タイ王国

ユアム川

水力発電開発計画

調査報告書

〔II〕

(Appendix 1, 2, 3, 4, 5)

1984年3月

国際協力事業団

タイ王国

ユアム川

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(Appendix 1, 2, 3, 4, 5)

1984年3月

国際協力事業団

Table of Content

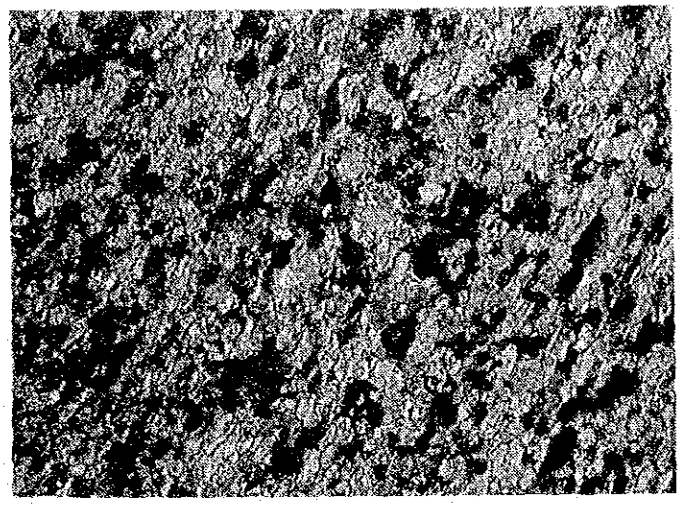
A 1 GEOLOGY

Micrograph and Petrographic Description of Rock

(Plate 1 of 5)

Locality: 5

600 m upstream of A dam axis, right bank of Yuam River.



(crossed nicols)

Rock name:

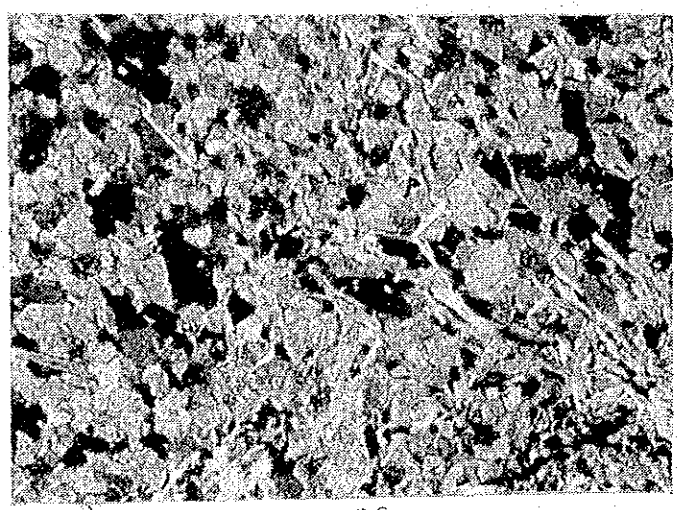
Limestone (massive)

Petrographic description:

Chief consisting minerals are calcite >> muscovite, quartz and chlorite. Dolomite and potassium feldspar are trace in amount.

Locality: 9

200 m upstream of A dam axis, right bank of Yuam River. (EL. 150 m)



(crossed nicols)

Rock name:

Limestone (laminated)

Petrographic description:

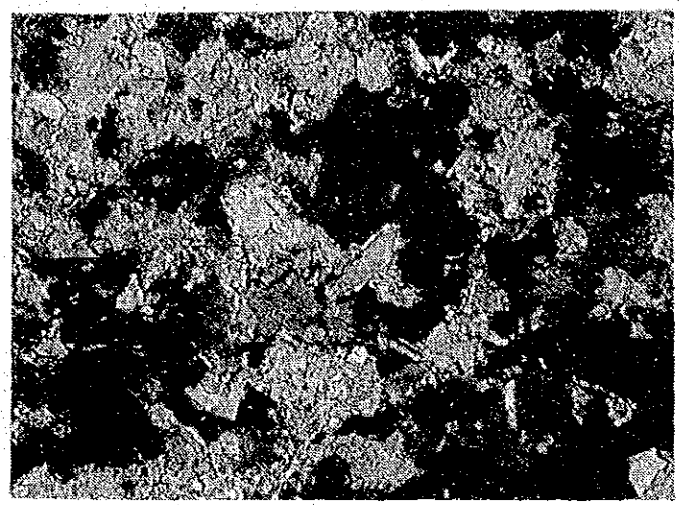
Chief consisting minerals are calcite > white mica, quartz. Banding texture consisting of calcite-rich and mica-rich layers is observed.

Micrograph and Petrographic Description of Rock

(Plate 2 of 5)

Locality: 13

1 km downstream of A dam axis, left bank of Yuam River.



0 0.2 mm (crossed nicols)

Rock name:

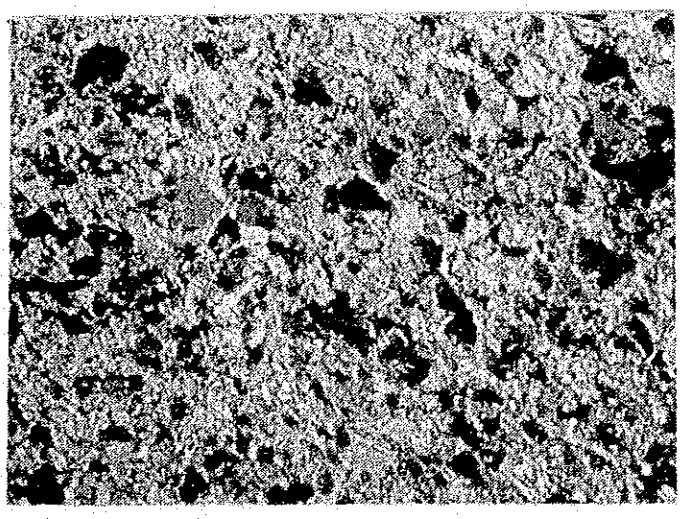
Sandy limestone

Petrographic description:

Chief consisting minerals are calcite, dolomite, quartz and muscovite.

Locality: 16

Tributary of Huai Uya Kra (EL. 460 m)



0 0.3 mm (crossed nicols)

Rock name:

Siliceous limestone (or calcareous sandstone)

Petrographic description:

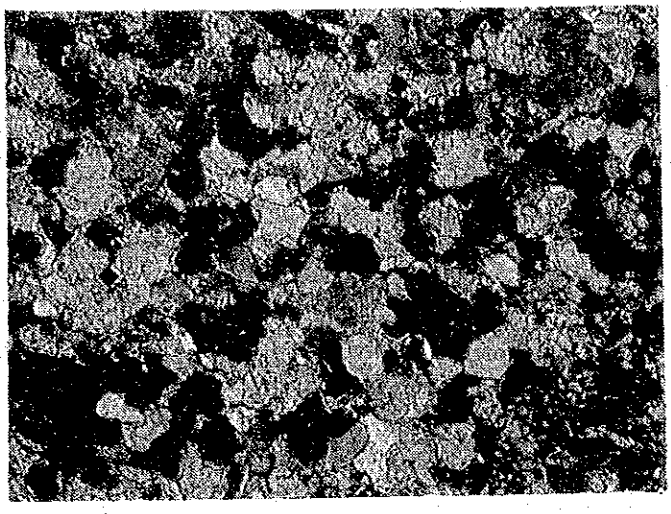
Chief consisting minerals are calcite, quartz and white mica.

Clay minerals are trace in amount, less than 0.1%.

Micrograph and Petrographic Description of Rock

(Plate 3 of 5)

Locality: 18
Huai Uya Kra

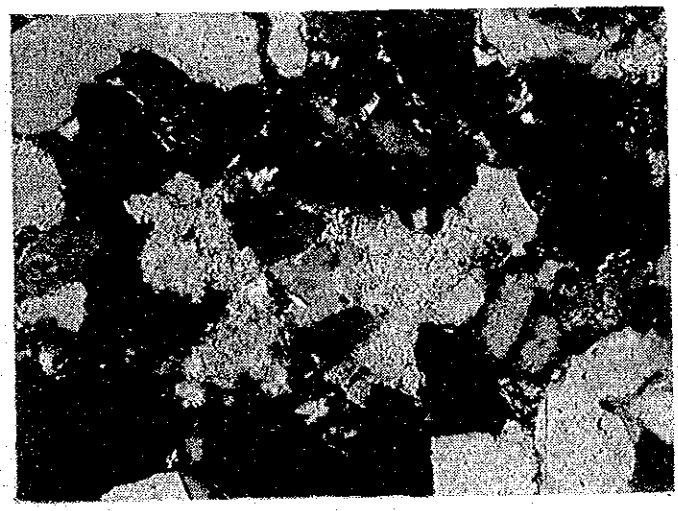


0 0.2mm (crossed nicols)

Rock name:
Calcareous sandstone

Petrographic description:
Chief consisting minerals are dolomite, calcite, quartz.
Accessory minerals are muscouvite and pyrite.

Locality: 20
Huai Mae Lamu



0 0.2mm (crossed nicols)

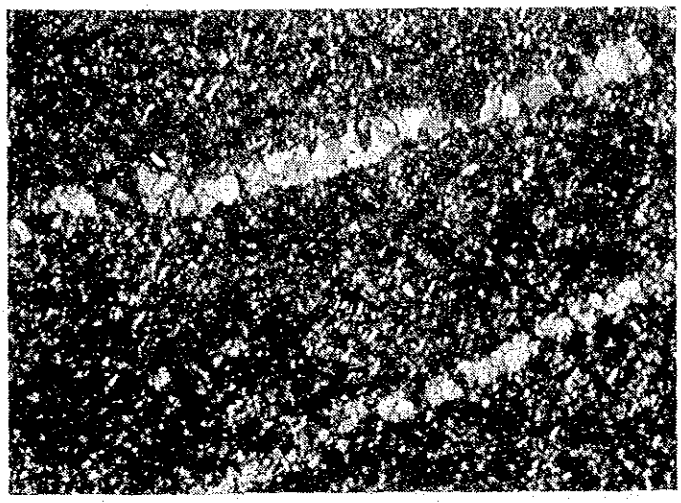
Rock name:
Sandstone

Petrographic description:
Chief consisting minerals are quartz, dolomite and plagioclase.
A trace amount of montmorillonite is found.

Micrograph and Petrographic Description of Rock

(Plate 4 of 5)

Locality: 19
Right bank of A dam axis



0 0.3mm (crossed nicols)

Rock name:
Shale

Petrographic description:
Chief consisting minerals are quartz, white mica, graphite and plagioclase. Quartz veins are common.

Locality:
Huai la cho Kra
(about 5 km upstream of
Damsite A)

0 0.2mm (crossed nicols)

Rock name:
Quartzose sandstone

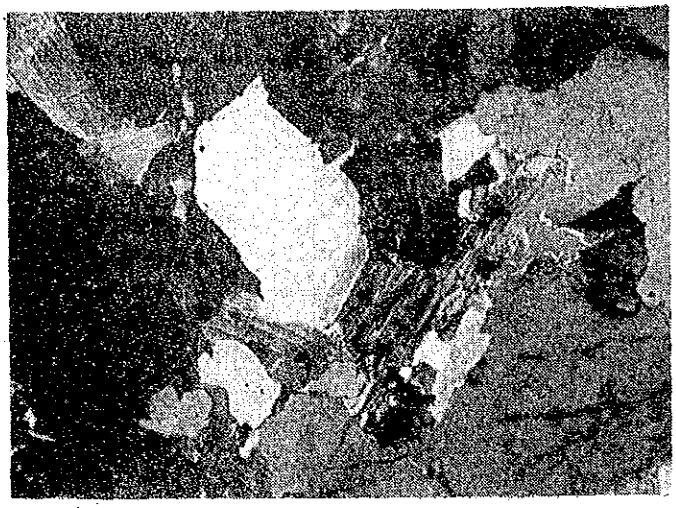
Petrographic description:
Chief consisting minerals are quartz, potassium feldspar and muscovite. A trace amount of tourmaline, zircon and apatite is found.

Micrograph and Petrographic Description of Rock

(Plate 5 of 5)

Locality:

Damsite C (about 12 km upstream of Damsite A)



Rock name:

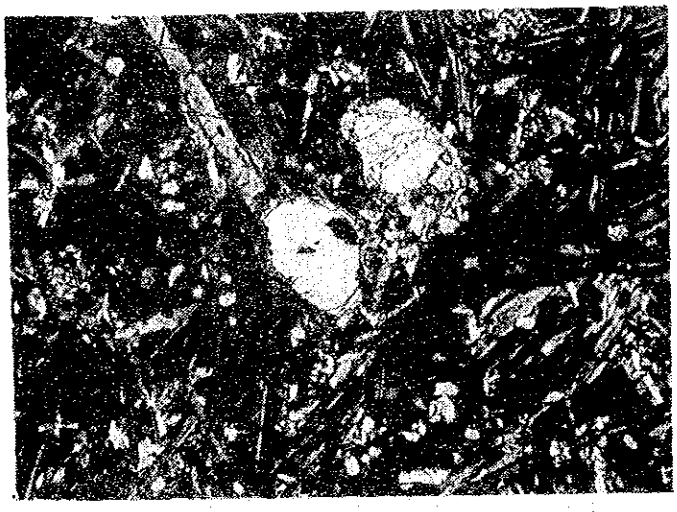
Granite

Petrographic description: 0 0.5mm (crossed nicols)

Chief consisting minerals are quartz, potassium feldspar, plagioclase, biotite and muscovite. Mica is partly replaced by chlorite and montmorillonite.

Locality:

Ngao river (about 3 km upstream of junction of Yuan river and Ngao river)



Rock name:

Basalt

Petrographic description: 0 0.5mm (crossed nicols)

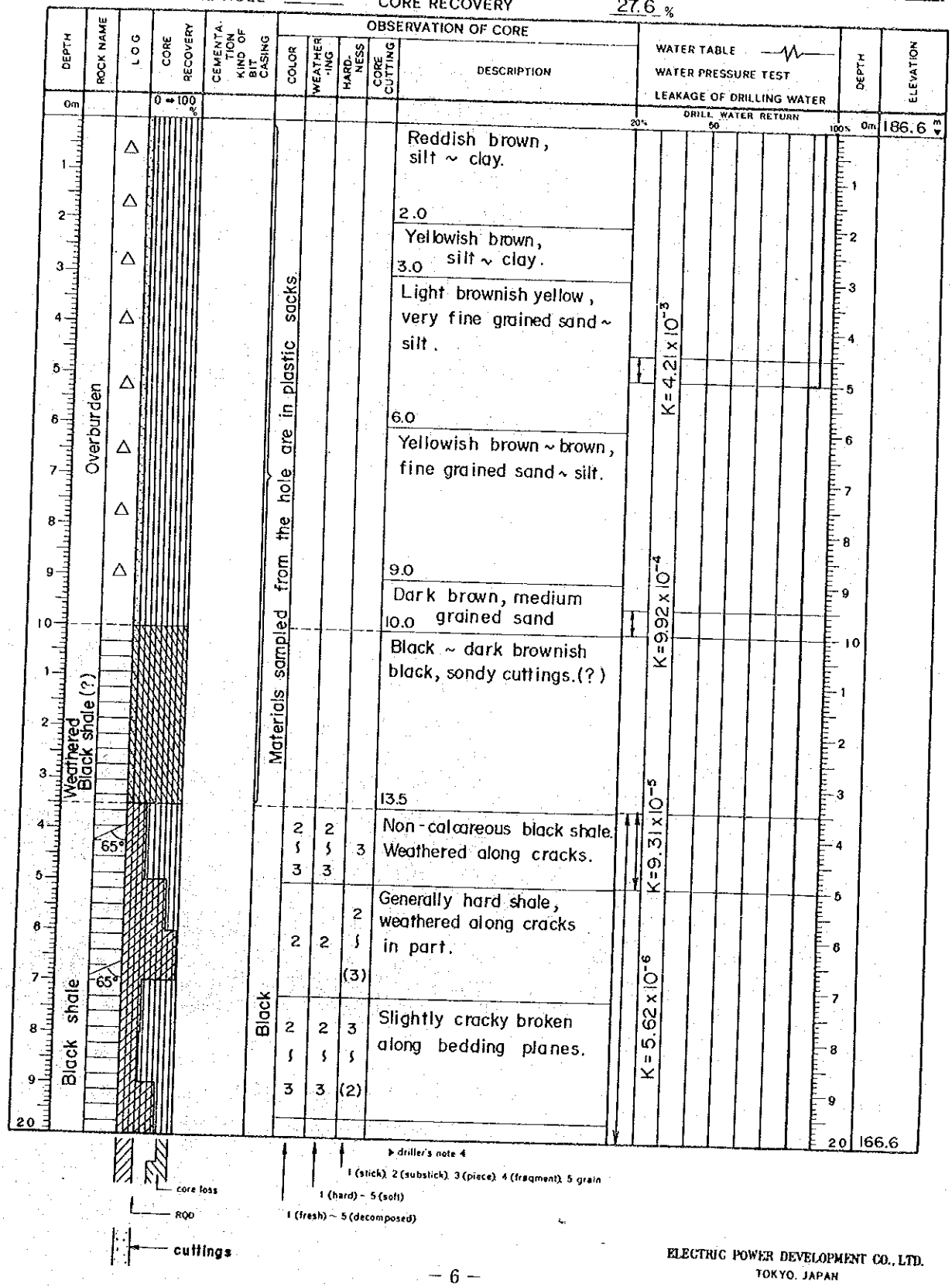
Phenocrysts are of olivine, plagioclase and clinopyroxne.

Microphenocrysts are of plagioclase, clinopyroxne and magnetite.

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT — HOLE No. DL - 1 (SHEET 1 OF 4)

LOCATION	Dam left bank	DEPTH OF HOLE	80.0 m	COMMENCED	Apr. 13 - 1983
ELEVATION	186.6 m	DEPTH OF OVERBURDEN	10.0 m	COMPLETED	Apr. 21 - 1983
COORDINATE	1966 286.9N 375 168.2E	LENGTH OF ROCK DRILLING	70.0 m	DRILLED BY	ROE M
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	19.34 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	—	CORE RECOVERY	27.6 %		



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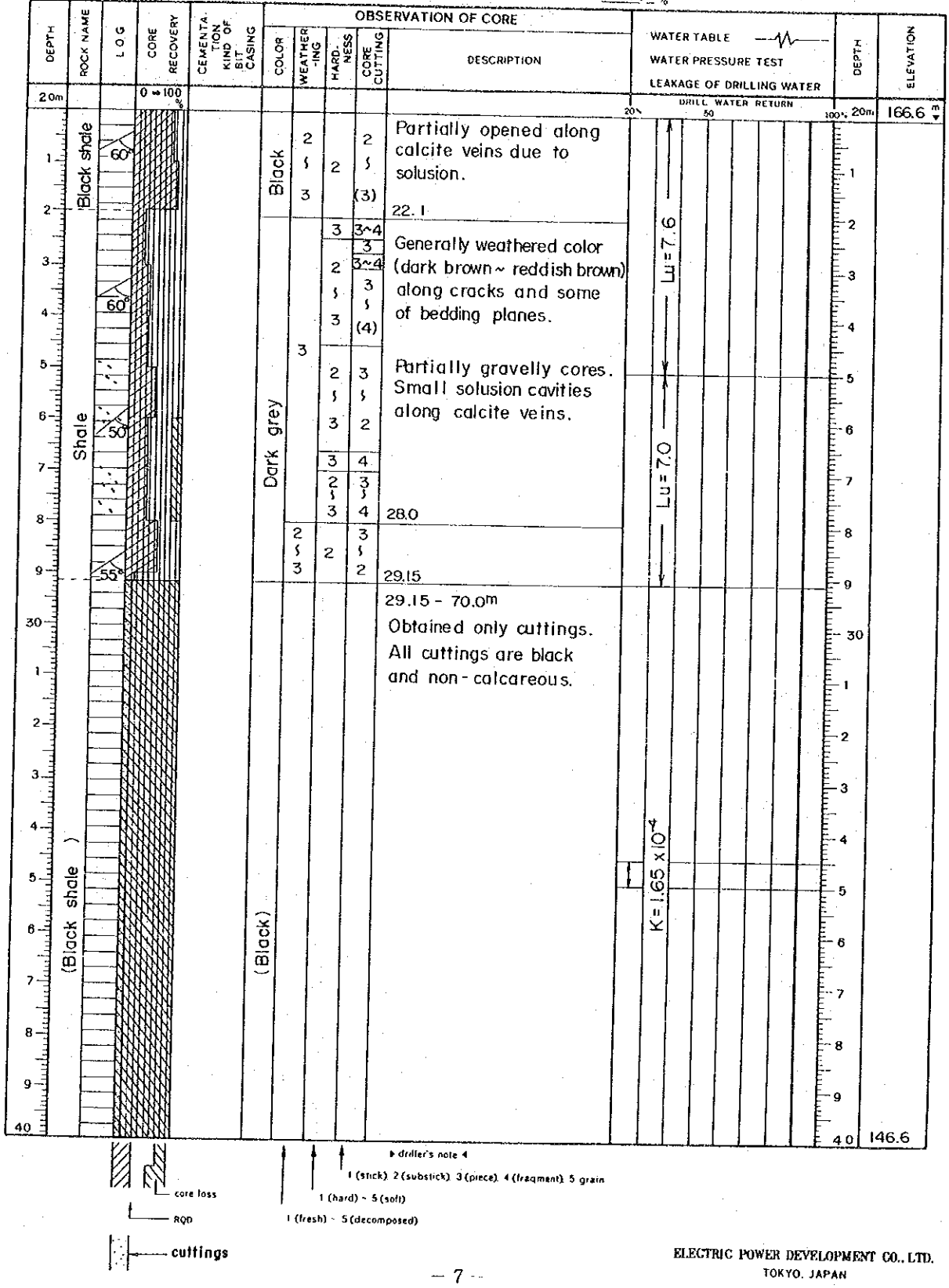
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT

HOLE No. DL-1 (SHEET 2 OF 4)

LOCATION	Dam left bank	DEPTH OF HOLE	80.0 m	COMMENCED	Apr.-13-1983
ELEVATION	186.6 m	DEPTH OF OVERBURDEN	10.0 m	COMPLETED	Apr.-21-1983
COORDINATE	1966 286.9N 375 168.2E	LENGTH OF ROCK DRILLING	70.0 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	19.34 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	—	CORE RECOVERY	27.6 %		



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GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DL-1 (SHEET 3 OF 4)

LOCATION	Dam left bank	DEPTH OF HOLE	80.0 m	COMMENCED	Apr. - 13 - 1983
ELEVATION	186.6 m	DEPTH OF OVERBURDEN	10.0 m	COMPLETED	Apr. - 21 - 1983
COORDINATE	1966 286.9N 375 168.2E	LENGTH OF ROCK DRILLING	70.0 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	19.34 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	—	CORE RECOVERY	27.6 %		

DEPTH | ROCK NAME | LOG | CORE RECOVERY 0 → 100 % | CEMENTATION, KIND OF BIT, CASING | OBSERVATION OF CORE: COLOR, WEATHERING, HARDNESS, CORE CUTTING, DESCRIPTION | WATER TABLE, WATER PRESSURE TEST, LEAKAGE OF DRILLING WATER, DRILL WATER RETURN 20% 50 100% | DEPTH | ELEVATION

40m

29.15m - 70.0 m

Obtained only cuttings.
All cuttings are black and non-calcareous.

