits, considerable excavation will be requiref for the construction.

#### (2) Power house

The power house is planned at around 2,000 m downstream on the right bank. The penstock and surge tank can be placed on a steep but stable ridge formed of well cemented sandstone and conglomerate with bedding plane of N10° to 15°W, 10°E, which outcrops in places on the slope. The power station can be constructed on the firm foundation of the same rock at the foot of the stable ridge at the river side after stripping of thin talus deposits.

### L 4.10.7 Comments

(1) The thickness of overburden and the characteristics of the Layer IV as well as the low velocity part in the Layer V shall be studied by means of the core drilling, water pressure test and adits observation for designing of the dam foundation.

(2) Permeability of the right bank shall be studied for the treatment against possible leakage through short path from the reservoir to the tributary.

(3) The quarry site shall be studied to confirm the quantity and quality of the concrete aggregate to be used.

(4) The power station site shall be mapped and studied to confirm the foundation of surge tank, penstock and the power house.

## L 4.11 Imha

### L 4.11.1 Outline of project

| | | |
|---|---|---|
| Location | : | See Fig. L 11 |
| Dam type | : | Concrete gravity |
| Dam height | : | 87 m |
| H.W.L. | : | El. 185 m |
| Power station | : | Attached to the dam |

### L 4.11.2 Geology of damsite (DRAWING NO. 016)

The base rock of the damsite is granite which crops out in the riverbed and the slope foot of both banks. The middle to upper part of the slopes of both banks are overlain by soil and arkosic sand of weathered materials. According to the seismic exploration and the core boring result, the thickness of the soil and arkosic sand, that is intensely weathered granite, will be around 20 m on the left bank slope but less thick; probably about 5 m on the right bank slope.

A sheared zone is suggested by a low velocity section at the left bank. The core boring drilled near the sheared zone indicate that cracky zone of granite is present deeply here as described in L 4.11.3.

The riverbed is rocky floor of outcrops of granite both under water and at islets. Gravel is deposited in places at concaves formed generally at the interesection of joints. Though joints occur remarkably in granite mass, no conspicuous sheared zone is observed at the river floor.

However, some joints, specially located at about 200 m downstream of the dam axis at the right bank, indicate a dip of 25° to 30° concordant with the slope. No appurtenant structure is allowed to be laid on and under the rock block having such joints without careful treatment because of fear of sliding.

### L 4.11.3 Drilling investigation (Fig. L 18 and GEOLOGIC LOGS)

A core boring was made at the intersection of Lines A-1 and B-1 on the left bank slope.

Arkosic sand, that is in-situ decomposed materials of granite, develops from the top to a depth of 15 m and intensely weathered granite occurs subsequently to a depth of 17.0 m in depth.

Below 17.0 m in depth hard granite appears but it is very cracky. Escape of drilling water happened intensely at the depths 18.0 to 18.3 m and 19.7 to 20.1 m. These leakage sections were inevitably cemented for further drilling operation.

From 20.0 to 29.0 m in depth the recovered rock pieces is almost fresh but slight weathering is seen in micas and feldsparts in places. The section between 29.0 and 31 m is presumed to be a sheared zone where the obtained rock fragments is stained in color and escape of drilling fluid happened during the operation. Below then, the rock becomes almost fresh but slightly weathered minerals are still present locally.

Fresh granite rock occurs below 35 m in depth.

The base rock of granite here is cracky throughout the borehole. This is probably affected by a shearing action occurred along a sheared zone presumed by a low velocity zone as mentioned in L 4.11.4. The low velocity zone should be carefully studied by adit excavation for the design of a dam.

### L 4.11.4 Seismic exploration (DRAWING NOS. 042 and 043)

The seismic exploration result indicates four velocity layers at the damsites. These velocity layers are interpreted in corresponding to the geology as shown below.

Interpretation of Velocity Layers,
Imha Damsite

| Layer | Velocity (km/sec) | Interpretation |
|---|---|---|
| I | 0.2 - 0.4 | Soil, debris |
| II | 0.6 - 1.0 | Arkosic sand and weathered rock |
| III | 2.0 - 2.4 | Cracky rock |
| IV | 4.7 - 5.7 | Fresh rock |

The Layers I, II and III will be removed to obtain a suitable foundation for the concrete gravity dam. The Layer IV will be an appropriate foundation after grouting treatment.