(Black shale)

(Black)

K = 1.10 x 10⁻⁴

K = 1.72 x 10⁻⁴

K = 1.98 x 10⁻⁴

K = 7.23 x 10⁻⁴

40m 146.6 m

60 126.6

core loss

RQD

cuttings

▶ driller's note 4

1 (stick) 2 (substick) 3 (piece) 4 (fragment) 5 grain

1 (hard) ~ 5 (soft)

1 (fresh) ~ 5 (decomposed)

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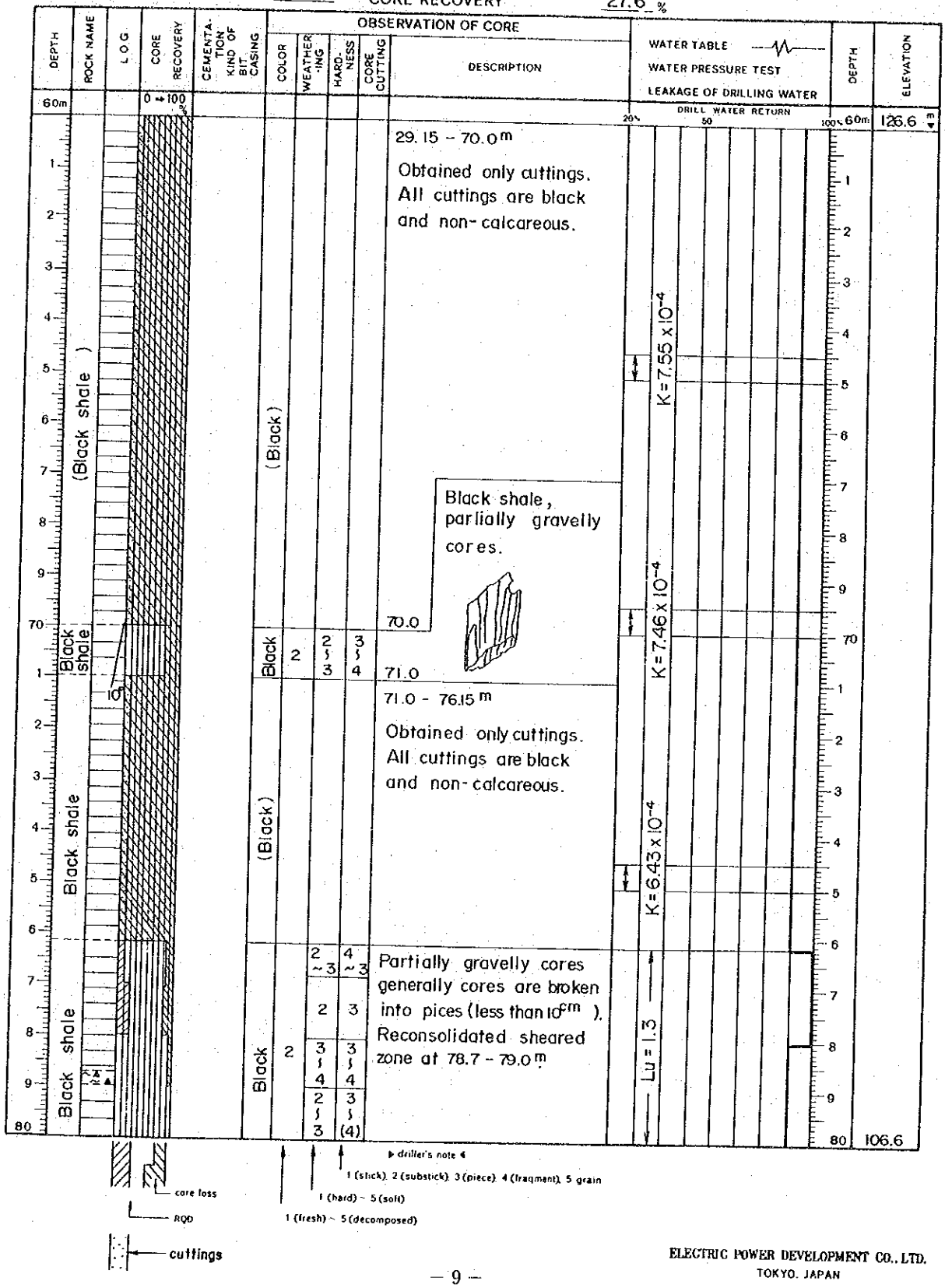
GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DL-1 (SHEET 4 OF 4)

LOCATION	Dam left bank	DEPTH OF HOLE	80.0 m	COMMENCED	Apr. 13 1983
ELEVATION	186.6 m	DEPTH OF OVERBURDEN	10.0 m	COMPLETED	Apr. 21 1983
COORDINATE	1966 286.9N 375 168.2E	LENGTH OF ROCK DRILLING	70.0 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90 °	TOTAL LENGTH OF CORE	19.34 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	—	CORE RECOVERY	27.6 %		



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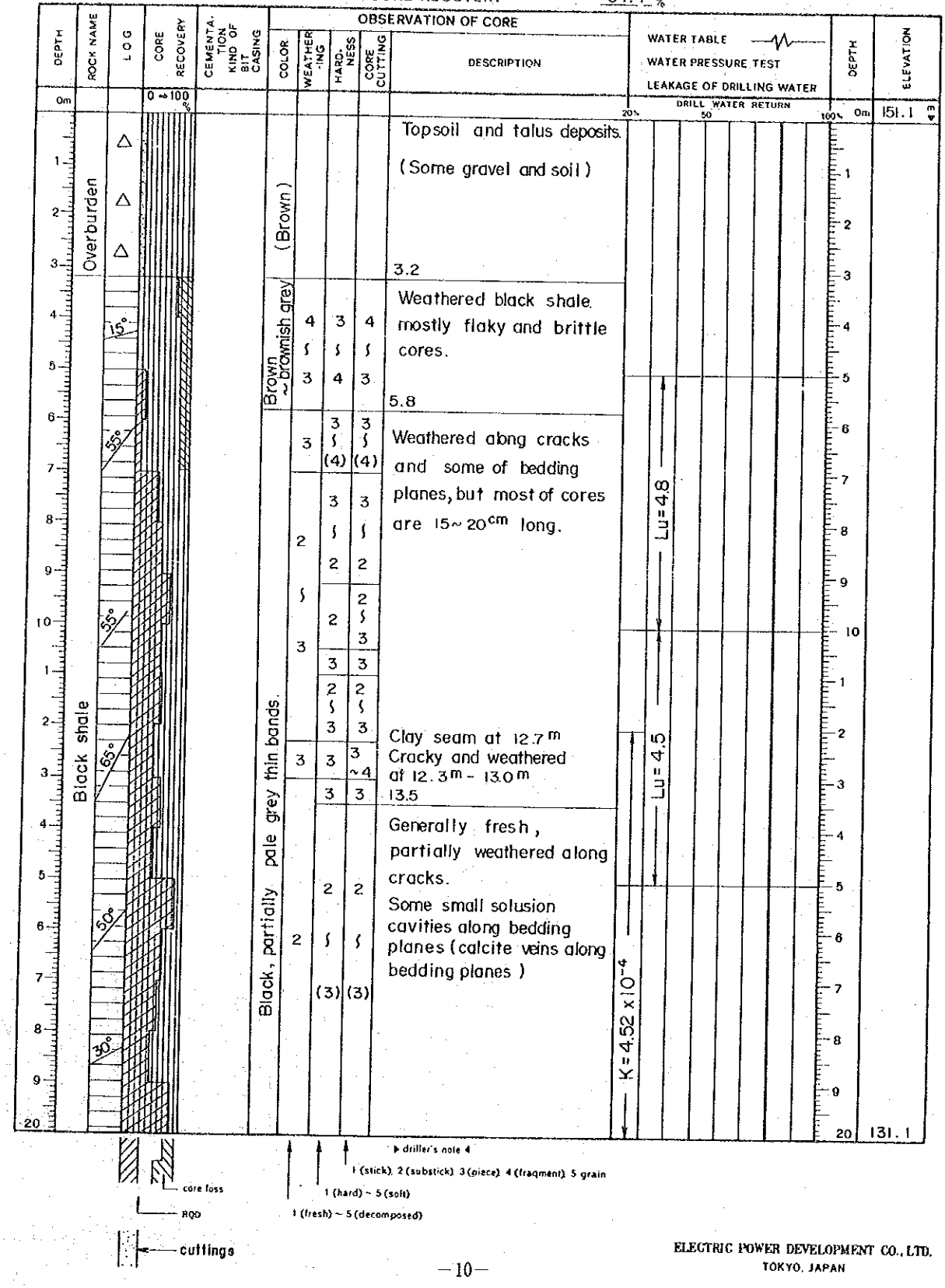
GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DL-2 (SHEET 1 OF 3)

LOCATION	Dam left bank	DEPTH OF HOLE	60.0 m	COMMENCED	May - 1 - 1983
ELEVATION	151.1 m	DEPTH OF OVERBURDEN	3.2 m	COMPLETED	May - 14 - 1983
COORDINATE	1966 350.7N 375 194.1E	LENGTH OF ROCK DRILLING	56.8 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	53.8 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE		CORE RECOVERY	94.7 %		



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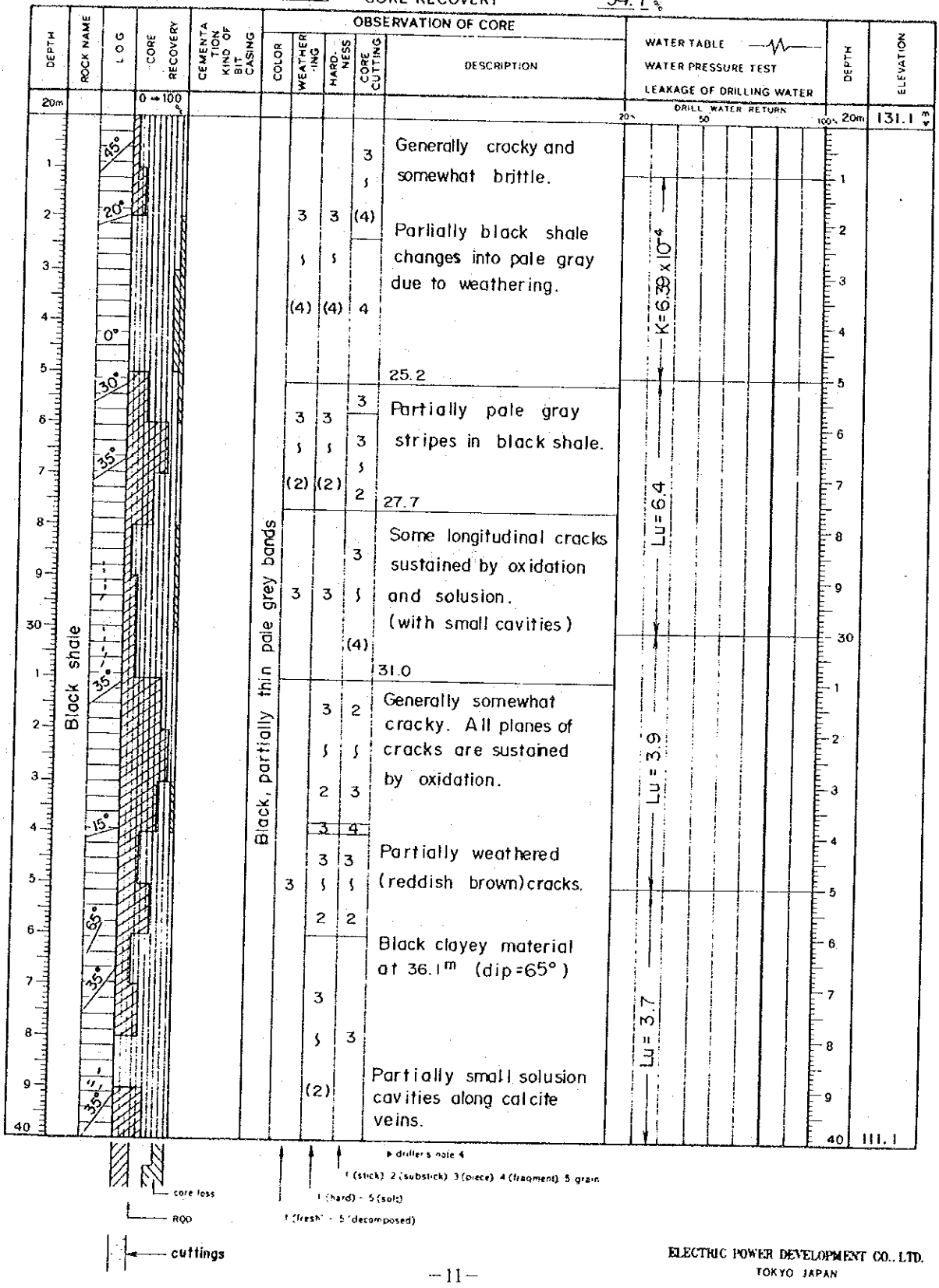
GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT — HOLE No. DL-2 (SHEET 2 OF 3)

LOCATION	Dam left bank	DEPTH OF HOLE	60.0 m	COMMENCED	May - 1 -1983
ELEVATION	151.1 m	DEPTH OF OVERBURDEN	3.2 m	COMPLETED	May - 14 -1983
COORDINATE	1966 350.7N 375 194.1E	LENGTH OF ROCK DRILLING	56.8 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	53.8 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	———	CORE RECOVERY	94.7 %		



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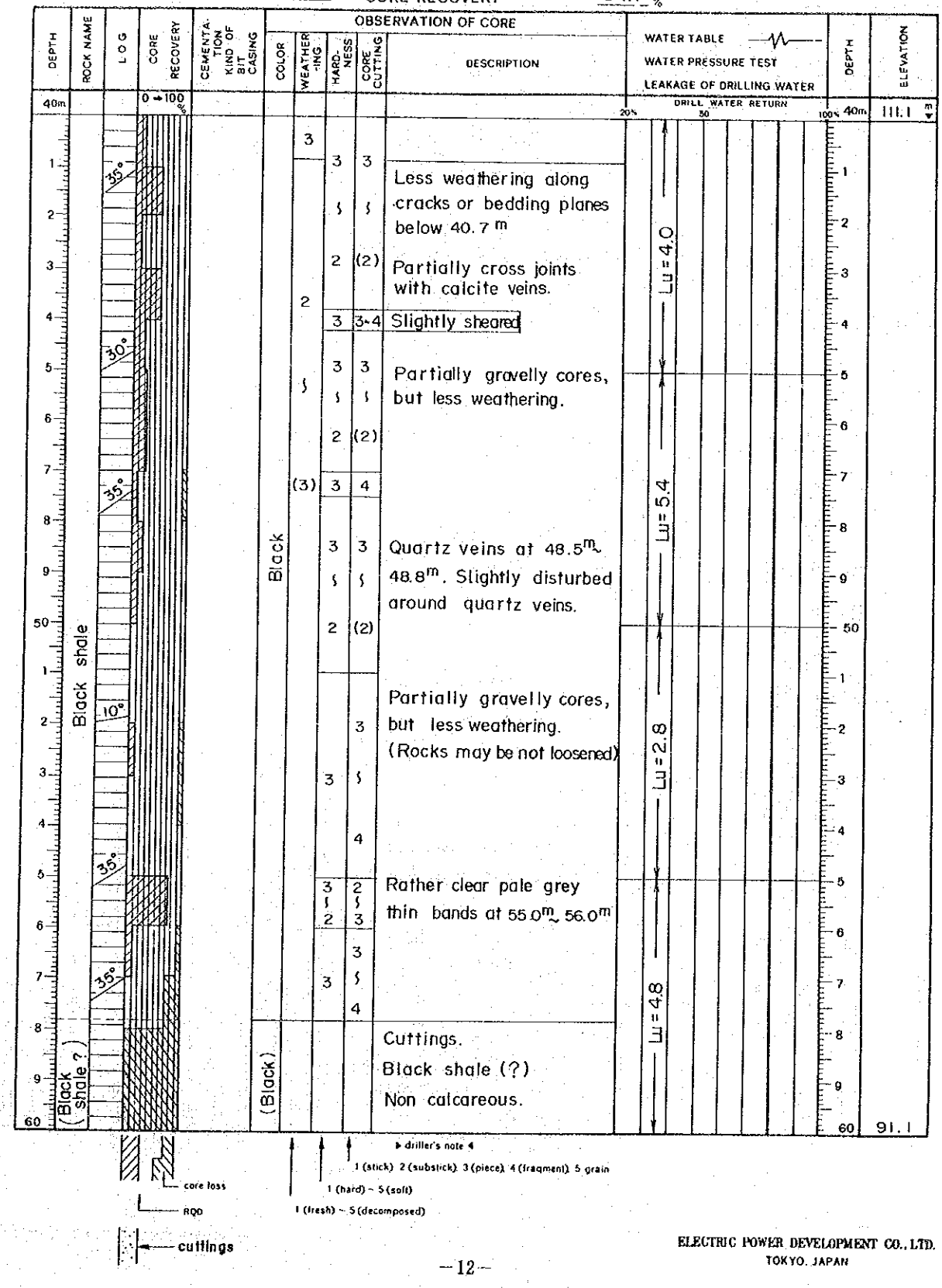
GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DL-2 (SHEET 3 OF 3)

LOCATION	Dam left bank	DEPTH OF HOLE	60.0 m	COMMENCED	May - 1 - 1983
ELEVATION	151.1 m	DEPTH OF OVERBURDEN	3.2 m	COMPLETED	May - 14 - 1983
COORDINATE	1966 350.7N 375 194.1E	LENGTH OF ROCK DRILLING	56.8 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	53.8 m	LOGGED BY	M.Shibata
BEARING OF ANGLE HOLE	———	CORE RECOVERY	94.7 %		



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GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DL-3 (SHEET 1 OF 6)

LOCATION	Dam left bank	DEPTH OF HOLE	120.0 m	COMMENCED	May-18-1983
ELEVATION	90.7 m	DEPTH OF OVERBURDEN	0.35 m	COMPLETED	Jun-24-1983
COORDINATE	1966 430.9N 375 229.3E	LENGTH OF ROCK DRILLING	119.65 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90 °	TOTAL LENGTH OF CORE	58.9 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE		CORE RECOVERY	49.2 %		

DEPTH	ROCK NAME	LOG	CORE RECOVERY	CEMENTATION KIND OF BIT CASING	OBSERVATION OF CORE: COLOR	WEATHERING	HARDNESS	CORE CUTTING	DESCRIPTION
0m			0 ≈ 100 %						0.35 Topsoil, dark brown
1	Black shale				Brownish grey ~ black	3	3 / 2	3 / 4	Weathered black shale. Cracky and weathered along cracks.
2									Cuttings
3		30°				3	3 / 2	3 / (4)	Partially solusion cavities along calcite veins.
4									4.6
5					Black	3	2 / 3	2 / 3	Bedding planes not so obvious. Sound shale but weathered along cracks.
6									
7									
8		20°				3	3 ≷ 4	3 ≷ 5	Sheared and black soft materials at 8.3 - 8.5m
9						3	3 / 2	3	
10						3	3 ≷ 4	3 ≷ (5)	Sheared and black soft materials at 10.85 - 10.95m
1					(Black)				11.0 - 20.0m Cuttings. Cutting materials are mostly medium or coarse grained rock fragments of black shale. (No reaction with acid)
20									

WATER TABLE / WATER PRESSURE TEST / LEAKAGE OF DRILLING WATER — DRILL WATER RETURN 20% 50 100%

K=7.43×10⁻⁴

G.L.11.0m

K=2.40×10⁻⁴

K=5.54×10⁻⁴

DEPTH	ELEVATION
0m	90.7
20	70.7

core loss

RQD

cuttings

▶ driller's note 4

1 (stick) 2 (substick) 3 (piece) 4 (fragment) 5 grain

1 (hard) ~ 5 (soft)

1 (fresh) ~ 5 (decomposed)

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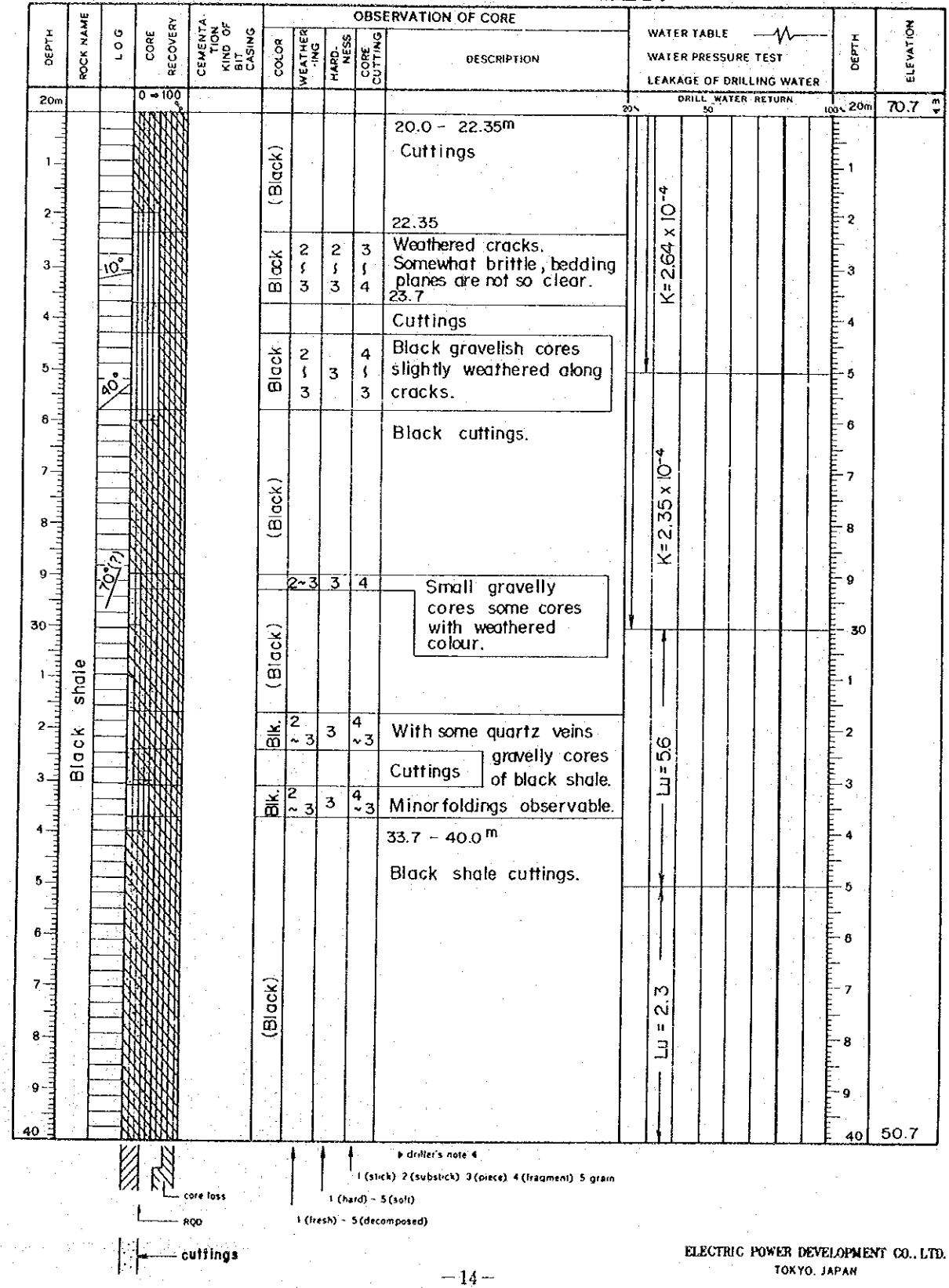
GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT — HOLE No. DL-3 (SHEET 2 OF 6)

LOCATION	Dam left bank	DEPTH OF HOLE	120.0 m	COMMENCED	May - 18 - 1983
ELEVATION	90.7 m	DEPTH OF OVERBURDEN	0.35 m	COMPLETED	Jun - 24 - 1983
COORDINATE	1966430.9N 375229.3E	LENGTH OF ROCK DRILLING	119.65 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90 °	TOTAL LENGTH OF CORE	58.9 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	———	CORE RECOVERY	49.2 %		



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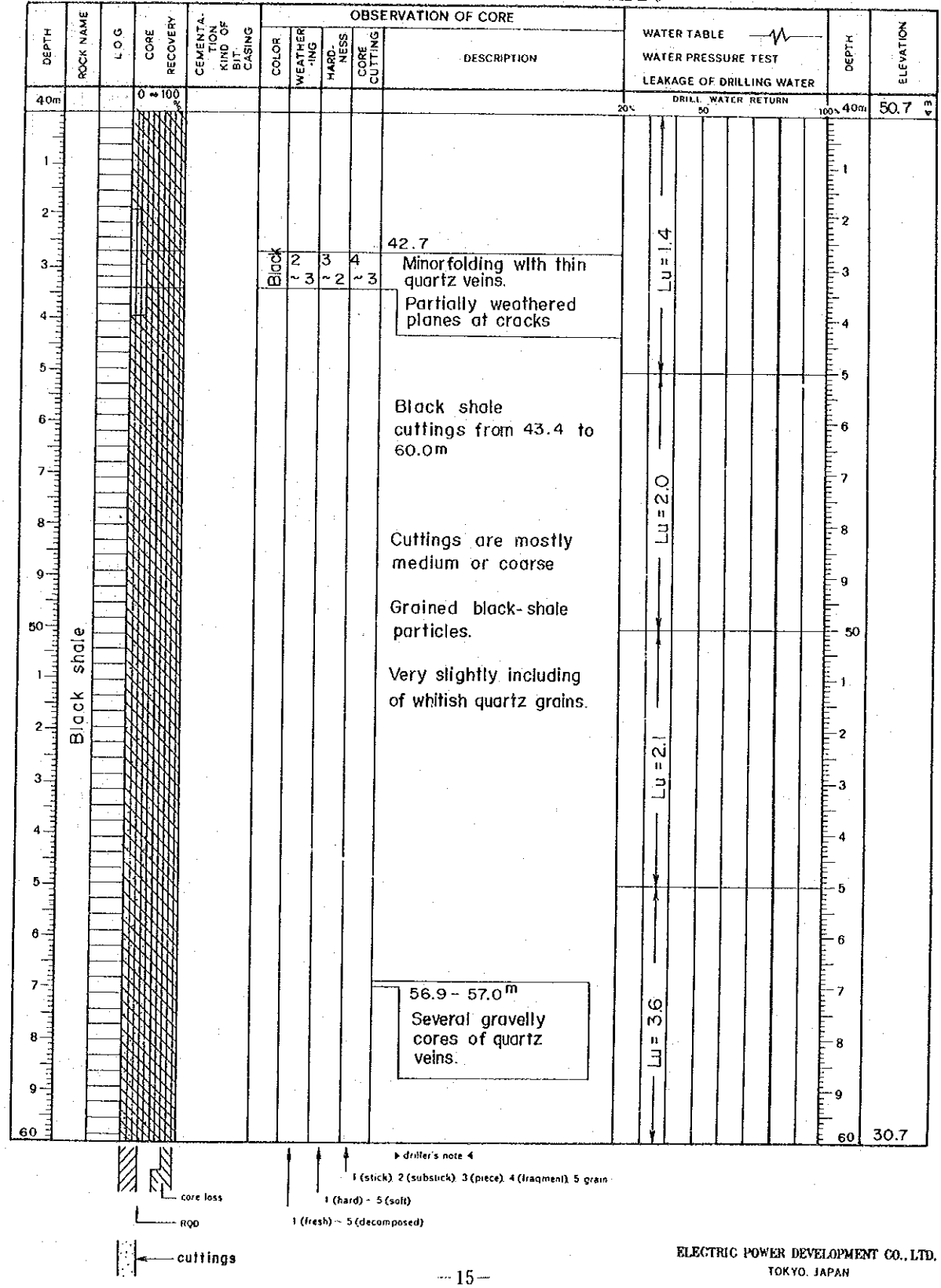
GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DL-3 (SHEET 3 OF 6)

LOCATION	Dam left bank	DEPTH OF HOLE	120.0 m	COMMENCED	May-18 - 1983
ELEVATION	90.7 m	DEPTH OF OVERBURDEN	0.35 m	COMPLETED	Jun - 24 - 1983
COORDINATE	1966430.9N 375229.3E	LENGTH OF ROCK DRILLING	119.65 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90 °	TOTAL LENGTH OF CORE	58.9 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE		CORE RECOVERY	49.2 %		



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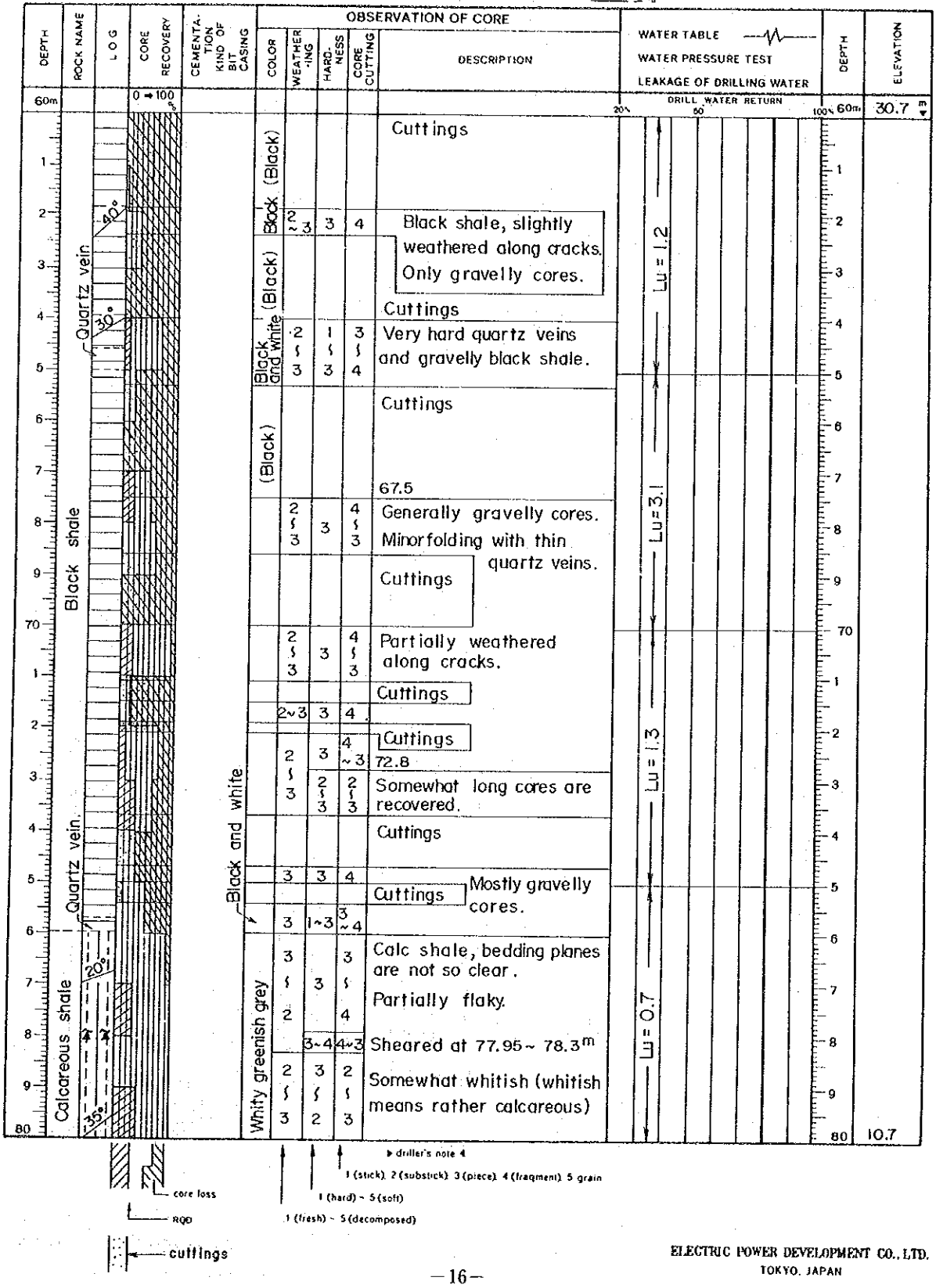
GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DL-3 (SHEET 4 OF 6)

LOCATION	Dam left bank	DEPTH OF HOLE	120.0 m	COMMENCED	May - 18 - 1983
ELEVATION	90.7 m	DEPTH OF OVERBURDEN	0.35 m	COMPLETED	Jun - 24 - 1983
COORDINATE	1966430.9N 375229.3E	LENGTH OF ROCK DRILLING	119.65 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	58.9 m	LOGGED BY	M.Shibata
BEARING OF ANGLE HOLE		CORE RECOVERY	49.2 %		



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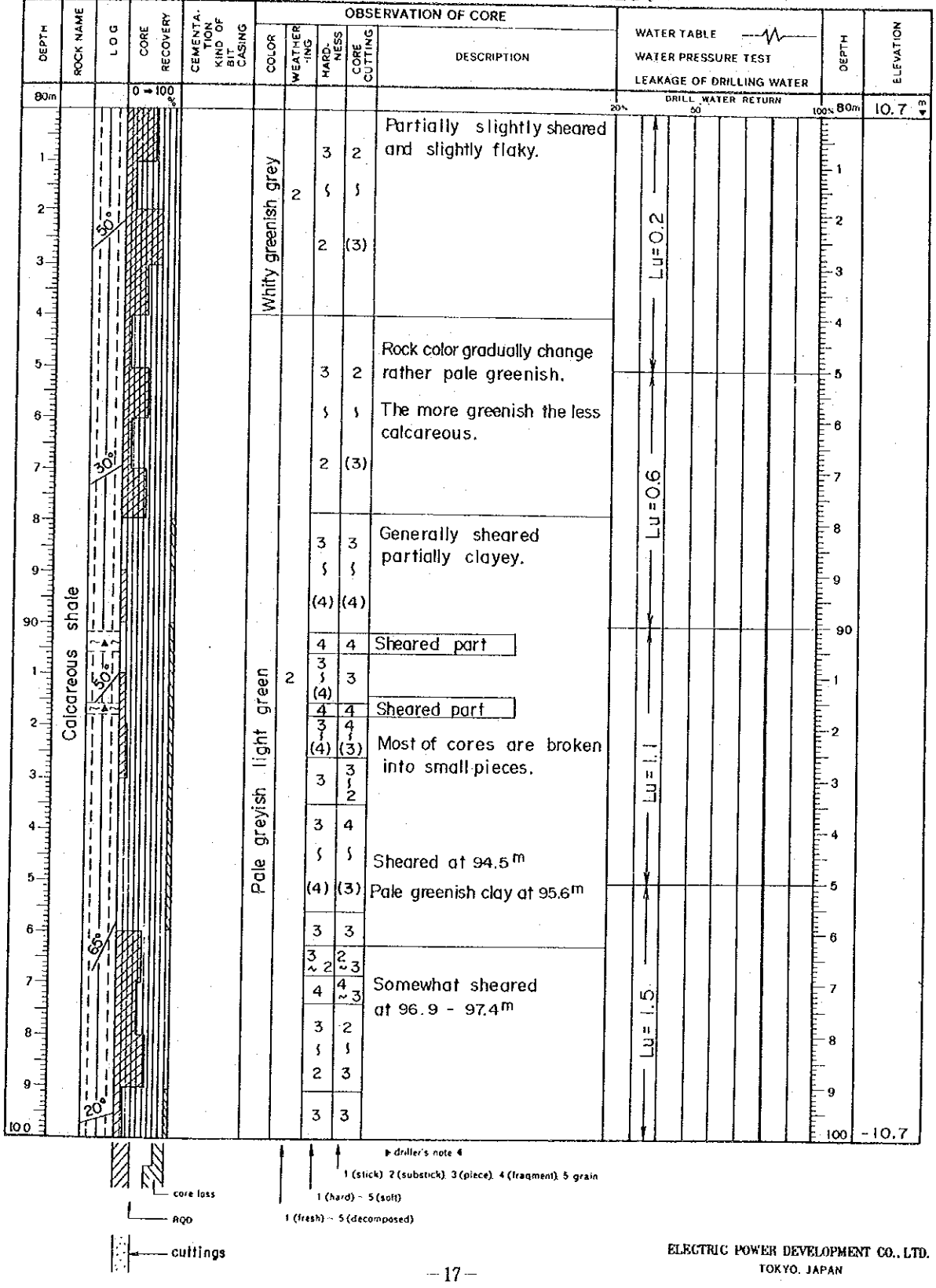
GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT — HOLE No. DL-3 (SHEET 5 OF 6)

LOCATION	Dam left bank	DEPTH OF HOLE	120.0 m	COMMENCED	May - 18 - 1983
ELEVATION	90.7 m	DEPTH OF OVERBURDEN	0.35 m	COMPLETED	Jun - 24 - 1983
COORDINATE	9664309N 375229.3E	LENGTH OF ROCK DRILLING	119.65 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	58.9 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	—	CORE RECOVERY	49.2 %		



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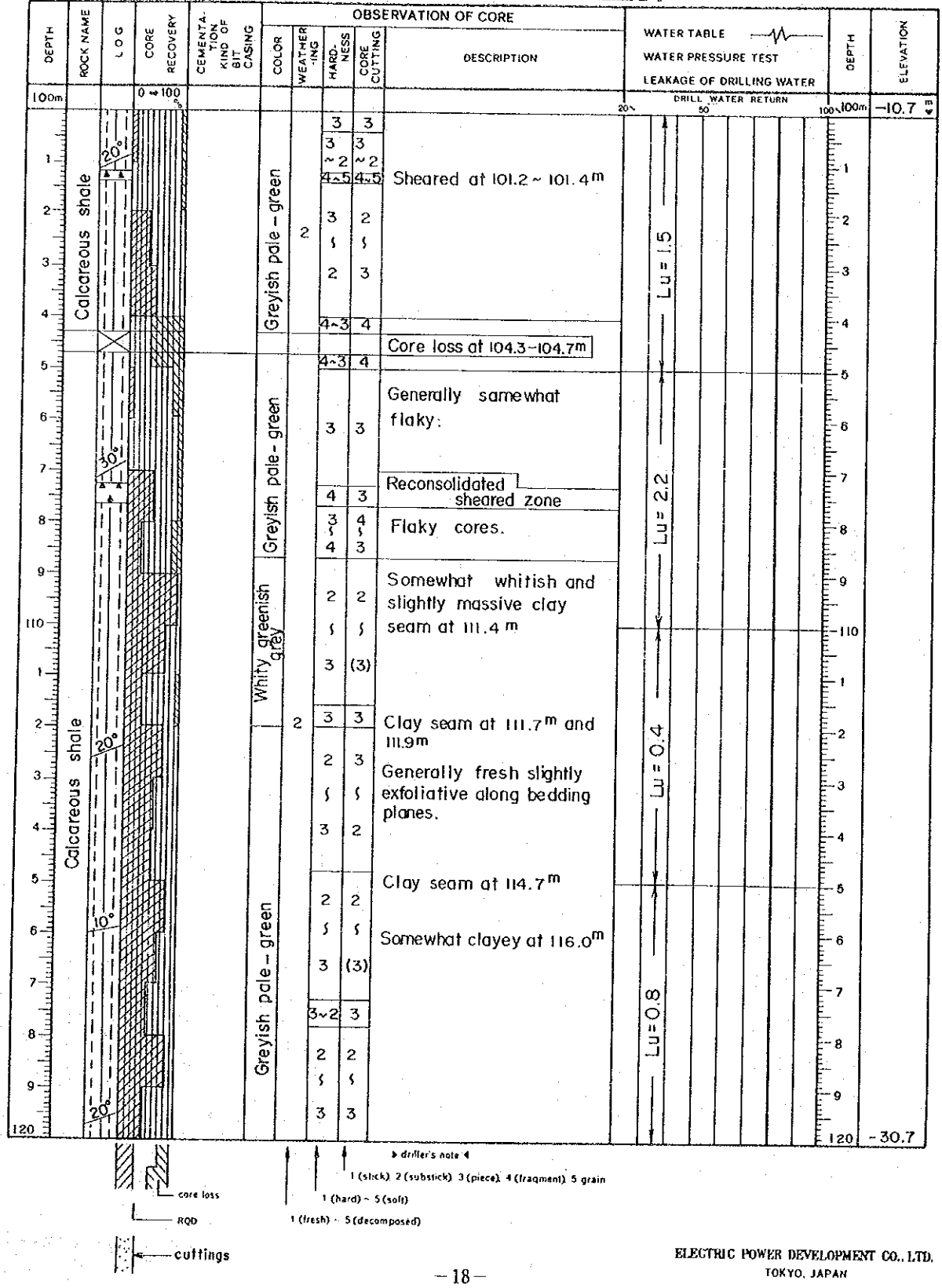
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT — HOLE No. DL-3 (SHEET 6 OF 6)

LOCATION	Dam left bank	DEPTH OF HOLE	120.0 m	COMMENCED	May-18-1983
ELEVATION	90.7 m	DEPTH OF OVERBURDEN	0.35 m	COMPLETED	Jun-24-1983
COORDINATE	1966430.9N 375229.3E	LENGTH OF ROCK DRILLING	119.65 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	58.9 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE		CORE RECOVERY	49.2 %		



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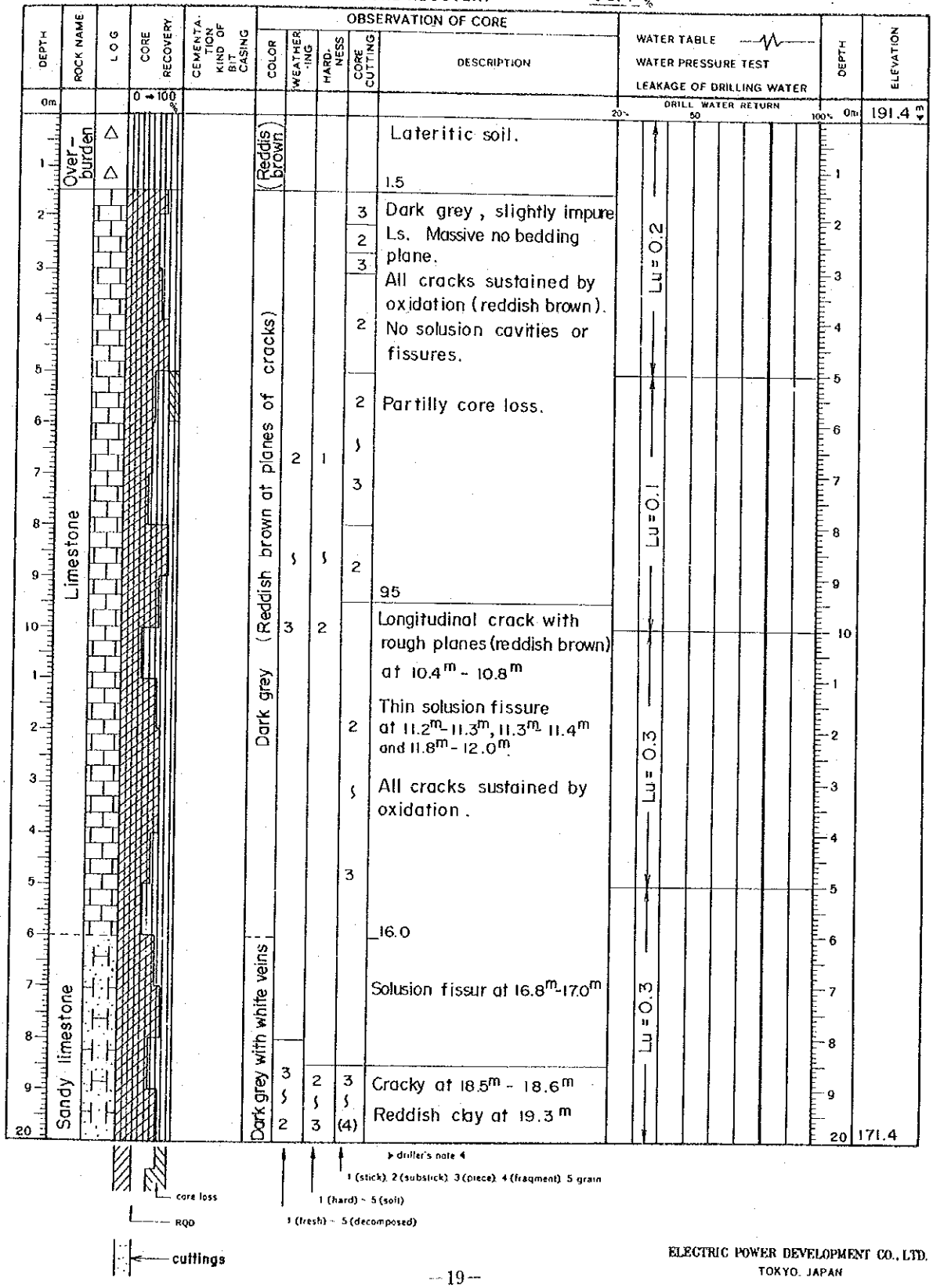
GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DL-4 (SHEET 1 OF 4)

LOCATION Dam left bank
ELEVATION 191.4 m
COORDINATE 1965 774.5N 375 425.7E
ANGLE FROM HORIZONTAL 90°
BEARING OF ANGLE HOLE

DEPTH OF HOLE 80.0 m
DEPTH OF OVERBURDEN 1.5 m
LENGTH OF ROCK DRILLING 78.5 m
TOTAL LENGTH OF CORE 77.0 m
CORE RECOVERY 98.1 %

COMMENCED Jul. 23 1983
COMPLETED Aug. 22 1983
DRILLED BY ROEM
LOGGED BY M. Shibata



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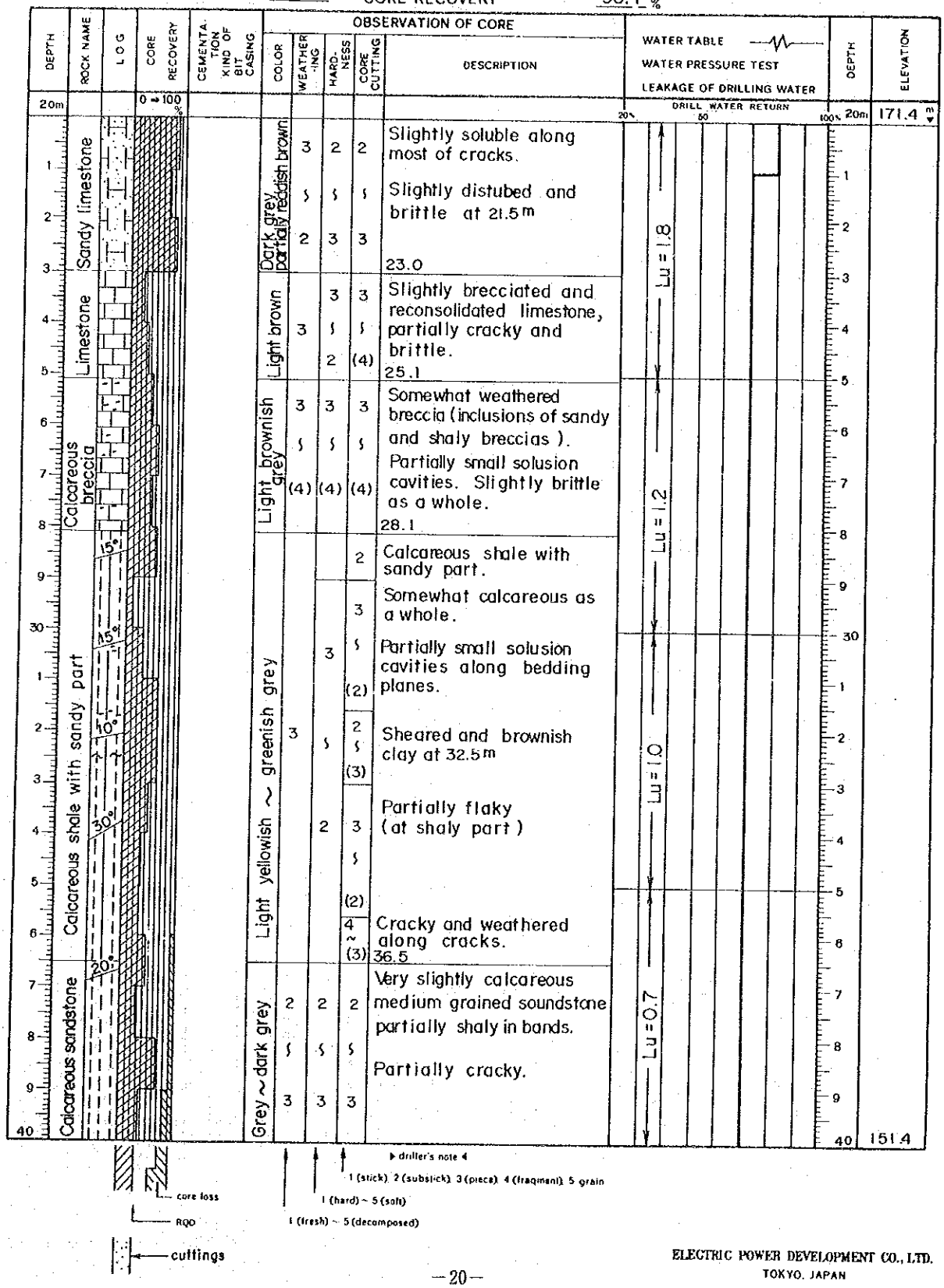
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DL-4 (SHEET 2 OF 4)

LOCATION	Dam left bank	DEPTH OF HOLE	80.0 m	COMMENCED	Jul. 23 1983
ELEVATION	191.4 m	DEPTH OF OVERBURDEN	1.5 m	COMPLETED	Aug 22 1983
COORDINATE	1965774.5N 375425.7E	LENGTH OF ROCK DRILLING	78.5 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	77.0 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	—	CORE RECOVERY	98.1 %		