Low velocity zones which may suggest the presence of sheared zones are observed in the fresh rock at the middle slope of the left bank.

### L 4.11.5 Quarry site

Two alternative quarry site are considered: One is located at a hillside about 1,400 m upstream of the left bank where quartzite crops out. The quartzite is rather cracky, so that rock blocks of 30 to 60 cm dimension will be prevailingly obtained. Another one is expected at about 2,000 m upstream of the right bank where quartzite, sandstone, intruded diolite can be obtained.

The former one is more promising for the quarry site due to eacy access.

### L 4.11.6 Geology of appurtenant structure

#### (1) Diversion tunnel

A diversion tunnel will be made in the left bank. The tunnel route will be generally in the firm granite moss, however, it may encounter a sheared zone which is suggested by the seismic exploration.

#### (2) Power house

The power house is planned at the right bank immediately downstream of the damsite. As mentioned in L 4.11.2, careful treatment of rock blocks of granite, which have joint system concordant with the slope, must be required before the construction in order to avoid sliding. Except such loosened block, firm foundation will be met easily for the power house.

### (3) Re-regulating pond damsite (DRAWING NO. 022)

Two laternative re-regulating pond damsite are found about 5,800 and 6,000 m downstream of the damsite as shown in Fig. L 11. The right bank of the downstream site shows an outcrop of granite on the cliff. The river bed is covered with gravel overlying granite with thickness of around 4 m according to the core boring result made in 1970 (see LAND AND WATER RESOURCES PLANNING IN THE NAGDONG RIVER BASIN, FAO/UNDP, 1971).

The left abutment rises on a gentle slope formed of intensely weathered granite.

The upstream alternative site is as in the almost same geological condition as the former, but, the width is around 200 m and granite at the left bank is less weathered.

## L 4.12 Hamyang

### L 4.12.1 Outline of project

| | | |
|---|---|---|
| Location | : | See Fig. L 12 |
| Dam type | : | Rockfill |
| Dam height | : | 80 m |
| H.W.L. | : | El. 376 m |
| Power station | : | Dam and tunnel |

### L 4.12.2 Geology of damsite (DRAWING NO. 017)

The left abutment rises on a steep slope for about 25 m from the river side and, then, become a gentle slope upward. The slope is formed of diorite covered with thin soil and partly slumping blocks. The overburden is estimated around 2 to 3 m in thickness, overlying weathered or or intensely cracky zone of the diorite.

The riverbed shows outcrops of diorite which has in palces open joints. The prevailing joint systems are in three planes showing around, N20°E. V, N60°E. V and N30°W. 15°W, respectively, and these systems are continuously seen on outcrops on the right abutment slope. The right abutment rises on very steep slope where scattered blocky rocks of slumps and weathered cracky outcrops of diorite develop. Such slumping blocks and intensely weathered rock may have the thickness of around 5 m. Tumbling down of block rocks should be protected during the excavation here.

### L 4.12.3 Drilling investigation (Fig. L 18 and GEOLOGIC LOGS)

A core boring was placed at the intersection of Lines A-1 and B-1 on the left bank slope. Top soil overlies weathered base rock of diorite with thickness of 0.8 m.

The base rock is intensely weathered at its top portion. Below 9.8 m in depth it becomes hard and, especially belows 12.2 m in depth it is fresh with wide interval of joint crack without stain nor clay materials, having less than 5 Lugeons in permeability.

The base rock mass below 12.2 m is sure at the core boring spot to provide an adequate foundation for a rockfill type dam as well as a concrete gravity type dam after grout treatment.

### L 4.12.4 Seismic exploration (DRAWING NOS. 044 and 045)

The seismic exploration result indicates the presence of five velocity layers underlying the damsite. They are interpreted as shown below.

Interpretation of Velocity Layers,
Hamyang Damsite

| Layer | Velocity (km/sec) | Interpretation |
|---|---|---|
| I | 0.3 - 0.4 | Soil and very loose slumping blocks |
| II | 0.6 - 1.0 | Slumping blocks and intensely weathered zone |
| III | 1.3 - 1.4 | Intensely cracked zone |
| IV | 2.5 - 2.6 | Cracky zone |
| V | 5.0 - 5.6 | Fresh rock |

The Layers I, II, III and a part of the Layer IV will be removed for the foundation of the impervious core zone of the rockfill dam, and the remaining part of the Layer IV and the Layer V will provide a good foundation after trouting treatment. On the shell zone, a part of the Layer II can be used for the foundation as far as it is formed of slumping blocky rock and weathered rock without clayey materials.

The Layer III will be used for the foundation of a cofferdam. Low velocity zones, suggesting presence of sheared zones, are seen in places in the fresh rock on both banks.

### L 4.12.5 Quarry site

Two alternative quarry sites were investigated; one is located 500 m upstream of the damsite on the right bank where diorite rock is expected under tumbling blocks. Another one, which seems more promising, is located about 700 m downstream of the damsite on the left bank where hard diorite crops out almost over a hillside. Access to the quarry site is easier in the latter one than in the former.

### L 4.12.6 Geology of appurtenant structure

#### (1) Diversion tunnel

A diversion tunnel will be made at the left bank. The inlet of it will be placed at the foot of slope where the talus deposits are developed. However, major part of the tunnel route will be in the firm diorite mass except minor sections of sheared zones suggested by the low velocity zones of the seismic velocity profile.

The outlet of the tunnel will meet a steep cliff formed of hard diorite outcrops.

#### (2) Spillway

The spillway will be laid on the left bank where firm diorite foundation is expected after deep excavation.

#### (3) Power house (DRAWING NO. 018)

The power house is planned about 13 km downstream of the damsite on the left bank. Tunnel route will pass through diorite, granite gneiss and granite. The boundaries of these rocks are fractured and there may be many minor faults especially in granite gneiss masses. Tunnel driving in these unfavorable sections should be carefully controlled against caving and ground-water spouting.

The penstock and surge tank will be laid on a narrow ridge of granite, but, as the granite is intensively weathered, especially above the altitude of El. 260 m, careful foundation treatment will be needed for the construction.

The power house can be built on the base rock of granite after excavation of talus deposits.

(4) Re-regulating pond damsite (DRAWING NO. 022)

A re-regulating pond damsite can be selected about 1,700 m downstream of the proposed power house as shown in Fig. L 12. The riverbed is 120 m in width and covered with gravels.

The left abutment has thick talus deposits covering the base rock of gneiss. The right abutment rises on a steep rocky cliff for 12 m and, then, become a gentle slope upward covered with soil and weathered materials.

### L 4.12.7 Comments

(1) The fresh bed rock will provide a firm foundation of the rock-fill type dam.

(2) The thickness of overburden and the characteristics of the Layers IV and V shall be investigated by means of core borings with water pressure test to confirm the foundation of the dam and adit excavation.

(3) Routine geological investigation by using core borings and other suitable methods shall be undertaken for confirming foundation of the appurtenant structures and temporary structures.

## L 4.13. Juam

### L 4.13.1 Outline of project

Location : See Fig. L 13
Dam type : Concrete gravity
Dam height : 72 m
H.W.L. : El. 120 m
Power station : Attached to the dam

### L 4.13.2 Geology of damsite (DRAWING NO. 019)

On the left bank talus deposits are developed at the foot of hill masses. The present dam axis at the left abutment is located on a gentle slope in gully formed of talus deposits with 5 m thickness overlying cracky zone of granite gneiss. The granite gneiss observed at the relief around the dam axis is generally weathered. The weathered zone at the relief becomes thicker upward on the slope, about 5 m at the foot of the slope and 15 m at around dam crest elevation suggested by the seismic exploration.

The riverbed is covered with gravel having no outcrops of bed rock, but, presence of a sheared zone is suggested partly at the right side of the water course by the seismic exploration.

The right abutment rises on a steep slope formed of granite gneiss which is covered with soil and arkosic sand. The weathered zone will be 5 to 10 m in thickness. The schistosity of the granite gneiss is N20° to 30°W, 30° to 60°S observed at the outcrops immediately upstream of the dam axis.

### L 4.13.3 Drilling investigation (Fig. L 19 and GEOLOGIC LOGS)

A core boring was carried out on Line A-1, 10 m apart from the intersection of Line B-1 toward the river.

Topsoil and talus deposits of boulder with sand covers the bed rock with thickness of 2.5 m.