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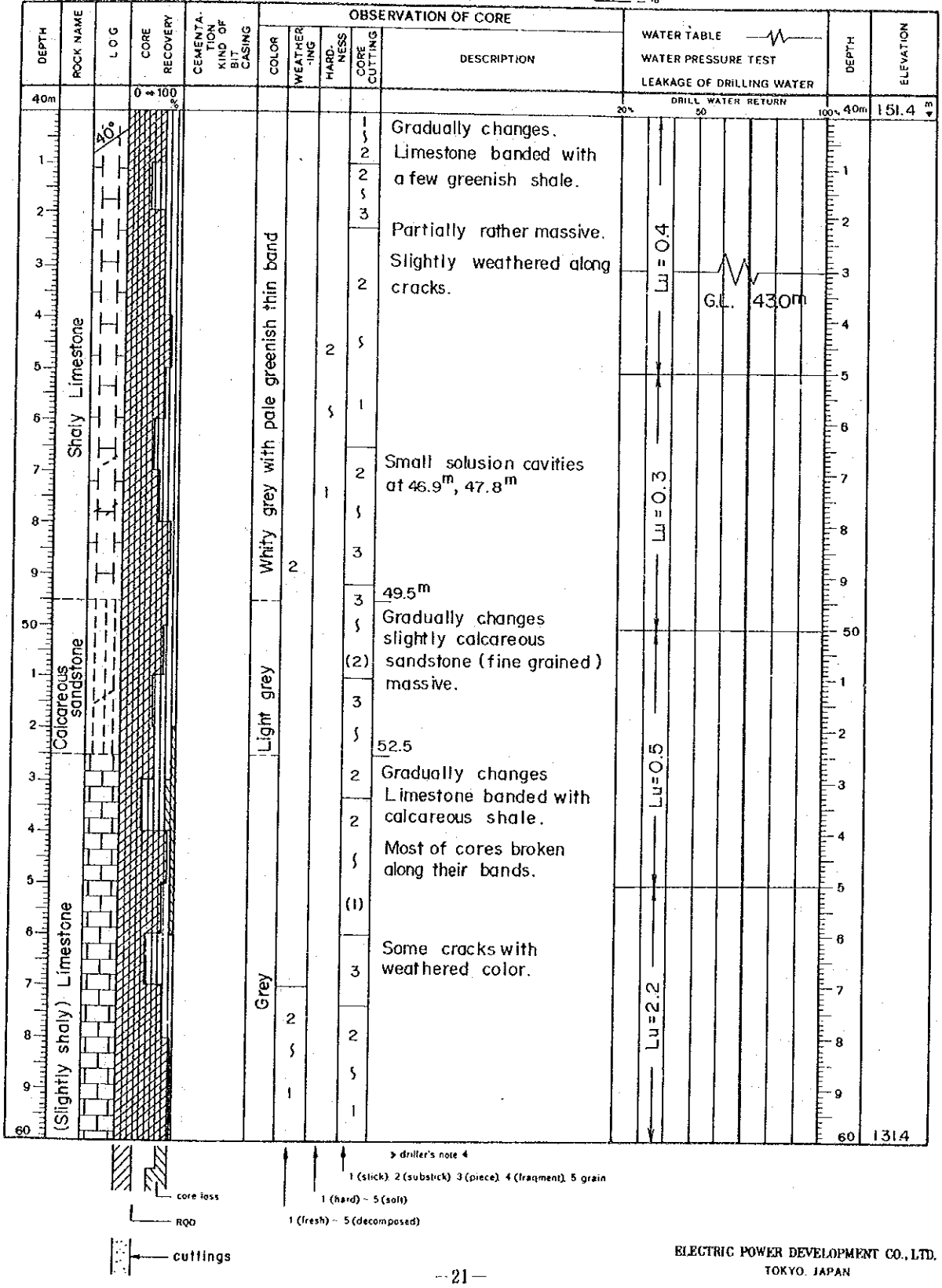
GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DL-4 (SHEET 3 OF 4)

LOCATION	Dam left bank	DEPTH OF HOLE	80.0 m	COMMENCED	Jul. - 23 - 1983
ELEVATION	191.4 m	DEPTH OF OVERBURDEN	1.5 m	COMPLETED	Aug. - 22 - 1983
COORDINATE	1965 774.5N 375 425.7E	LENGTH OF ROCK DRILLING	78.5 m	DRILLED BY	R O E M
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	77.0 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE		CORE RECOVERY	98.1 %		

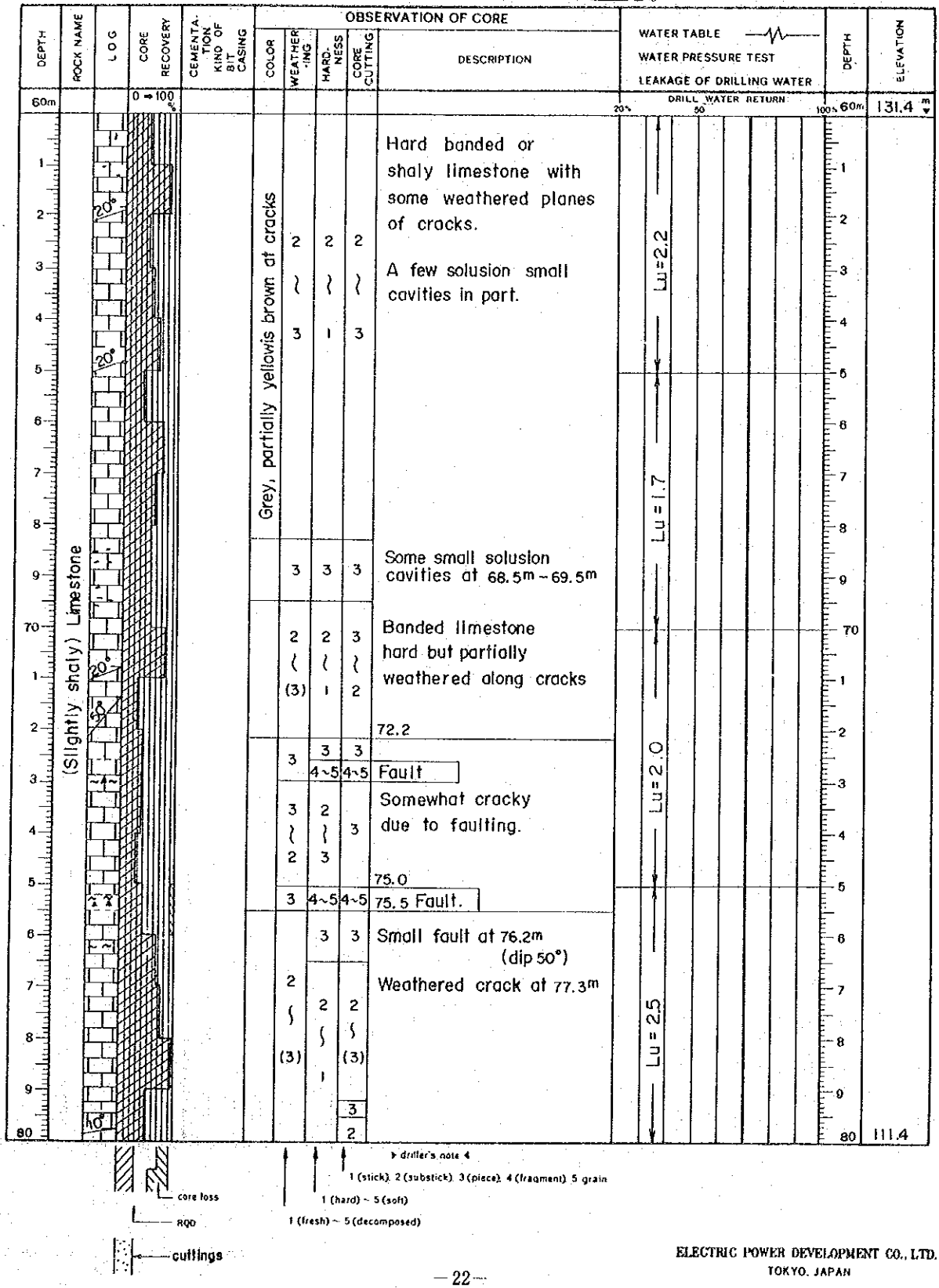


ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DL-4 (SHEET 4 OF 4)

LOCATION	Dam left bank	DEPTH OF HOLE	80.0 m	COMMENCED	Jul. - 23 - 1983
ELEVATION	191.4 m	DEPTH OF OVERBURDEN	1.5 m	COMPLETED	Aug. - 22 - 1983
COORDINATE	1965 774.5N 375 425.7E	LENGTH OF ROCK DRILLING	78.5 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	77.0 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE		CORE RECOVERY	98.1 %		

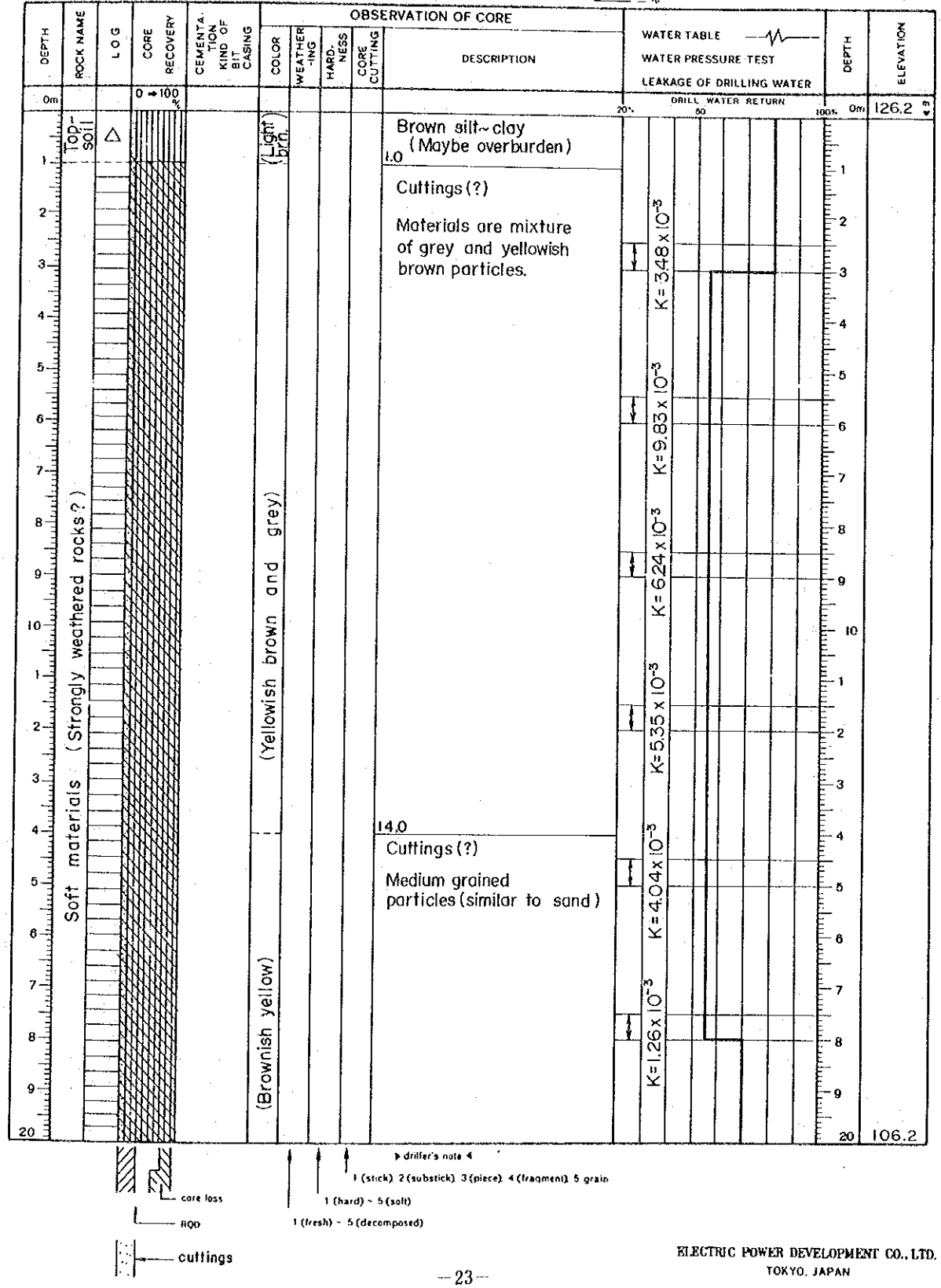


ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT — HOLE No. S-1 (SHEET 1 OF 3)

LOCATION	Spillway	DEPTH OF HOLE	43.5 m	COMMENCED	Mar.-24-1983
ELEVATION	126.2 m	DEPTH OF OVERBURDEN	1.0 m	COMPLETED	Apr.-2-1983
COORDINATE	1966 3953N 375 0142E	LENGTH OF ROCK DRILLING	42.5 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	6.9 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE		CORE RECOVERY	19.2 %		

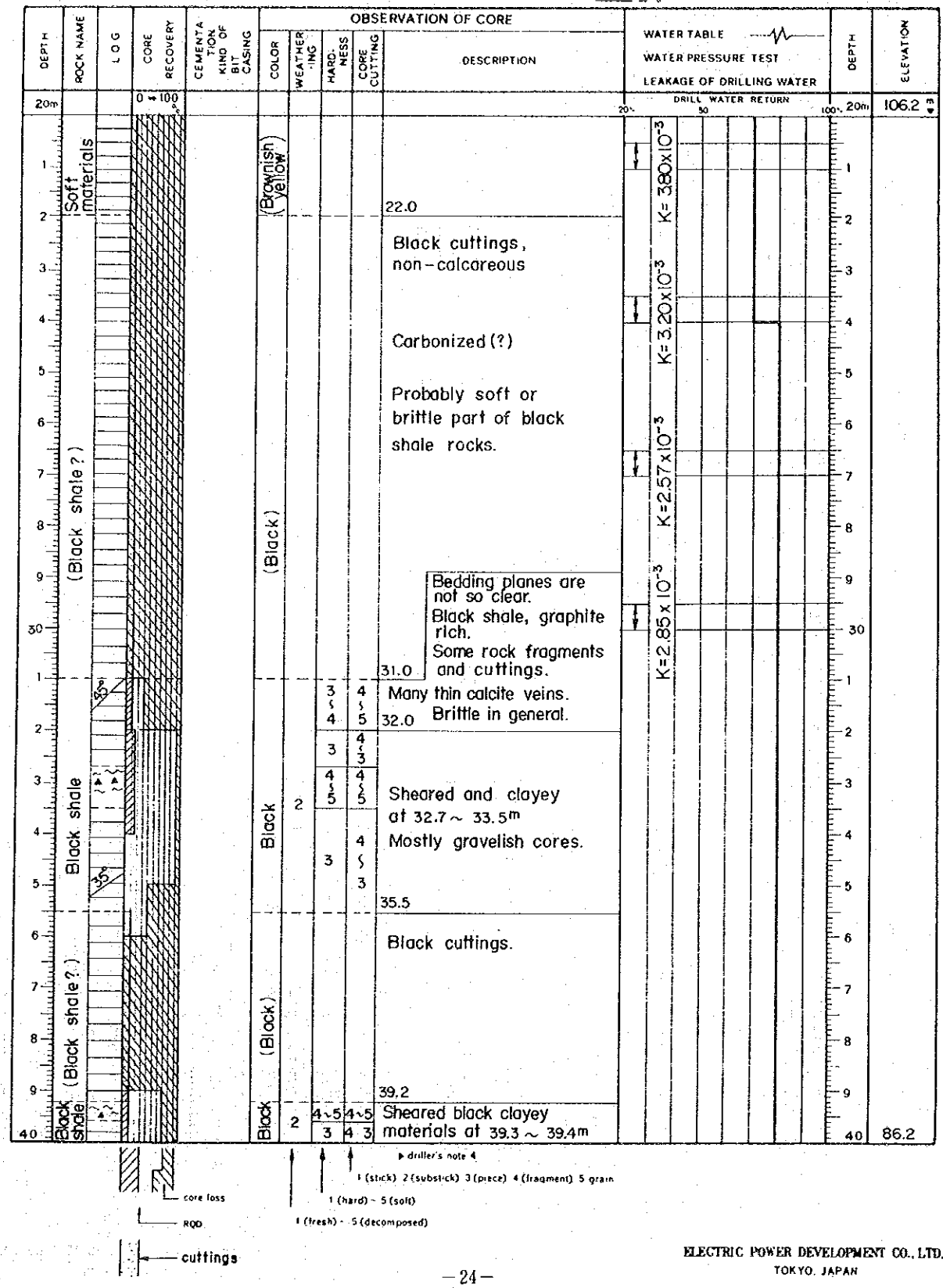


ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. S-1 (SHEET 2 OF 3)

LOCATION	Spillway	DEPTH OF HOLE	43.5 m	COMMENCED	Mar.-24-1983
ELEVATION	126.2 m	DEPTH OF OVERBURDEN	1.0 m	COMPLETED	Apr.-2-1983
COORDINATE	1966 395.3N 375 014.2E	LENGTH OF ROCK DRILLING	42.5 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	6.9 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE		CORE RECOVERY	19.2 %		



ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. S-1 (SHEET 3 OF 3)

LOCATION	Spillway	DEPTH OF HOLE	43.5 m	COMMENCED	Mar.-24-1983
ELEVATION	126.2 m	DEPTH OF OVERBURDEN	1.0 m	COMPLETED	Apr.-2-1983
COORDINATE	1966395.3N 375014.2E	LENGTH OF ROCK DRILLING	42.5 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	6.9 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	—	CORE RECOVERY	19.2 %		

DEPTH	ROCK NAME	LOG	CORE RECOVERY	CEMENTATION, KIND OF BIT, CASING	OBSERVATION OF CORE: COLOR	WEATHERING	HARDNESS	CORE CUTTING	DESCRIPTION	WATER TABLE / WATER PRESSURE TEST / LEAKAGE OF DRILLING WATER / DRILL WATER RETURN	DEPTH	ELEVATION
40m			0 → 100 %							20% 50 100%	40m	86.2
1	Black shale	20°			Black	2	3	4 ≤ (3)	Generally brittle. Partially calcite veins.		1	
2							4~5	4~5	Sheared black clayey materials at 41.3 - 41.4m		2	
3							3	4 ≤ (3)	Black clayey materials at bottom of hole. Bottom of hole at 43.5m		3	82.7
4											4	
5											5	
6											6	
7											7	
8											8	
9											9	
0											0	
1											1	
2											2	
3											3	
4											4	
5											5	
6											6	
7											7	
8											8	
9											9	
0											0	

core loss
RQD
cuttings

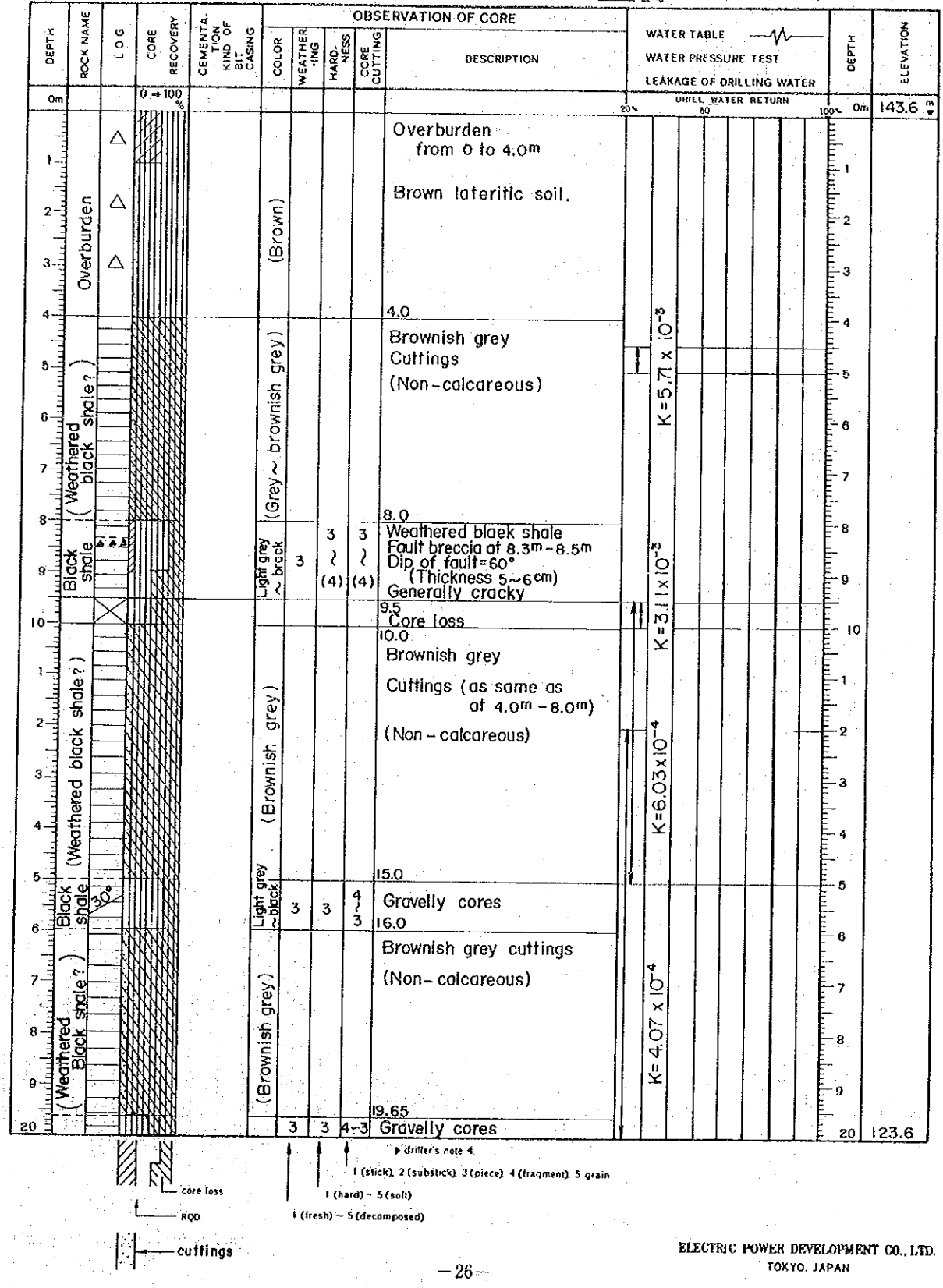
▶ driller's note ◀
1 (stick), 2 (substick), 3 (piece), 4 (fragment), 5 grain
1 (hard) ~ 5 (soft)
1 (fresh) ~ 5 (decomposed)

ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. I - 1 (SHEET 1 OF 2)

LOCATION	Intake	DEPTH OF HOLE	40.0 m	COMMENCED	May - 18 - 1983
ELEVATION	143.6 m	DEPTH OF OVERBURDEN	4.0 m	COMPLETED	Jul - 27 - 1983
COORDINATE	1966516.2N 375 483.6E	LENGTH OF ROCK DRILLING	36.0 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	13.4 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE		CORE RECOVERY	31.5 %		

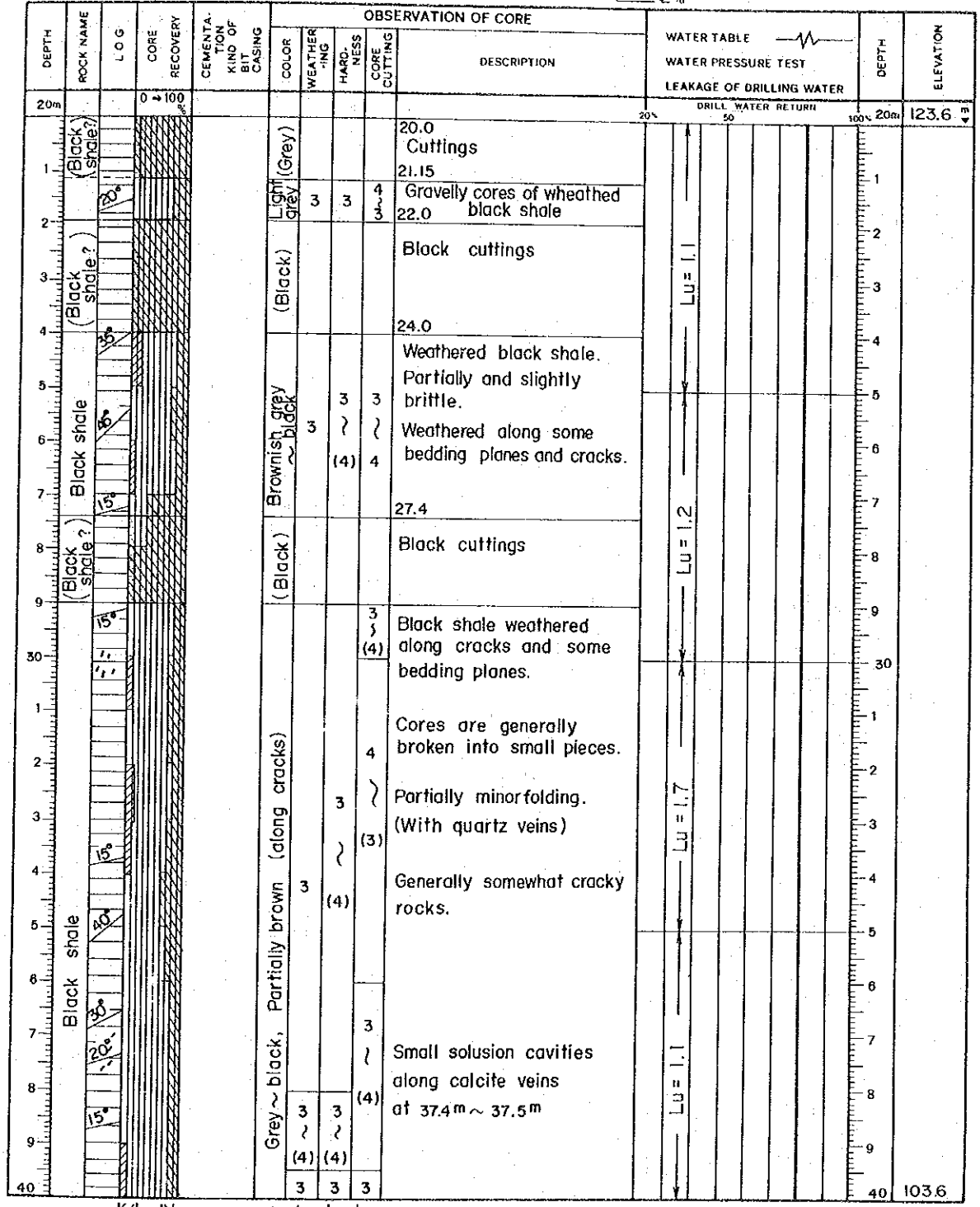


ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT — HOLE No. I - 1 (SHEET 2 OF 2)