The bed rock of granite gneiss is weathered at the top portion. Below 9.5 m in depth the rock pieces become fresh and hard, but, joint fractures show stained surface partly. Fresh rock with joint cracks occurred often at biotite bands develops below 20.1 m.

Water pressure test indicates that the rock mass below 12.0 m have less than 10 Lugeons in permeability, which suggests that most of cracks there is almost tight even though partly stained on fracture surface.

It is supposed at the core boring spot that the rock mass will provide a suitable foundation for a concrete gravity type dam after careful grout treatment below 12 m in depth.

### L 4.13.4 Seismic exploration (DRAWING NOS. 046, 047 and 048)

The seismic exploration result indicates six velocity layers underlying the damsite. The interpretation of each velocity layer is shown below.

Interpretation of Velocity Layers,
Juam Damsite

| Layer | Velocity (km/sec) | Interpretation |
|---|---|---|
| I | 0.3 - 0.4 | Soil, arkosic sand, talus deposits |
| II | 0.5 - 0.7 | Talus deposits, very weathered zone |
| III | 1.0 - 1.2 | Talus deposits (tumbling rocks) at the left bank, weathered zone |
| IV | 1.8 | Gravel and weathered zone at riverbed |
| V | 2.1 - 2.5 | Cracky zone |
| VI | 4.8 - 5.3 | Fresh bed rock |

The Layers I, II, III, IV and V will be excavated to prepare the foundation for the concrete gravity dam. The Layer VI will be an appropriate foundation after grouting treatment.

Some sheared zones are suggested in places by low velocity sections observed in the Layers V and VI of the bedrock.

### L 4.13.5 Quarry site

A suitable quarry site is selected at the hillside formed of granite gneiss about 800 m upstream of the left tributary joining the major stream at about 350 m upstream of the damsite. Overburden on the slope seems thin and access is easy to the quarry site.

### L 4.13.6 Geology of appurtenant structure

#### (1) Diversion channel

A diversion channel by a multiple stage diversion method will be placed on the left bank. The channel route will require considerable excavation and slope cutting. As the channel will be located at the foot of the slope of weathered granite gneiss covered with talus deposits, careful treatment will be needed.

#### (2) Power house

The power house will be made at the right abutment just downstream of the dam. A firm foundation will be obtained after shallow excavation of river deposits and talus deposits.

#### (3) Re-regulating pond damsite (DRAWING NO. 022)

Two alternative sites are selected around 5,900 and 7,200 m downstream of the damsite as shown in Fig. L 13.

The upstream site (A) has 120 m width of water course with rocky floor of granite. The left abutment rises on a gentle slope of intensely weathered granite. The right bank is formed of talus deposits and further to the right of the abutment, firm granite crops out in places.

The downstream site (B) is 240 m in width in the riverbed covered with gravels. The left bank is formed of firm granite outcrop. The right bank is composed of a terrace, 5 m above the riverbed with 30 m width, and intensely weathered granite in further right slope.

### L 4.13.7 Comments

(1) The fresh bedrock will provide a suitable foundation for the concrete gravity dam as well as the rockfill dam at the proposed site.

(2) The thickness of overburden and weathered rock, and characteristics of the Layers V and VI shall be studied by means of core borings with water pressure test and adit excavation at the damsite.

(3) The low velocity sections at the damsite shall be investigated in parallel to the above study to confirm the foundation.

(4) Routine geological investigation shall be undertaken for the quarry site and for the appurtenant structures.