LOCATION	Intake	DEPTH OF HOLE	40.0 m	COMMENCED	May - 18 - 1983
ELEVATION	143.6 m	DEPTH OF OVERBURDEN	4.0 m	COMPLETED	Jul. - 27 - 1983
COORDINATE	196516.2N 375483.6E	LENGTH OF ROCK DRILLING	36.0 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90 °	TOTAL LENGTH OF CORE	13.4 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	———	CORE RECOVERY	31.5 %		



ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

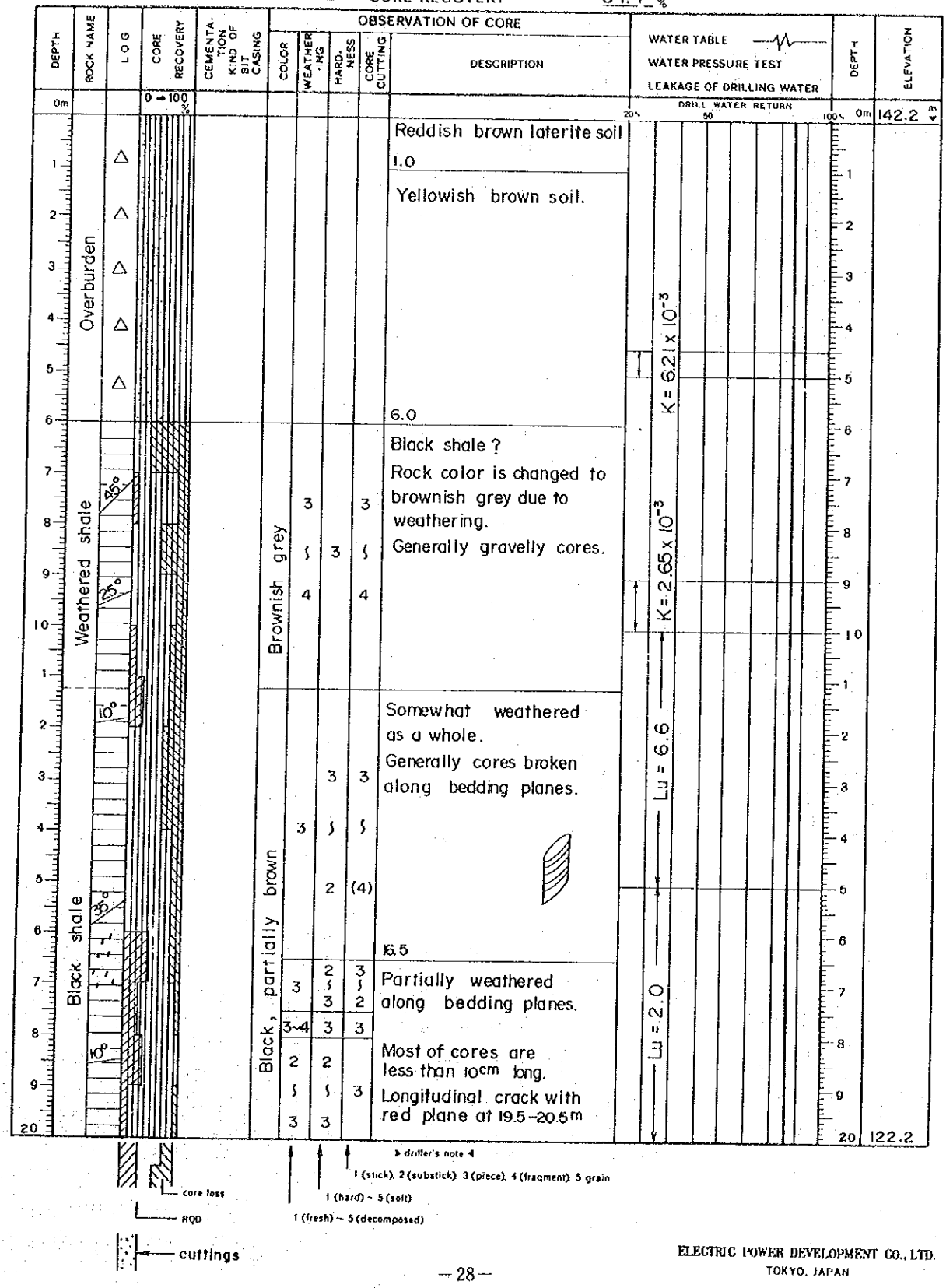
GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DR-1 (SHEET 1 OF 3)

LOCATION Dam right bank
ELEVATION 142.2 m
COORDINATE 1966561.8N 375447.3E
ANGLE FROM HORIZONTAL 90°
BEARING OF ANGLE HOLE ———

DEPTH OF HOLE 60.0 m
DEPTH OF OVERBURDEN 6.0 m
LENGTH OF ROCK DRILLING 54.0 m
TOTAL LENGTH OF CORE 34.8 m
CORE RECOVERY 64.4 %

COMMENCED Aug.-18-1983
COMPLETED Sep.-1-1983
DRILLED BY ROEM
LOGGED BY M. Shibata

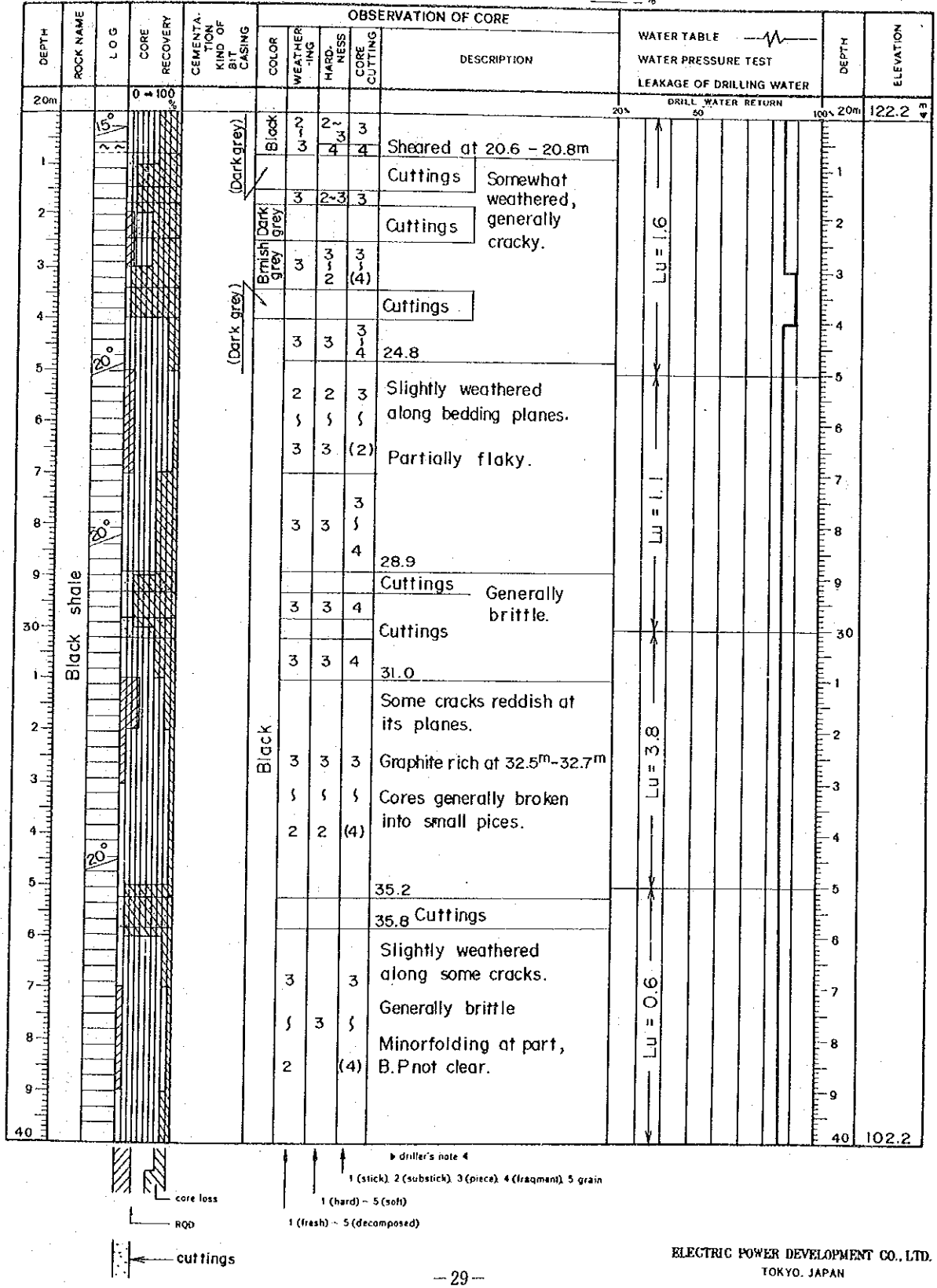


ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DR-1 (SHEET 2 OF 3)

LOCATION	Dam right bank	DEPTH OF HOLE	60.0 m	COMMENCED	Aug-18-1983
ELEVATION	142.2 m	DEPTH OF OVERBURDEN	6.0 m	COMPLETED	Sep-1-1983
COORDINATE	196655.8N 37544.73E	LENGTH OF ROCK DRILLING	54.0 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	34.8 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE		CORE RECOVERY	64.4 %		

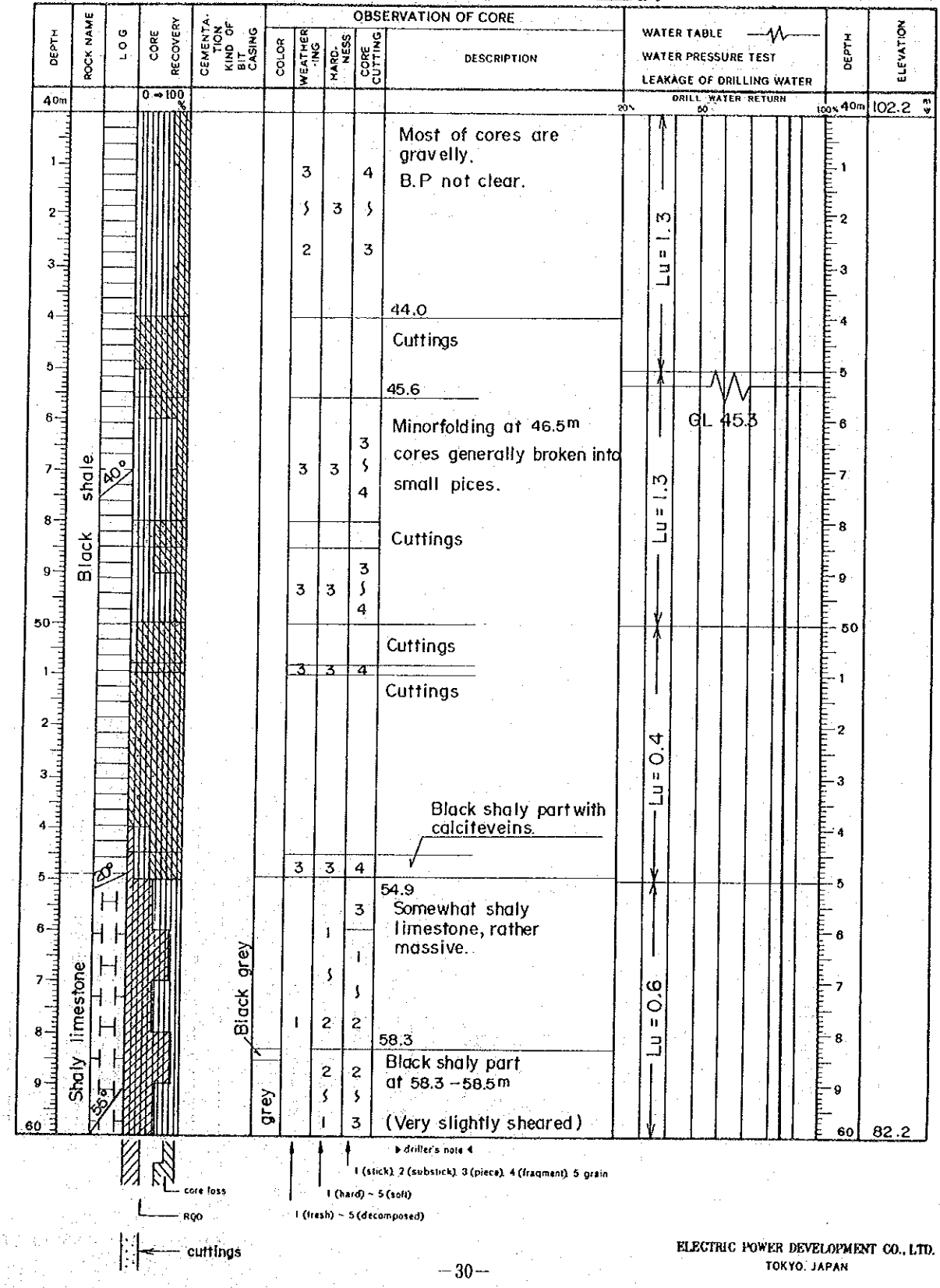


ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DR-1 (SHEET 3 OF 3)

LOCATION	Dam right bank	DEPTH OF HOLE	60.0 m	COMMENCED	Aug-18-1983
ELEVATION	142.2 m	DEPTH OF OVERBURDEN	6.0 m	COMPLETED	Sep-1-1983
COORDINATE	966 551.8N 375 447.3E	LENGTH OF ROCK DRILLING	54.0 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	34.8 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE		CORE RECOVERY	64.4 %		

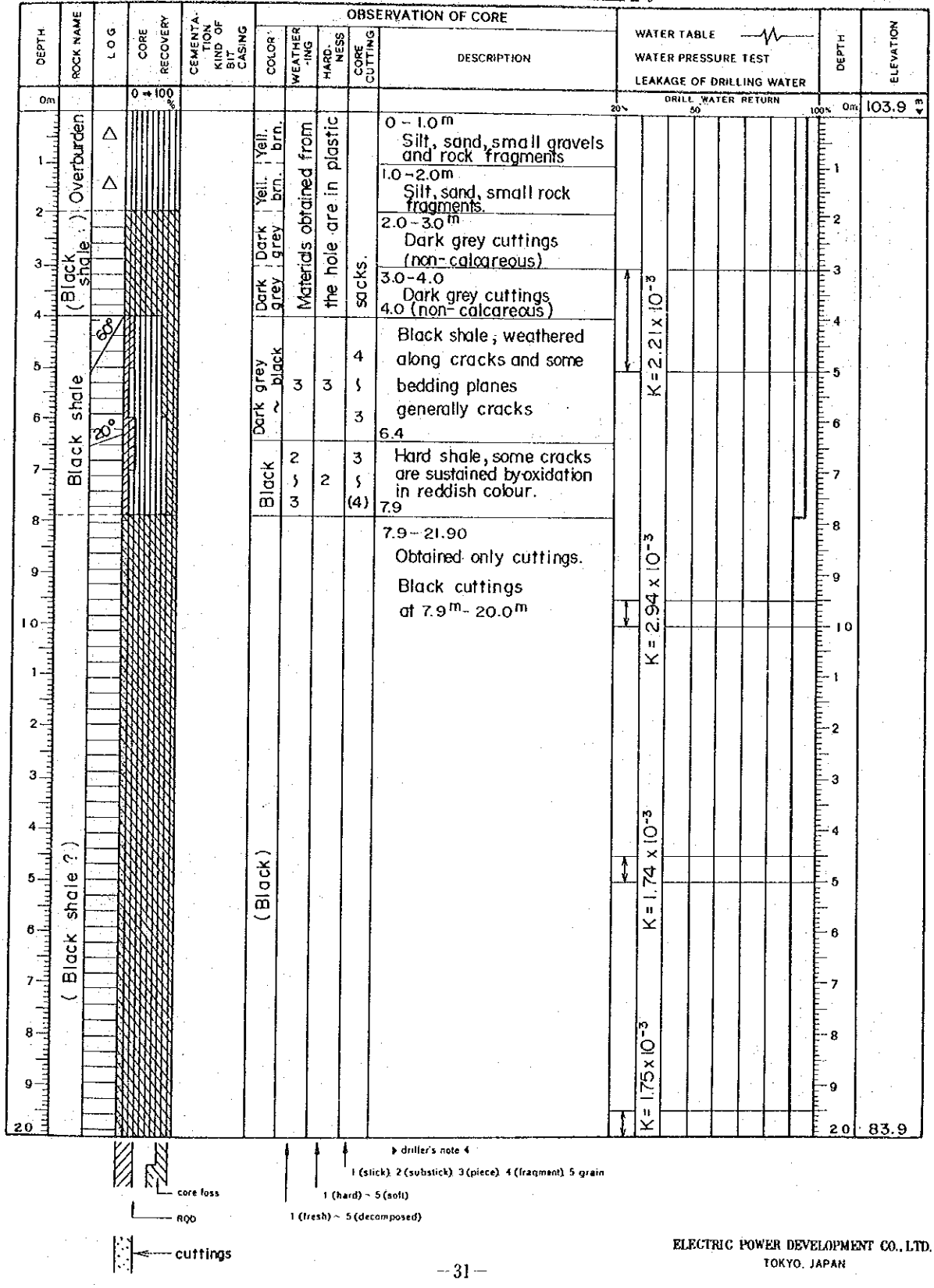


ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DR-2 (SHEET 1 OF 4)

LOCATION	Dam right bank	DEPTH OF HOLE	80.0 m	COMMENCED	Sep - 10 - 1983
ELEVATION	103.9 m	DEPTH OF OVERBURDEN	2.0 m	COMPLETED	Oct. - 14 - 1983
COORDINATE	1966 502.2N 375 412.9E	LENGTH OF ROCK DRILLING	78.0 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	52.95 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	———	CORE RECOVERY	67.9 %		

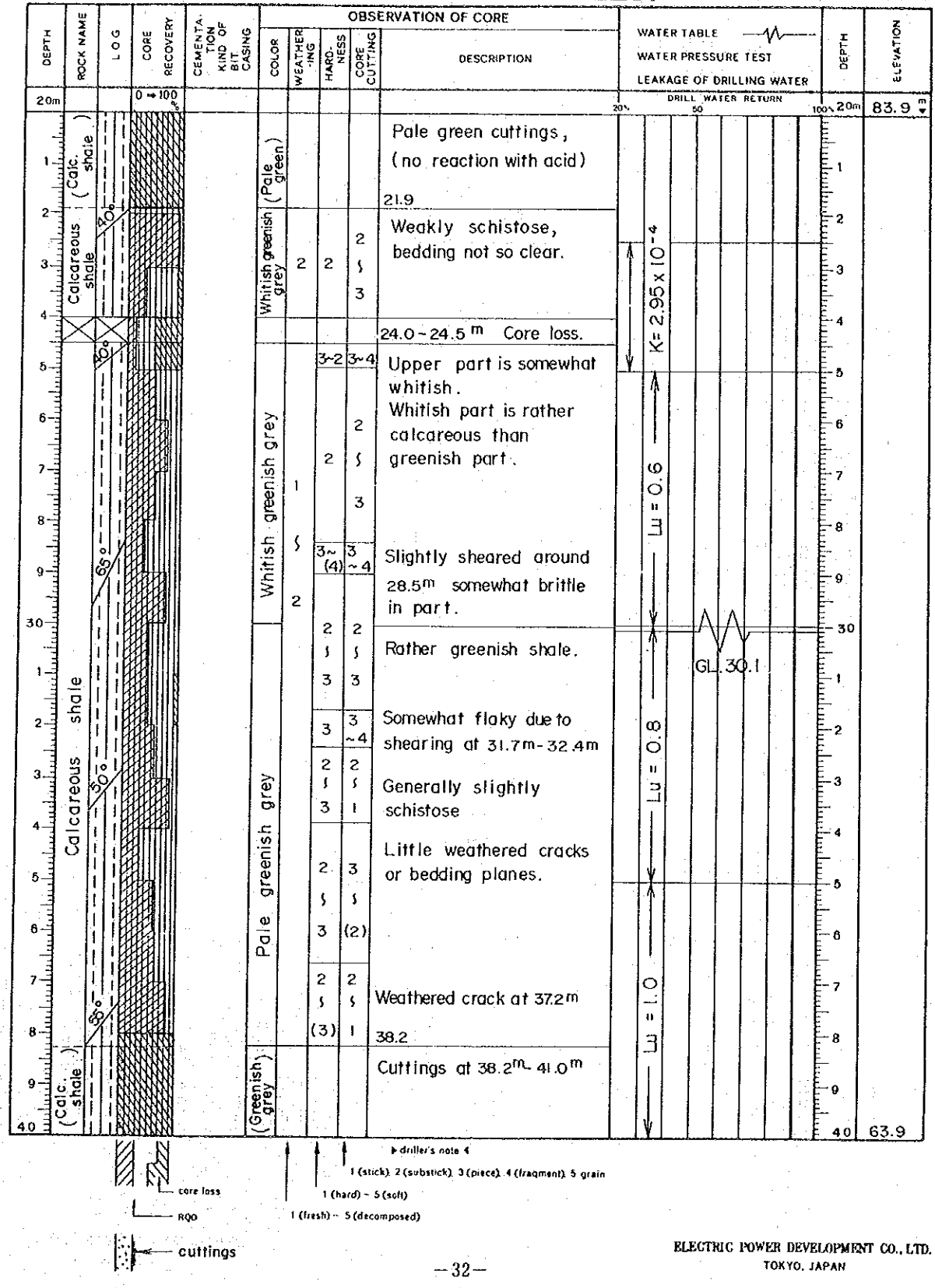


ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DR-2 (SHEET 2 OF 4)

LOCATION	Dam right bank	DEPTH OF HOLE	80.0 m	COMMENCED	Sep-10-1983
ELEVATION	103.9 m	DEPTH OF OVERBURDEN	2.0 m	COMPLETED	Oct.-14-1983
COORDINATE	1966 502.2N 355 412.9E	LENGTH OF ROCK DRILLING	78.0 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	52.95 m	LOGGED BY	M.Shibata
BEARING OF ANGLE HOLE	———	CORE RECOVERY	67.9 %		

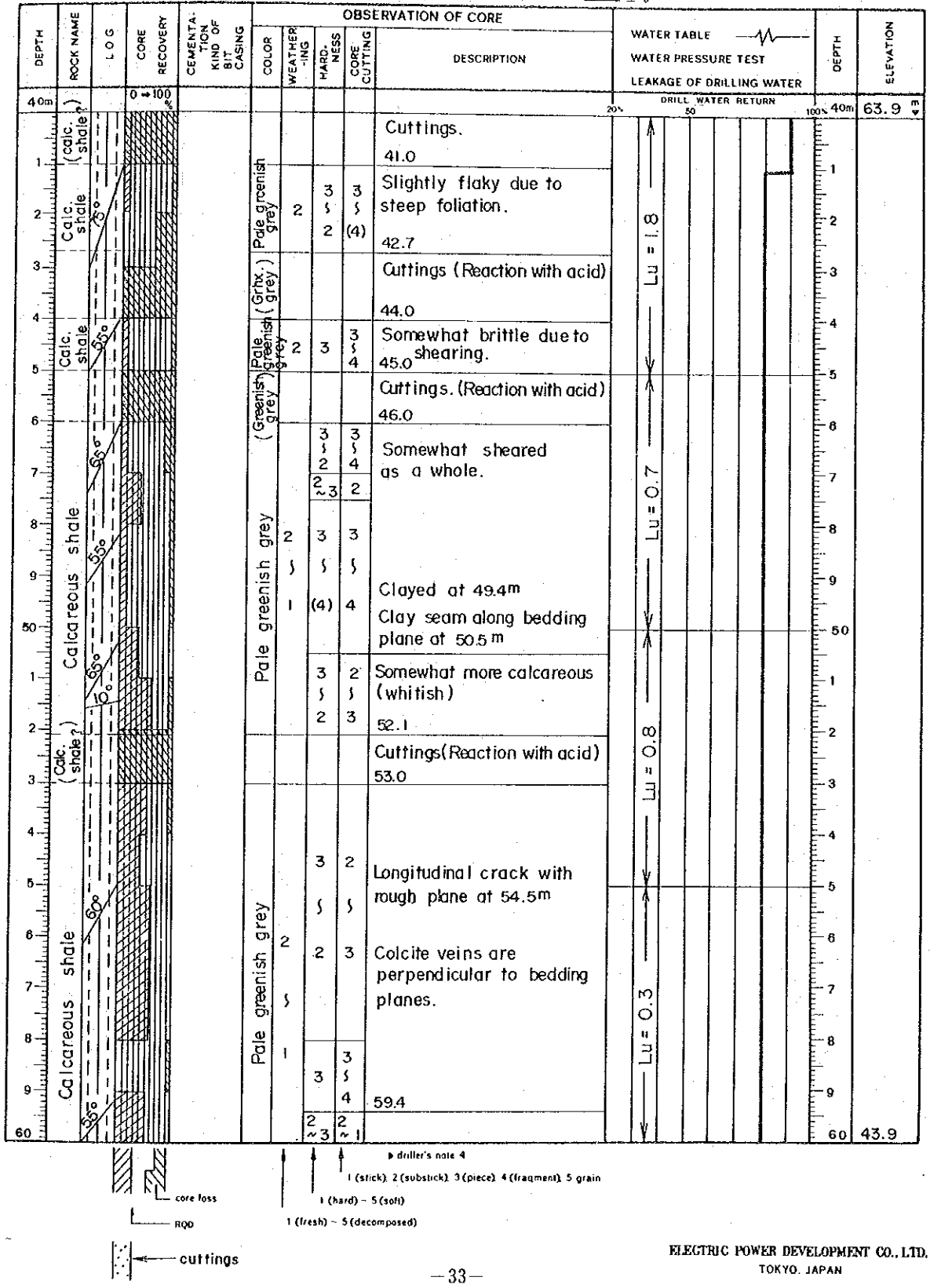


ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DR-2 (SHEET 3 OF 4)

LOCATION	Dam right bank	DEPTH OF HOLE	80 m	COMMENCED	Sep-10-1983
ELEVATION	103.9 m	DEPTH OF OVERBURDEN	2.0 m	COMPLETED	Oct.-14-1983
COORDINATE	1966502.2N 375412.9E	LENGTH OF ROCK DRILLING	78.0 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	52.95 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE		CORE RECOVERY	67.9 %		



ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DR-2 (SHEET 4 OF 4)

LOCATION	Dam right bank	DEPTH OF HOLE	80.0 m	COMMENCED	Sep. 10 - 1983
ELEVATION	103.9 m	DEPTH OF OVERBURDEN	2.0 m	COMPLETED	Oct. - 14 - 1983
COORDINATE	1966 502.2N 375 412.9E	LENGTH OF ROCK DRILLING	78.0 m	DRILLED BY	ROEM
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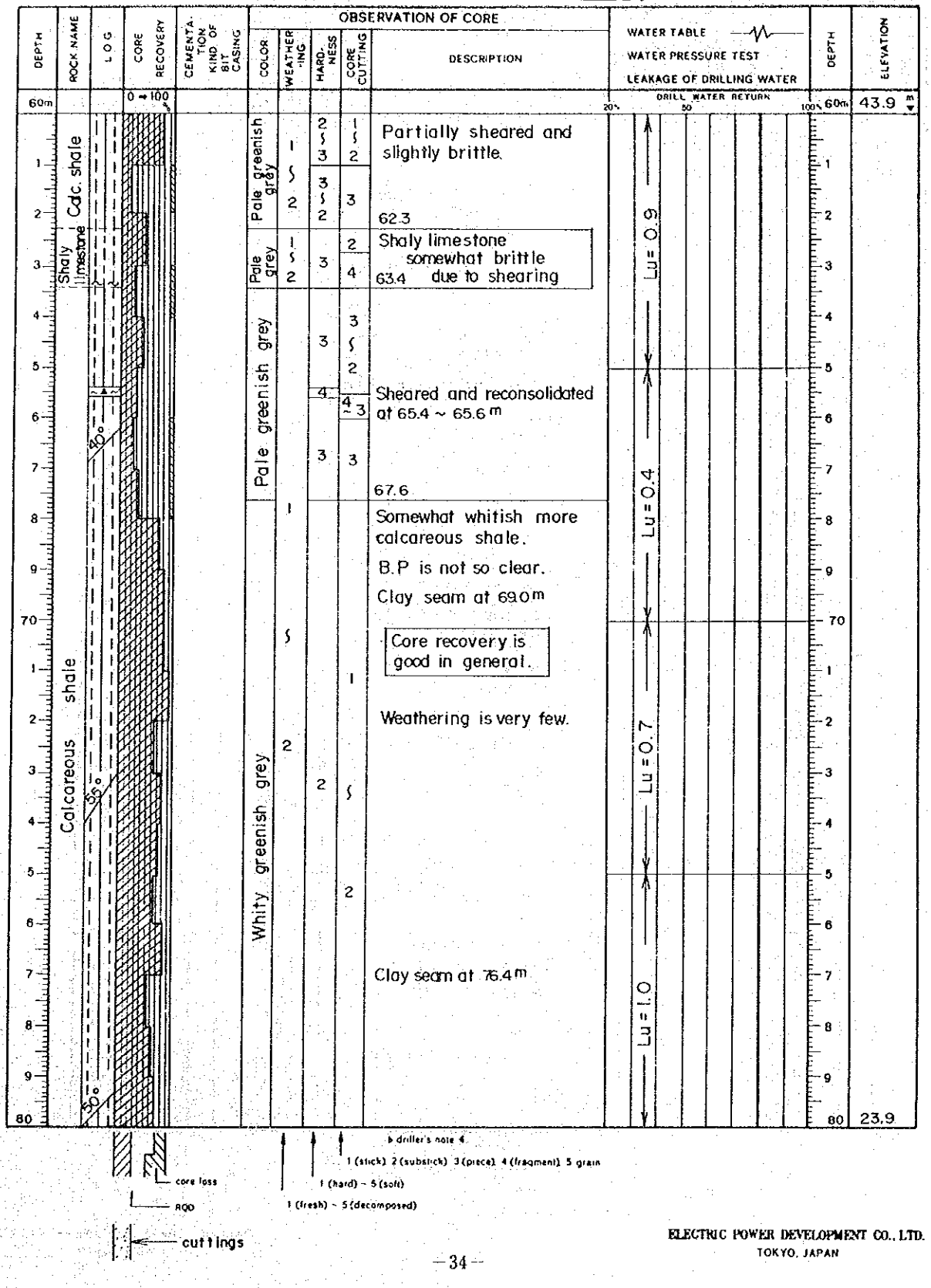
BEARING OF ANGLE HOLE		CORE RECOVERY	67.9 %		

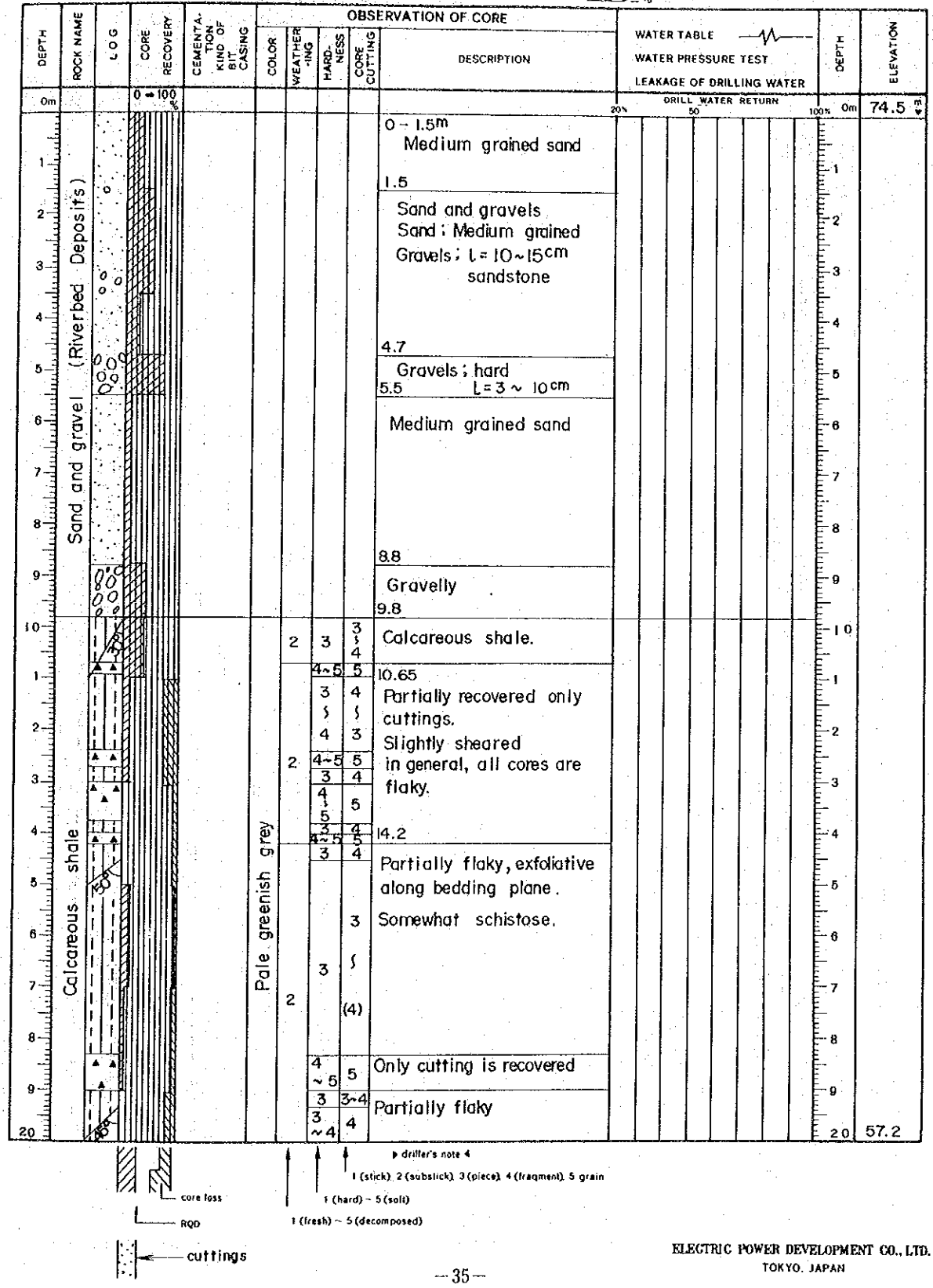


ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DU-1 (SHEET 1 OF 2)

LOCATION	Dam upstream	DEPTH OF HOLE	22.0 m	COMMENCED	– –
ELEVATION	74.5 m	DEPTH OF OVERBURDEN	9.8 m	COMPLETED	– –
COORDINATE	1966 424.9N 375 397.6E	LENGTH OF ROCK DRILLING	12.2 m	DRILLED BY	
ANGLE FROM HORIZONTAL	60°	TOTAL LENGTH OF CORE	10.6 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	S59°W	CORE RECOVERY	86.9 %		



ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DU-1 (SHEET 2 OF 2)

LOCATION	Dam upstream	DEPTH OF HOLE	22.0 m	COMMENCED	– –
ELEVATION	74.5 m	DEPTH OF OVERBURDEN	9.8 m	COMPLETED	– –
COORDINATE		LENGTH OF ROCK DRILLING	12.2 m	DRILLED BY	
ANGLE FROM HORIZONTAL	60°	TOTAL LENGTH OF CORE	10.6 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	S59°W	CORE RECOVERY	86.9 %		

DEPTH	ROCK NAME	LOG	CORE RECOVERY	CEMENTATION, KIND OF BIT, CASING	OBSERVATION OF CORE: COLOR	WEATHERING	HARDNESS	CORE CUTTING	DESCRIPTION	WATER TABLE / WATER PRESSURE TEST / LEAKAGE OF DRILLING WATER / DRILL WATER RETURN	DEPTH	ELEVATION
20m			0 ⇒ 100 %							20% 50 100%	20m	57.2 m
1	Calcareous shale	50°			Pale greenish grey	2	3 ∫ (4)	3 ∫ 4	Partially minorfolding with calcite veins		1	
2											2	55.5
									End of hole at 22m			
3											3	
4											4	
5											5	
6											6	
7											7	
8											8	
9											9	
0											0	
1											1	
2											2	
3											3	
4											4	
5											5	
6											6	
7											7	
8											8	
9											9	
0											0	

core loss
RQD
cuttings

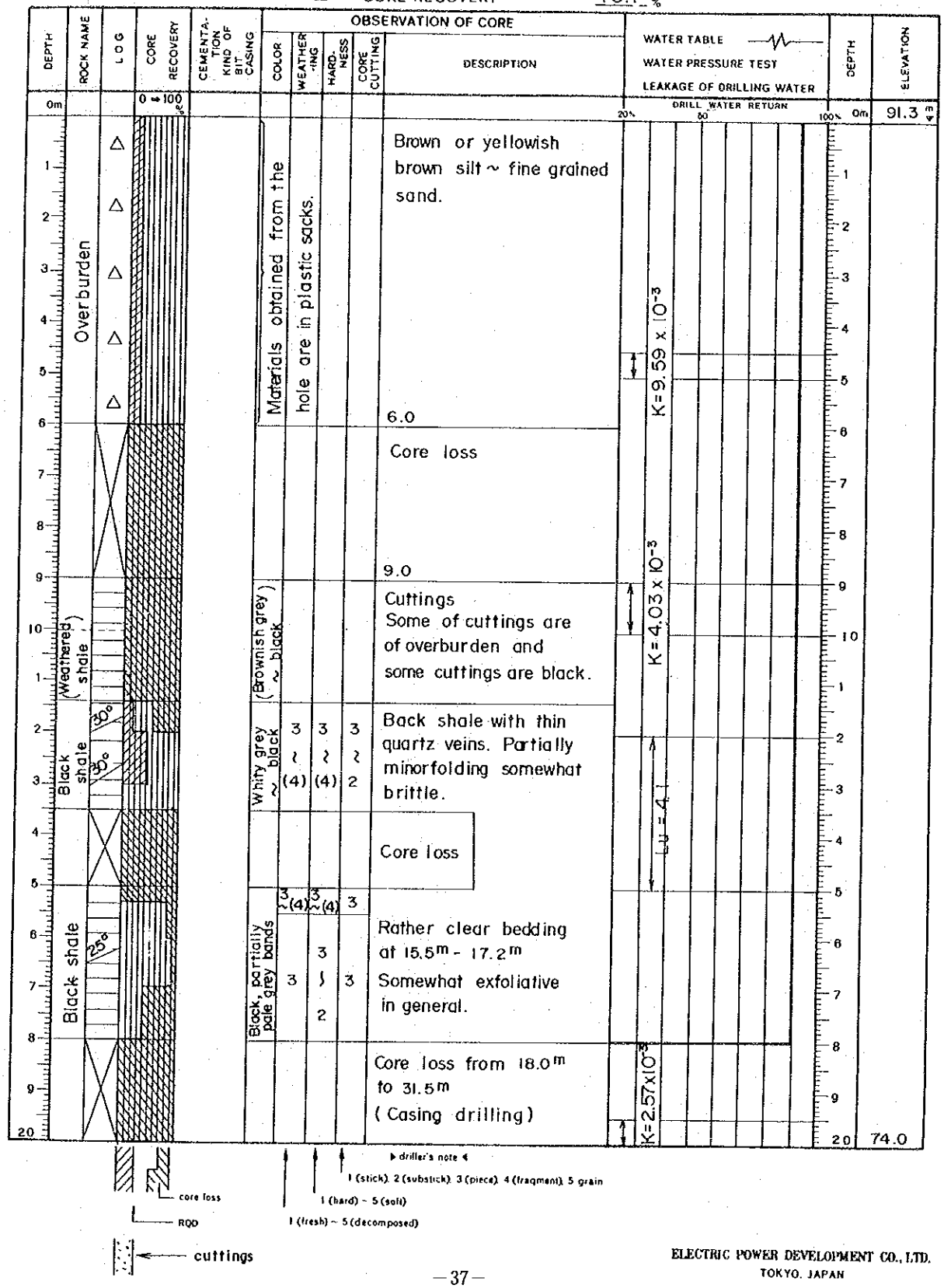
▶ driller's note ◀
1 (stick) 2 (substick) 3 (piece) 4 (fragment) 5 grain
1 (hard) ~ 5 (soft)
1 (fresh) ~ 5 (decomposed)

ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DU-2 (SHEET 1 OF 6)

LOCATION	Dam upstream	DEPTH OF HOLE	120.0 m	COMMENCED	Sep - 3 - 1983
ELEVATION	91.3 m	DEPTH OF OVERBURDEN	6.0 m	COMPLETED	Oct. - 21 - 1983
COORDINATE	1966 333.3N 375 398.2E	LENGTH OF ROCK DRILLING	114.0 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	60°	TOTAL LENGTH OF CORE	79.9 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	N31°E	CORE RECOVERY	70.1 %		

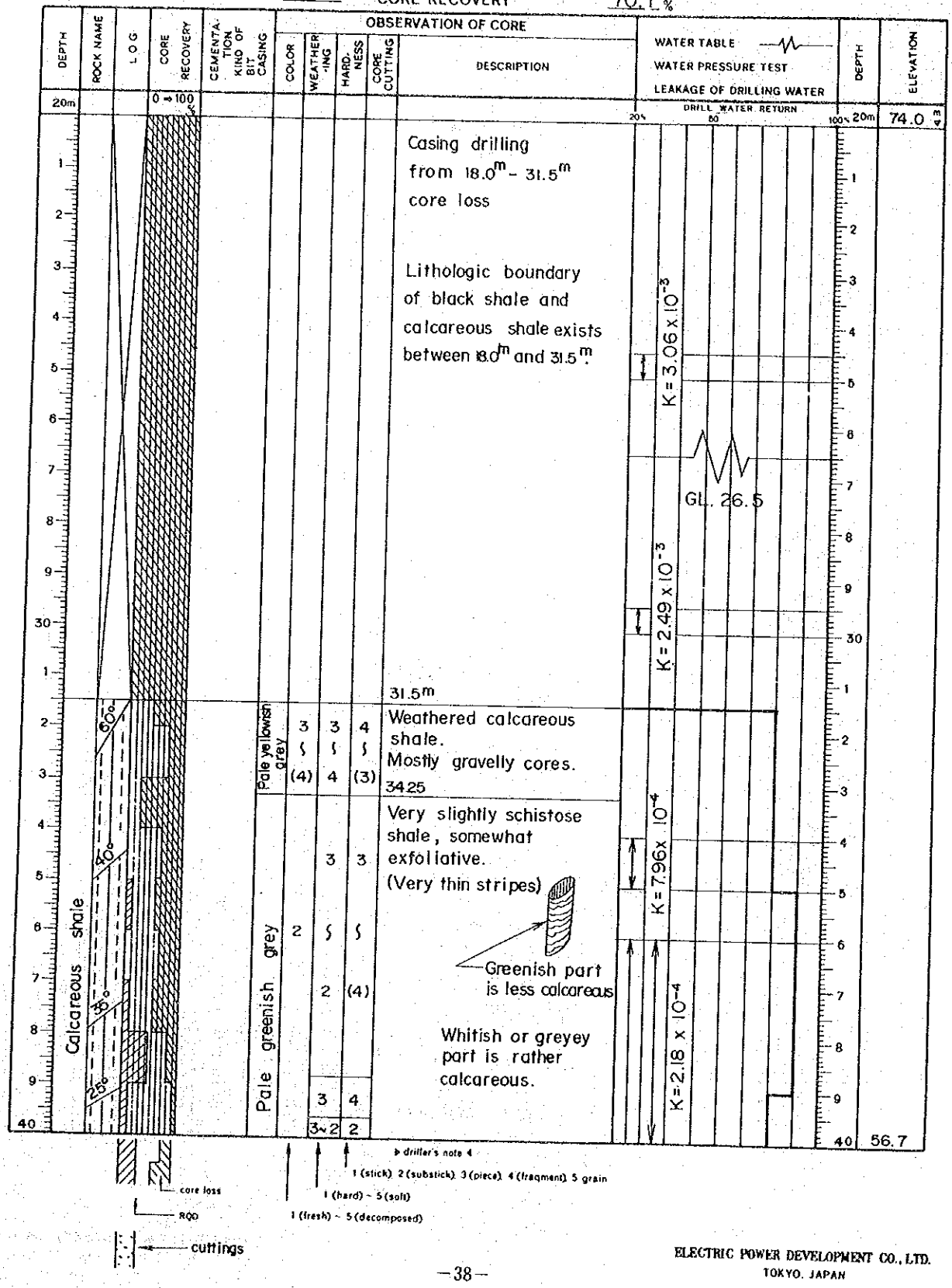


ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DU-2 (SHEET 2 OF 6)

LOCATION	Dam upstream	DEPTH OF HOLE	120.0 m	COMMENCED	Sep. - 3 - 1983
ELEVATION	91.3 m	DEPTH OF OVERBURDEN	6.0 m	COMPLETED	Oct. - 21 - 1983
COORDINATE	E66 333.3 N375 398.2 E	LENGTH OF ROCK DRILLING	114.0 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	60°	TOTAL LENGTH OF CORE	79.9 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	N31°E	CORE RECOVERY	70.1 %		



ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

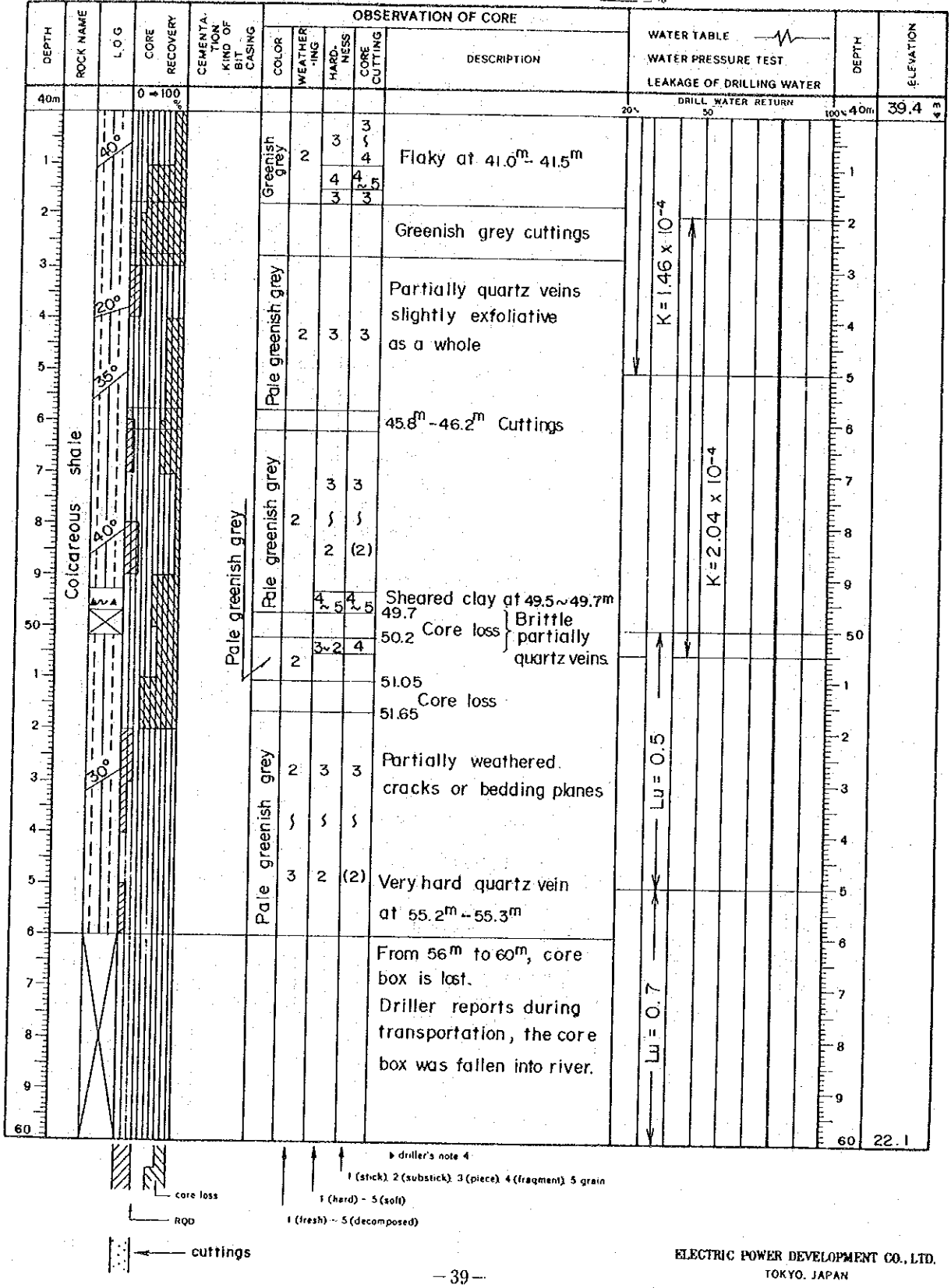
GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DU-2 (SHEET 3 OF 6)