Table L 1 STRATIGRAPHIC UNIT IN KOREA

| Age | | Sedimentary and metamorphic rock | | | Igneous activity |
|---|---|---|---|---|---|
| Cenozoic | Quarternary | | Alluvial deposits | | Basalt, Trachyte |
| | | | Sinyangdong F. | | |
| | Tertiary | | Seogwipo F. | | Volcanic rocks |
| | | | Yeonil Group | | |
| | | | Yongbug Group | | |
| Mesozoic | Cretaceous | Gyeongsang Supergroup | Upper Silla Group | Neungju Group | Porphyry, Balgugsa granite, intermediate-basic plutonic rock, acidic-intermediate volcanic rock |
| | | | Lower Silla Group | Jinam Group | |
| | | | Upper Nagdong Group | | |
| | | | Lower Nagdong Group | | |
| | Jurassic | Daedong Supergroup | Bansong Group | | Age unknown granites,<br>Daebo granites,<br>schistose granites.<br>Hypabyssal rocks** |
| | | | Upper Nampo Group | | |
| | | | Lower Nampo Group | | |
| | Triassic | Pyeongan Supergroup | Nogam Group | Yeoryang Group** | |
| Palaeozoic | Permian | | Gobangsan Group | | |
| | | | Sadong Group | | |
| | Carboniferous | | Hongjeona Group | | |
| | Devonian | | | | |
| | Gotlandian | | | | |
| | Ordovician | Joseong Supergroup | Upper Great Limestone Group | Yeongweol Group | |
| | | | Middle Great Limestone Group | | |
| | Cambrian | | Lower Great Limestone Group | | |
| | | | Yangdeog Group | | |
| Pre-Cambrian | | | | Ogcheon Group | Intermediate-basic, plutonic rocks** |
| | | | Euiam Group | Buncheon Granite Gneiss | |
| | | | Gyeonggi Gneiss Complex, Sobaegsan Gneiss Complex, Jirisan Gneiss Complex | | |
| | | | Seosan Group, | Weonnam Group<br>Pyeonghae Group | |

Source ; Geological map 1/250,000 compiled by Geological and Mineralogical Institute of Korea.

Remarks; * *: Age unknown

Table L 2 QUANTITY OF GEOLOGICAL INVESTIGATION

| Project | Site | Geological mapping | Seismic exploration | Core boring with water pressure test |
|---|---|---|---|---|
| Bamseonggol (upstream) | Damsite | 0.53 km$^2$ | 1.10 km | 1 hole, 40 m |
| | Quarry site | 2 nos. | - | - |
| | Power station | 1 no. | - | - |
| Bamseonggol (downstream) | Damsite | 0.27 km$^2$ | 0.81 km | 1 hole, 40 m |
| | Quarry site | 2 nos. | - | - |
| Inje (upstream) | Damsite | 0.81 km$^2$ | 1.71 km | 1 hole, 40 m |
| | Quarry site | 2 nos. | - | - |
| | Power station | 1 no. | - | - |
| Inje (downstream) | Damsite | 0.81 km$^2$ | 1.20 km | - |
| | Quarry site | 2 nos | - | - |
| Hongcheon | Damsite | 0.69 km$^2$ | 1.38 km | 2 holes, each 40 m |
| | Re-regulating pond | 4 nos. | - | - |
| Gujeol | Damsite | 0.73 km$^2$ | 0.90 km | 1 hole, 30 m |
| | Quarry site | 2 nos. | - | - |
| | Power station | 2 nos. | - | - |
| | Re-regulating pond | 1 no. | - | - |
| Dalcheon | Damsite | 0.71 km | 1.515km | 1 hole, 40 m |
| | Quarry site | 1 no. | - | - |
| | Re-regulating pond | 3 nos. | - | - |
| Ganhyeon | Damsite | 0.77 km$^2$ | 1.00 km | 1 hole, 20 m |
| | Quarry site | 2 nos. | - | - |
| | Re-regulating pond | 2 nos. | - | - |
| Bonghwa (upstream) | Damsite | 0.95 km$^2$ | 0.877km | 1 hole, 50 m |
| | Quarry site | 1 no. | - | - |

Table L 2 Continued (2)

| Project | Site | Geological mapping | Seismic exploration | Core boring with water pressure test |
|---|---|---|---|---|
| Bonghwa (downstream) | Damsite | 0.81 $km^2$ | 1.04 km | 1 hole, 40 m |
| | Quarry site | 2 nos. | - | - |
| | Power station | 1 no. | - | - |
| Imha | Damsite | 0.33 $km^2$ | 1.82 km | 1 hole, 40 m |
| | Quarry site | 2 nos. | - | - |
| | Re-regulating pond | 2 nos. | - | - |
| Hamyang | Damsite | 1.08 $km^2$ | 1.30 km | 1 hole, 40 m |
| | Power station | 1 no. | - | - |
| | Quarry site | 2 nos. | - | - |
| | Re-regulating pond | 1 no. | - | - |
| Juam | Damsite | 0.30 $km^2$ | 1.85 km | 1 hole, 30 m |
| | Quarry site | 1 no. | - | - |
| | Re-regulating pond | 2 nos. | - | - |