LOCATION Dam upstream
ELEVATION 91.3 m
COORDINATE 1966333.3N 375398.2E
ANGLE FROM HORIZONTAL 60°
BEARING OF ANGLE HOLE N31E

DEPTH OF HOLE 120.0 m
DEPTH OF OVERBURDEN 6.0 m
LENGTH OF ROCK DRILLING 114.0 m
TOTAL LENGTH OF CORE 79.9 m
CORE RECOVERY 70.1 %

COMMENCED Sep. 3 - 1983
COMPLETED Oct. - 21 - 1983
DRILLED BY ROEM
LOGGED BY M. Shibata

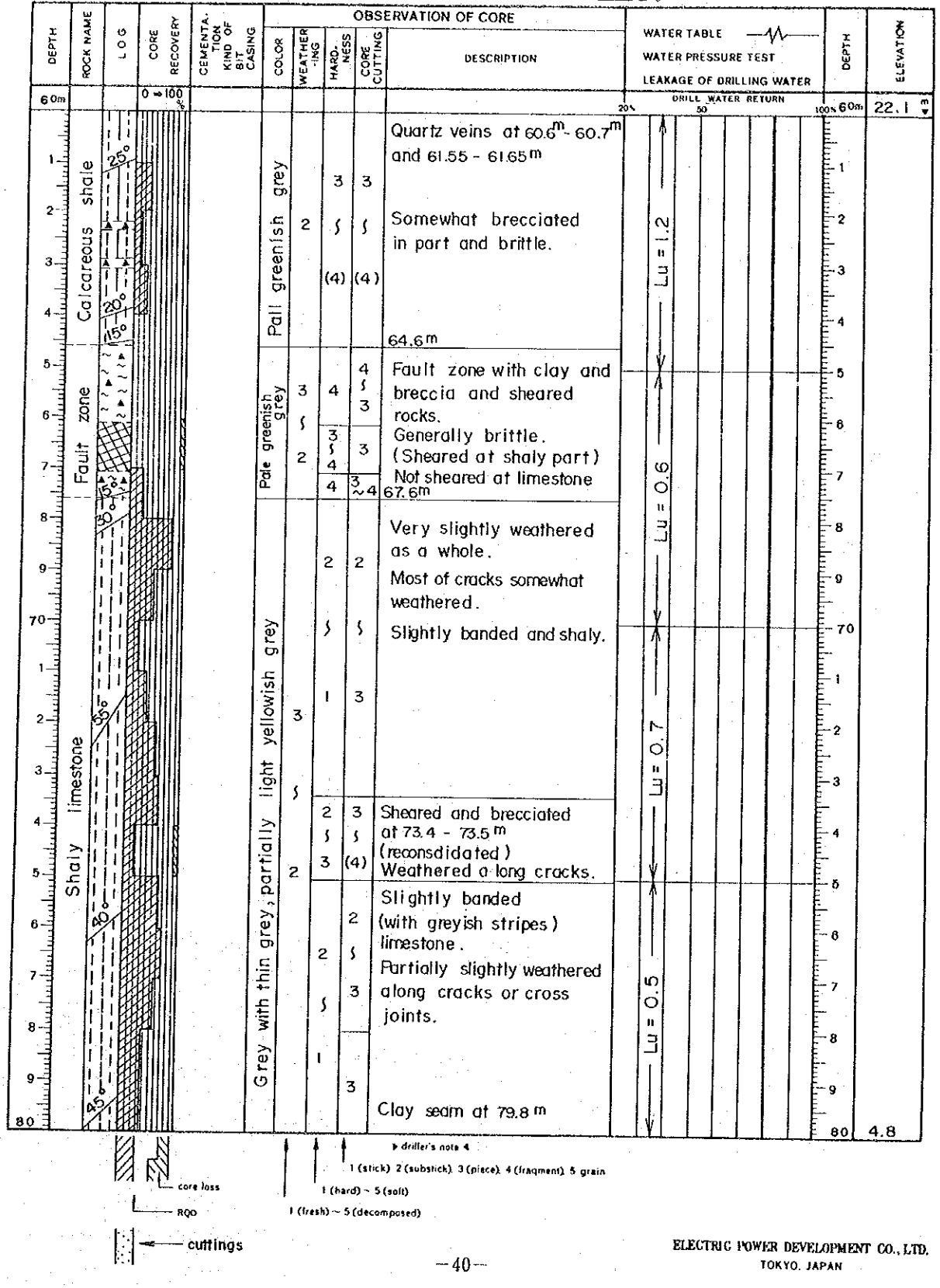


ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DU-2 (SHEET 4 OF 6)

LOCATION	Dam upstream	DEPTH OF HOLE	120.0 m	COMMENCED	Sep. - 3 - 1983
ELEVATION	91.3 m	DEPTH OF OVERBURDEN	6.0 m	COMPLETED	Oct. - 21 - 1983
COORDINATE	1966 333.3N375 398.2E	LENGTH OF ROCK DRILLING	114.0 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	60°	TOTAL LENGTH OF CORE	79.9 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	N31E	CORE RECOVERY	70.1 %		

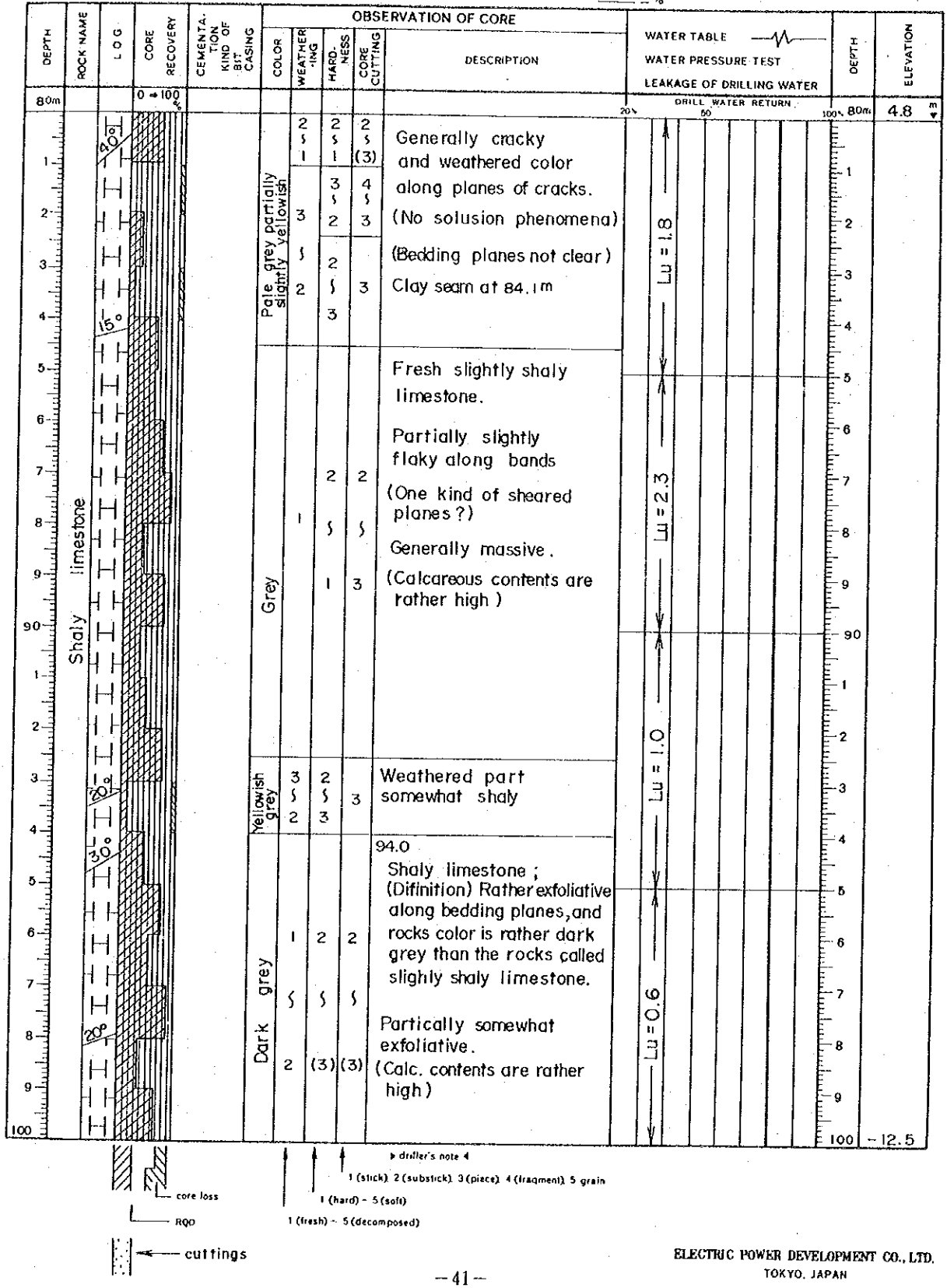


ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam. Yuam PROJECT HOLE No. DU-2 (SHEET 5 OF 6)

LOCATION	Dam upstream	DEPTH OF HOLE	120.0 m	COMMENCED	Sep. - 3 - 1983
ELEVATION	91.3 m	DEPTH OF OVERBURDEN	6.0 m	COMPLETED	Oct. - 21 - 1983
COORDINATE	1966 333.3N 375 398.2E	LENGTH OF ROCK DRILLING	114.0 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	60 °	TOTAL LENGTH OF CORE	79.9 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	N31E	CORE RECOVERY	70.1 %		

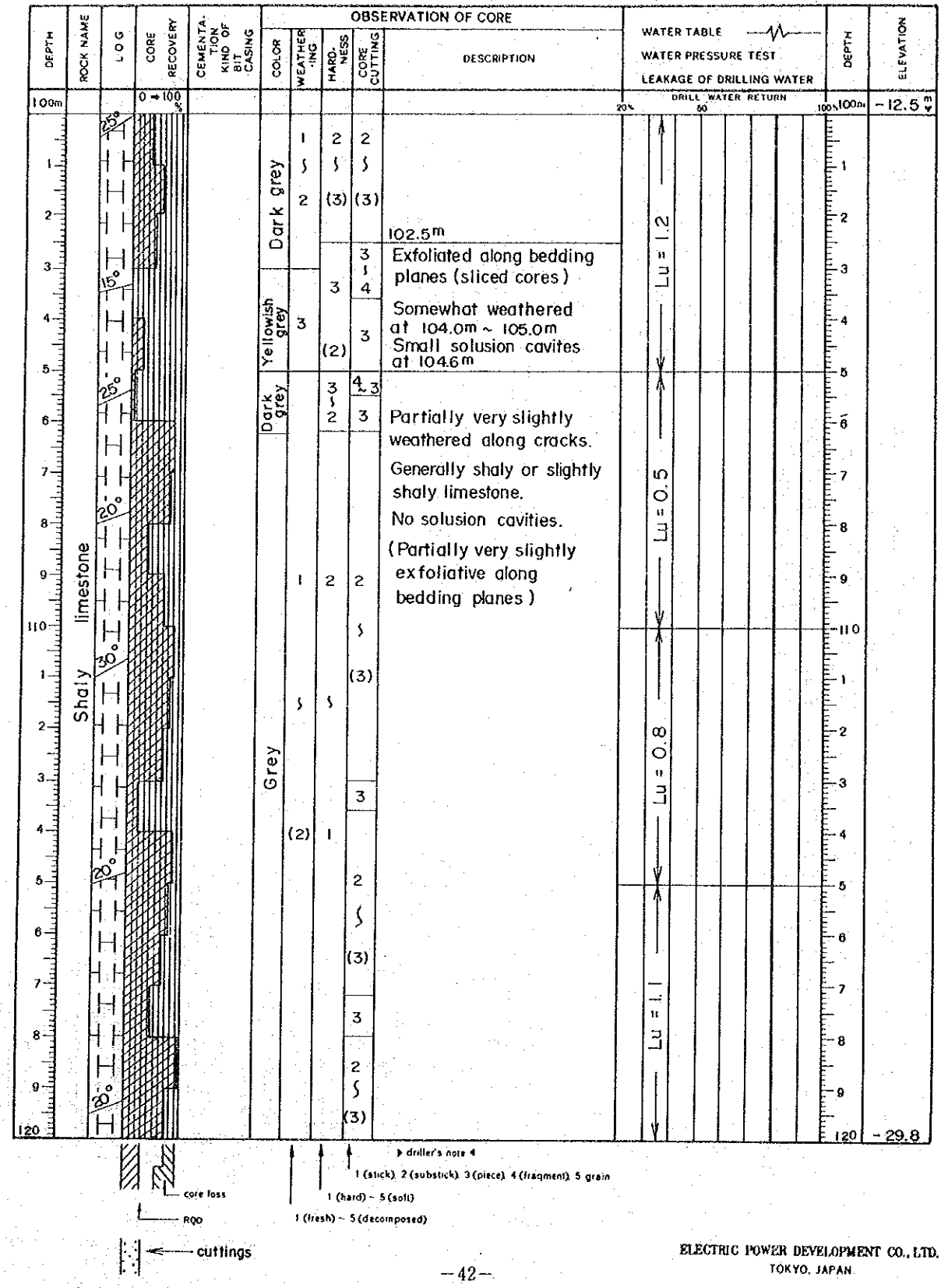


ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. DU-2 (SHEET 6 OF 6)

LOCATION	Dam upstream	DEPTH OF HOLE	120.0 m	COMMENCED	Sep - 3 -1983
ELEVATION	91.3 m	DEPTH OF OVERBURDEN	6.0 m	COMPLETED	Oct -21 -1983
COORDINATE	1966333.3N375398.2E	LENGTH OF ROCK DRILLING	114.0 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	60°	TOTAL LENGTH OF CORE	79.9 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	N31E	CORE RECOVERY	70.1 %		

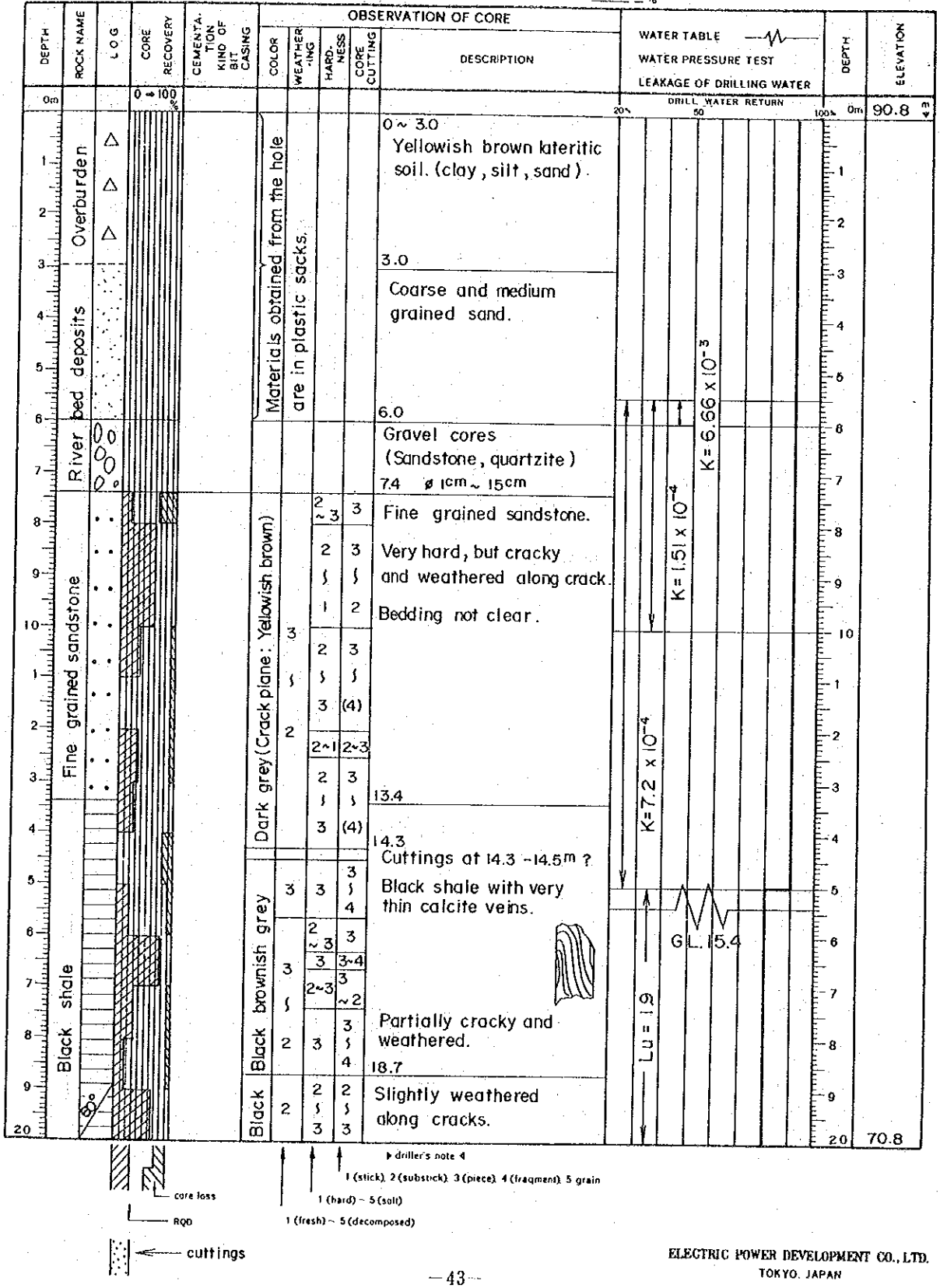


ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. P-1 (SHEET 1 OF 2)

LOCATION	Power house	DEPTH OF HOLE	40.0 m	COMMENCED	Oct.-19-1983
ELEVATION	90.8 m	DEPTH OF OVERBURDEN	7.4 m	COMPLETED	Oct.-23-1983
COORDINATE	1966 669.5N 375 088.3E	LENGTH OF ROCK DRILLING	32.6 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	31.5 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE		CORE RECOVERY	96.6 %		

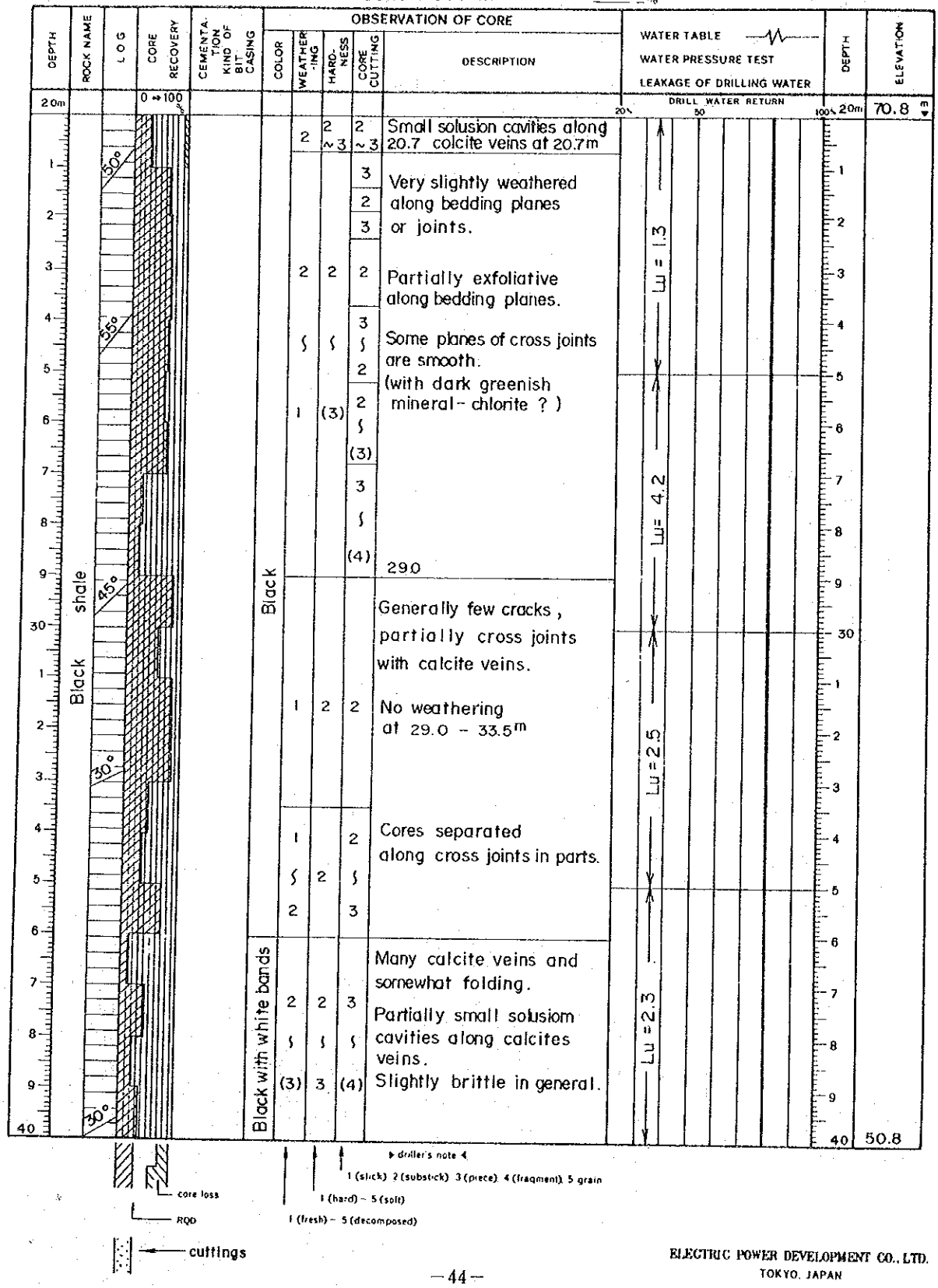


ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO, JAPAN

GEOLOGIC LOG OF DRILL HOLE

Nam Yuam PROJECT HOLE No. P-1 (SHEET 2 OF 2)

LOCATION	Power house	DEPTH OF HOLE	40.0 m	COMMENCED	Oct-19-1983
ELEVATION	90.8 m	DEPTH OF OVERBURDEN	7.4 m	COMPLETED	Oct.-23-1983
COORDINATE	966 669.5N 375 088.3E	LENGTH OF ROCK DRILLING	32.6 m	DRILLED BY	ROEM
ANGLE FROM HORIZONTAL	90°	TOTAL LENGTH OF CORE	31.5 m	LOGGED BY	M. Shibata
BEARING OF ANGLE HOLE	———	CORE RECOVERY	96.6 %		



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A 2 HYDROLOGY

1. Catchment Area of the Damsites

In this study, two damsites, i.e. site A and B were proposed for investigation. Catchment areas of both sites were measured with the available topographical maps (scale: 1/250,000, "Chiangwat Chiang Mai" and "Amphoe Li") published by U.S. Army Map Service, Far East.

Catchment area of Ban Tha Rua G.S. was also measured with the said map.

The catchment areas employed in the study were as follows.

Damsite A	:	5,920 km^2
Damsite B	:	5,810 km^2
Ban Tha Rua G.S.	:	5,770 km^2

2. Evapotranspiration

Evapotranspiration was calculated by the following two methods.

(1) Thernthwaite Method

$$E_{PT} = 0.533\ Do\ \left(\frac{10tj}{J}\right)^{a}$$

where $a = 6.75 \times 10^{-7} J^3 - 7.71 \times 10^{-5} J^2 + 1.79 \times 10^{-2} J + 0.49$

$$J = \sum_{j=1}^{12} \left(\frac{ti}{5}\right)^{1.514}$$

E_{PT} = Monthly average of daily evapotranspiration [mm/day]

Do = Daytime ratio i.e. daily daytime/12 hrs

t = Monthly average temperature [°C]

j = Month (1 - 12)

J = Indicator of Month

(2) Blaney and Criddle Method

$$E_{PT} = KCt$$

where E_{PT} = Monthly average evaporation [inch/month]

C = Ratio of monthly daytime to annual daytime

t = Monthly average temperature [°F]

K = Coefficient corresponding to kind of flora

When units are converted to metric system, the equation becomes:

$$E_{PT} = K \cdot C \cdot (45.72^{t} + 812.8)$$

In these equations, daytime ratios Do and C were obtained by the following way.

Do; based on the table below, the value at latitude 18° North was interporated.

C; given by the following figure.

Coefficient for flora (K) is 0.7 corresponding to deciduous forest in semi-dry region(1).

References

(1) Hideaki Nakano, "Forestry Hydrology" p.p.95 - 120, 1980. 3rd ed. Kyo-ritsu Press.

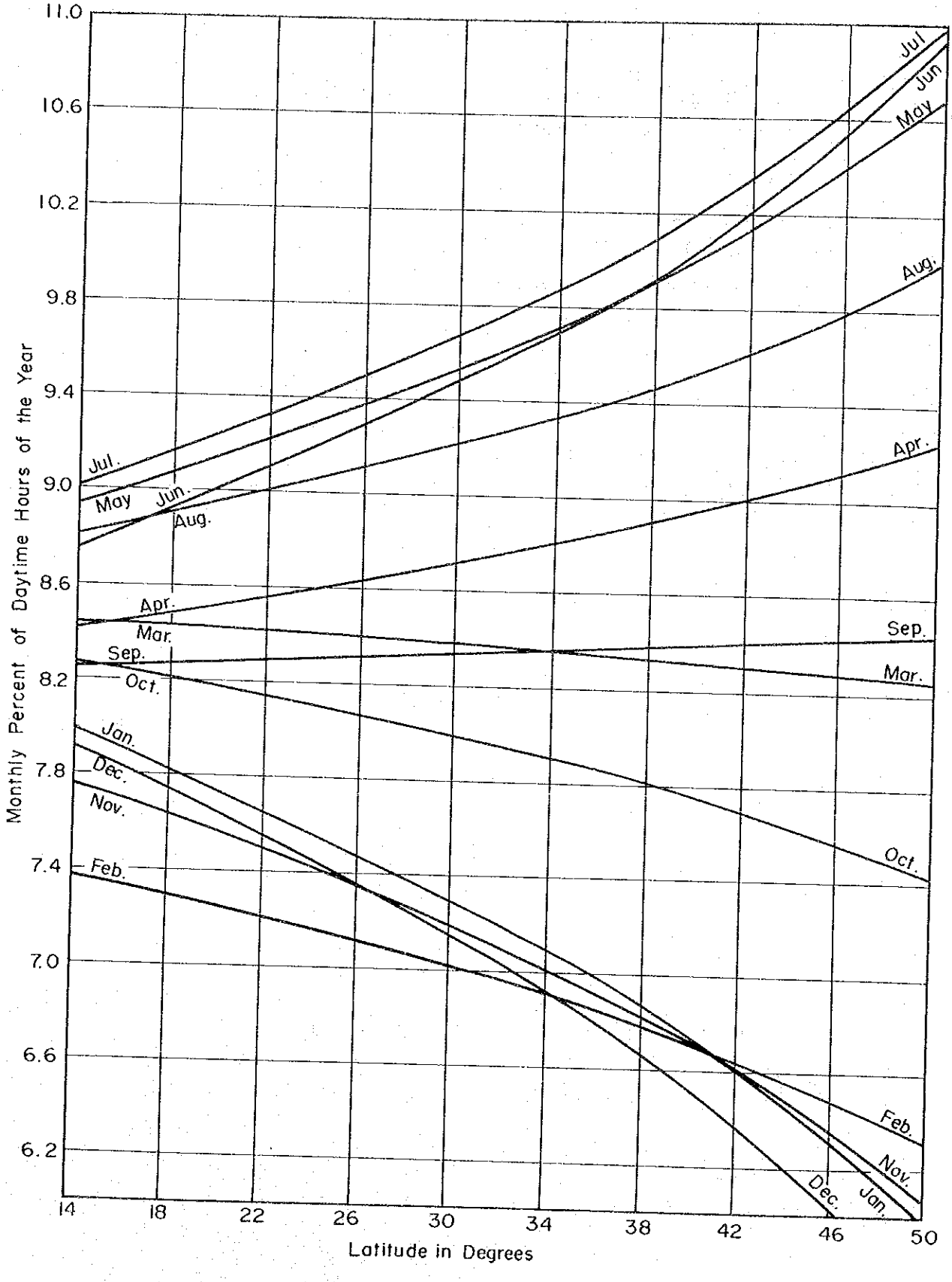

Fig. 2.1 Percent of Annual Sunshine Hours Occurring During the Indicated Month

Table 2.1 Daytime Ratio, ref. (1)

(Unit: 12 hr/day)

Lat. N. / Mon.	10	18*	20	24	26	28	30	32	34	36	38	40	42	44	46
JAN	0.965	0.929	0.920	0.899	0.889	0.878	0.867	0.855	0.843	0.830	0.817	0.802	0.787	0.770	0.752
FEB (28)	0.982	0.961	0.956	0.941	0.935	0.929	0.922	0.915	0.908	0.900	0.893	0.884	0.875	0.865	0.855
FEB (29)	0.982	0.961	0.956	0.942	0.936	0.930	0.923	0.916	0.909	0.902	0.894	0.885	0.877	0.867	0.857
MAR	1.003	1.001	1.000	0.997	0.996	0.996	0.995	0.994	0.993	0.992	0.991	0.990	0.989	0.988	0.986
APR	1.026	1.044	1.048	1.055	1.060	1.065	1.070	1.076	1.081	1.087	1.093	1.100	1.107	1.115	1.123
MAY	1.045	1.079	1.087	1.104	1.114	1.123	1.134	1.144	1.156	1.167	1.180	1.193	1.208	1.223	1.240
JUN	1.055	1.096	1.106	1.129	1.141	1.153	1.166	1.180	1.194	1.209	1.225	1.242	1.261	1.280	1.302
JUL	1.051	1.088	1.097	1.118	1.129	1.140	1.152	1.164	1.177	1.191	1.206	1.221	1.237	1.255	1.274
AUG	1.034	1.057	1.063	1.077	1.084	1.091	1.098	1.106	1.114	1.123	1.132	1.141	1.151	1.162	1.174
SEP	1.012	1.017	1.018	1.022	1.024	1.025	1.027	1.029	1.031	1.033	1.035	1.037	1.039	1.041	1.045
OCT	0.990	0.975	0.971	0.964	0.960	0.956	0.952	0.947	0.942	0.938	0.932	0.927	0.921	0.915	0.909
NOV	0.970	0.937	0.929	0.913	0.904	0.895	0.885	0.875	0.865	0.854	0.842	0.830	0.817	0.803	0.787
DEC	0.960	0.919	0.909	0.887	0.875	0.863	0.850	0.838	0.824	0.809	0.794	0.778	0.760	0.742	0.721

Note: *; Lat. 18°N. was interporated

3. Sedimentation

3.1 Geology in the project area

The project area stretches from North to South with distance of 160 km while from West to East with 30 to 50 km width, covering catchment of 6,000 km^2. In the area, rugged topography in youthfulage is widely seen.

The area is mainly composed of sedimentary rock of Paleozoic and Mesozoic age, and granite of Mesozoic age. The ground is covered in most area by laterite which is generally formed by weathering in humid and high temperature region.

3.2 Sediment

Due to the laterite covering the ground, eroded and flowing material in the river is very fine. In other words, the river flow contains suspended load. On the other hand, since the river gradient is rather mild and river flow is relatively slow, bed material would not be very involved in the flow. Measurement of suspended load has been conducted at three gaging stations along the river. But one gaging station was omitted because it measures on a tributary. Instead, a measurement on the Moei river was taken into account.

(1) Density of sediment deposit

The following equation gives an average density of sediment deposit after t years.

$$W_{av.} = W_1 + 0.434\ K\ \left[\frac{t}{t-1}(\ln t - 1)\right] \qquad \text{ref.(1)}$$

where $W_{av.}$ = Average density of sediment deposit after t years.

W_1 = Initial density of sediment deposit shown in the table below.

K = Coefficient

t = Years

Table 3.1 Initial Density and Coefficient

(Unit: lb/ft^3)

Reservoir Operation	Sand (>0.05 mm)		Silt (0.005 to 0.05 mm)		Clay (0.005 mm)	
	W_1	K	W_1	K	W_1	K
Sediment always submerged or nearly submerged	93	0	65	5.7	30	16.0
Normally a moderate reservoir drawdown	93	0	74	2.7	46	10.7
Normally a considerable reservoir drawdown	93	0	79	1.0	60	6.0
Reservoir normally empty	93	0	82	0.0	78	0.0

For a hundred year sedimentation, the following densities were derived

Table 3.2 Average Density after 100 years

(Unit: gr/cm^3)

Reservoir Operation	Sand	Silt	Clay
	W_{100}	W_{100}	W_{100}
Sediment always submerged or nearly submerged	1.490	1.185	0.886
Normally a moderate reservoir drawdown	1.490	1.254	1.008
Normally a considerable reservoir drawdown	1.490	1.291	1.113
Reservoir normally empty	1.490	1.313	1.249

In this study stage, no information is available for composition of sediment deposit in Nam Yuam reservoir. Therefore, an average figure of the said densities could be employed, i.e. 1.30 gr/cm^3.

(2) Estimation of sediment

Using the average density derived above, the suspended load measured in weight at gaging stations was converted to load in volume. At the same time the amount of load was expressed by form of specific discharge.

In addition, bed load was considered, referring other report. The report of Lower Quae Yai Environmental and Ecological Invistigation mentiones 10% of bed load against suspended load in terms of volume, while the Feasibility Study Report of Upper Quae Yai mentiones 20% thereof. In this report, thus, it is decided to consider 20% of bed load against suspended load in terms of volume.

Consequently, following sediments are estimated at each gaging stations.

Sop Han	(C.A. = 2,496 km^2)	136.2 $m^3/km^2/yr$
Ban Tha Rua	(C.A. = 5,770 km^2)	109.6 $m^3/km^2/yr$
Tha Song Yang	(C.A. = 8,360 km^2)	196.9 $m^3/km^2/yr$

Finally the specific sediment discharge of 140 $m^3/km^2/yr$ which is conservatively obtained by enlarging the figure at Sop Han has been adopted in this study.
Therefore, the total amount of sediment deposit is estimated to be 82.9×10^6 m^3

$$140 \times 5,920 \times 100 = 82.9 \times 10^6$$

This sediment occupies only 18.6% of total storage volume of the reservoir. Assuming horizontal surface of deposit, sediment level becomes EL.129.0 m.

References

(1) Davis, Sorensen "Handbook of Applied Hydraulics" McGraw-Hill, 1969

(2) SETEC, "Environmental and Ecological Investigation of L.Q.Y. Project" Vol.II : Main Report, 1978. Aug.

(3) JICA, "Feasibility Study Report of U.Q.Y. Project" Vol.I : Main Report, 1980 Jun.

4. Generation of Runoff Data by Tank Model

4.1 Purpose

Generation of runoff data of Yuam river aimed to examine reasonability of the runoff data which was actually observed and employed as a basic information in energy computation.

4.2 Observed data utilized in the generation

The observed daily runoff data collected at Ban Tha Rua was available for eleven years from 1970 to 1980, while daily rainfall was observed at Mae Saviang for thirty-one years from 1950 to 1980 and other four observatories, i.e. Ban Tha Rua, Chom Chaeng, Sop Han and Mae La Luang for fourteen years or so.

In the generating process, however, those four rainfall observatories were not taken into consideration because the observing periods are much shorter than of Mae Saviang, and most of the periods are overlapping with the period of runoff data at Ban Tha Rua, thus no point to be used in generating the runoff of Yuam river. Consequently runoff data was generated on the basis of the thirty-one year daily rainfall at Mae Sariang which overlaps for the full period of eleven years of daily runoff at Ban Tha Rua and, in addition, extends twenty years more to the past till 1950.

The generating model, i.e. the tank model, was first adjusted during the overlapping period and then generated the runoff of the river taking the daily rainfall as input.

4.3 Tank model

1) General

Tank model is one method of runoff analysis, being widely adopted in the world. Tank model applicable to both flood and daily runoff analysis can estimate runoff of a river by taking rainfall as input. Basically the model is composed of several tanks combined each other in series or parallel, each tank of which has outlets in the bottom or side corresponding to seepage to the ground or discharge to a river. The conceptional illustration is given Fig. 4.1(a).

Function of tank model is explained as follows, taking simplest component (one tank with two outlets in the bottom and side) as an example. See Fig. 4.1(b).

In the model, section of all tanks is 1, thus storage volume can be simply expressed by height of the water stored in the tank. All the inputs and outputs are considered in time series and expressed by unit of millimeter (mm).

Rainfall	$\{x_n\}$	
Storage	$\{X_n\}$	
Discharge	$\{y_n\}$	
Seepage	$\{z_n\}$	$n = 1, 2, 3, \cdots\cdots$

The outlets equipped in the side and bottom have respective coefficient α and β adjusting the discharge or seepage rate. The side outlet is usually equipped above the bottom with certain distance H which also enables to adjust the discharge and seepage rate.

The output from the tank can be expressed as follows.

$$y_n = \begin{cases} 0 & \text{if } 0 \leq Xn \leq H \\ \alpha(Xn - H) & \text{if } H < Xn \end{cases}$$

$$z_n = \beta Xn$$

Considering the process in time series, time n and n+1, as shown Fig. 4.1(c), outputs are then expressed in the following way.

time n;

$y_n = \alpha(Xn - H)$, since Xn>H in the figure

$z_n = \beta Xn$

then

$X'n = Xn - y_n - z_n$

time n+1;

$X_{n+1} = X'n + x_{n+1}$

$y_{n+1} = \alpha(X_{n+1} - H)$

$z_{n+1} = \beta X_{n+1}$

then

$X'_{n+1} = X_{n+1} - y_{n+1} - z_{n+1}$

This process is repeated afterwards as time proceeds.

In ordinary tank model shown in Fig. 4.1(a), the said tanks are combined each other vertically in series. In such case, discharge to a river is summation of all the output from the side outlets, while output from the bottom outlet is regarded as seepage to the ground, which is trapped in the lower tank.

Structure of the ordinary tank model is also understood on the analogy of real structure of the ground. Fig. 4.2 shows the correspondence between them.

Rainfall falls into the top tank. Lower tanks receive the water coming out of the upper tank through the bottom outlet. On the other hand, a part of water stored in each tank is discharged to a river through the side outlet. This process is seemed resemble to the real structure of the ground shown in left-hand side, figure (a).

Rainfall falling on the surface of the ground is partially discharged immediately, while the rest seepages to the ground. Outflow from the side outlet of each tank shown in the figure (b) can be considered discharge from each permeable layer of the ground as shown in the figure (a). On the other hand outflow from the bottom outlet of each tank can be thought infiltration from upper permeable layer to lower permeable layer. In the model, outlets of lower tanks are made narrower, i.e. smaller coefficient α or β, because discharge rates in real situation are smaller in lower layers.

This model can well reflect variety of discharge pattern resulted from rainfall pattern. For example, continuous rainfall could cause floods, even if the rainfall is less intensified, while highly intensified rainfall could cause floods even if the whole amount of precipitation is small. In this tank model, if the rainfall continues at a rate exceeding the infiltration rate of the bottom outlet of the top tank, storage in the top tank increases gradually and it causes a large amount of discharge from the top tank where side outlet is wide and enables to release water quickly. If the rainfall occured in short period with high intensity, it also causes a large amount of discharge because storage in the top tank increases rapidly and most of the water trapped in the tank is released from the side outlet.

Generally speaking, if the tank model is composed of three or four tanks combined vertically in series, the top tank is considered corresponding to surface runoff, the second tank is to be subsurface flow and the third and fourth tanks are to be base flow. The tank model where each tank has differet discharge rate, α and β, is, thus, considered to represent the actual physical characteristics of the phenomenon.

Problem of the tank model is to decide the parameters of the model. As seen in the previous figures, the model

consists of several tanks and each tank has parameters of outflow rate α and β and the distance of the side outlet from the bottom. These parameters have to be decided by trial and error, namely taking rainfall data as input, the parameters are so adjusted that the model as a whole can generate runoff well-matched to the observed runoff.

2) Tank model considered in the study

Tank model has variety in its structure, reflecting basin condition. Following three types were considered in this study.

(i) Ordinary series combination of four tanks
(ab. ordinary model, see Fig. 4.3(a))

(ii) Ordinary model equipped with soil moisture function in the top tank
(ab. soil moisture model, see Fig. 4.3(b))

(iii) Parallel combination of four soil moisture models
(ab. 4 x 4 model, see Fig. 4.3(c))

It is generally said that the ordinary model is suitable for such region that climate is mild and there is moderate rainfall throughout a year rendering the ground always wet. On the other hand, the soil moisture model is said appropriate for such region where long dry season exists and thus the ground becomes dry for certain period in a year. If the dry condition of climate is much severer, the 4x4 model is considered suitable.

All the simulation by these three models had been conducted by computer and the soil moisture model was eventually employed in analysis in this study.

3) Soil moisture model

Fig. 4.4 shows detail of the soil moisture function equipped in the top tank.

The soil moisture function consists of two components, the primary and the secondary, which have saturation capacity of S1 and S2, respecttively Symbols appearing in the figure have the following meanings.

S1: Saturation Capacity of the primary soil moisture function

S2: Saturation Capacity of the secondary soil moisture function

XP: Actual Storage in the primary soil moisture function

XS: Actual Storage in the secondary soil moisture function

XF: Free Water stored above the primary soil moisture function, learing the primary function full.

$$XA = XP + XF$$

$$T1 = K1\left(1 - \frac{XP}{S1}\right)$$

$$T2 = K2\left(\frac{XP}{S1} - \frac{XS}{S2}\right)$$

Rainfall is accumulated into XA. If XA is less than S1, whole XA is considered XP. If XA is greater than S1, XP is saturated (XP=S1) and the rest is considered free water (XF=XA-S1). Thus, seepage and discharge from the top tank is caused by the free water XF.

In additrion to the ordinary process of the tank model, this model allows water to move between S1 and S2, and between the top tank and the second tank. It is shown in Fig. 4.4 (3). If S1 portion is not saturated and there is free water left in the second tank, water is supplyed to the S1 portion from the second tank. This water movement is expressed by the equation below.

$$T1 = K1(1 - \frac{XP}{S1})$$

where K1 is a coefficient.

As seen in the equation, water moves only from the second tank to the S1 portion in proportion to XP/S1 which is relative humidity of the S1 portion.

On the other hand, water moves between S1 and S2 portions in a manner expressed by the following equation;

$$T2 = K2(\frac{XP}{S1} - \frac{XS}{S2})$$

If T2 is positive, water moves from the second to the top tank, on the contrary if T2 is negative, water moves from the top to the second tank. This means, in other words, water moves from dry portion to wet portion in proportion to the difference of relative humidities between the two portions.

As described above, the soil moisture function can be controlled by the four parameters, i.e. S1, S2, K1, K2.

Fig. 4.5 shows the soil moisture model with the parameters which were finally employed in the analysis. As seen in the figure, there are totally eighteen (18) parameters to be decided. These parameters were decided by trial and error. That is, under certain value of parameters given, runoff was generated by taking Mae Saviang rainfall as input, and hydrograph was then synthesized. Comparing these synthetic hydrograph with the observed hydrograph at Ban Tha Rua, parameters had been adjusted little by little so as to make the synthetic hydrograph more fit to observed.

Fig. 4.6 gives the result, where solid line in the observed hydrograph and dot line is the synthetic one.

Based on the synthetic hydrograph, periodic feature of Yuam river was studyed by spectlum analysis.

References

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(2) Sugawara, M., Ozaki, E., Watanabe, I. & Katsuyama, Y.: "On A Method of Forecasting The Daily Discharge of The Mae Nam Chao Phraya and Its Tributaries at Several Points by Means of Tank Model", Research Notes of The National Research Center for Disaster Prevention No.24, July 1976.

(3) Sugawara, M., Ozaki, E., Watanabe, I. & Katsuyama, Y.: "Tank Model and Its Application to Bird Creek, Wollombi Brook, Bikin River, Kitsu River, Sanaga River and Nam Mune", Research Notes of The National Research Center for Disaster Prevention No.11, June 1974.

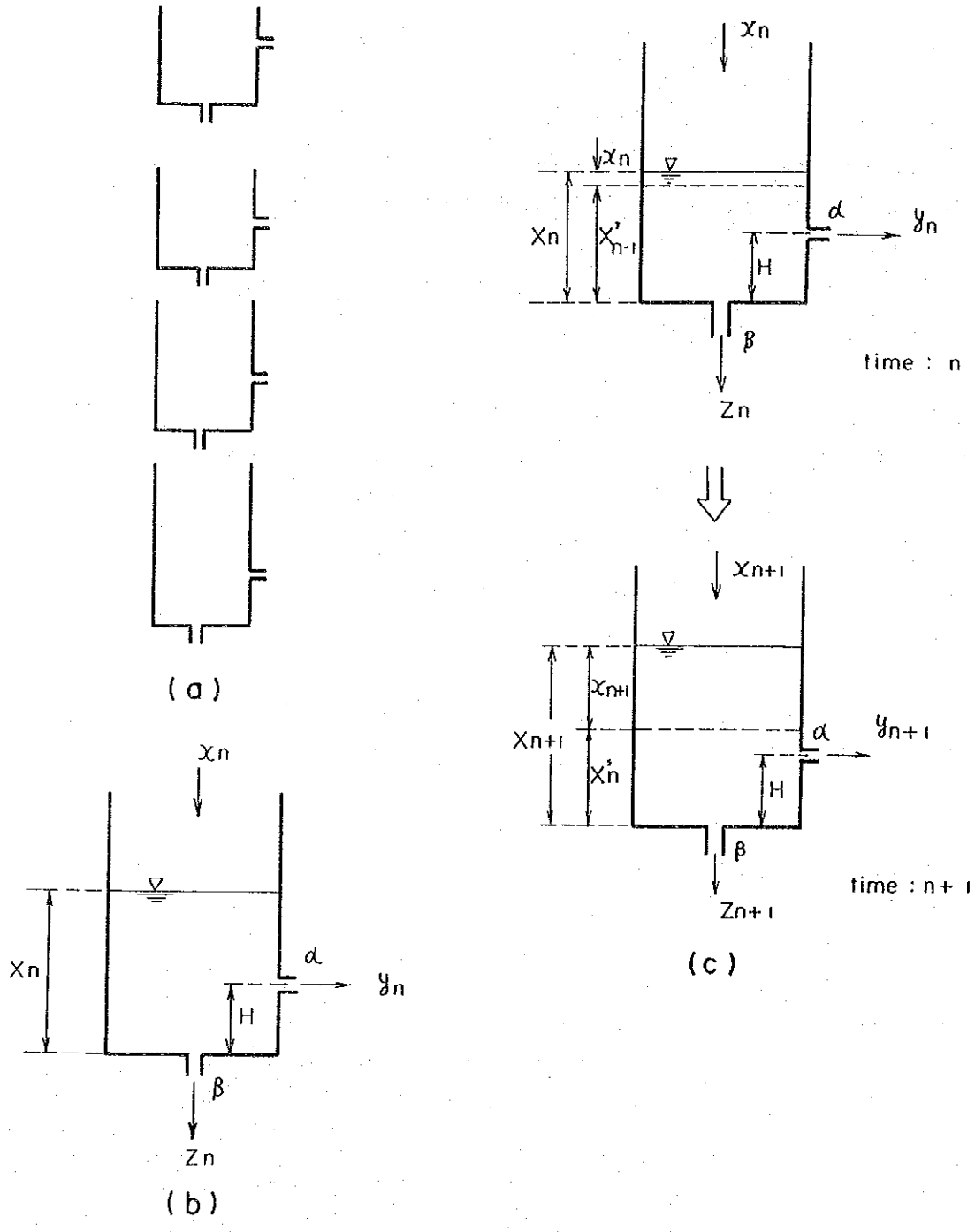


Fig. 4.1 Tank Model, Conceptional Illustration

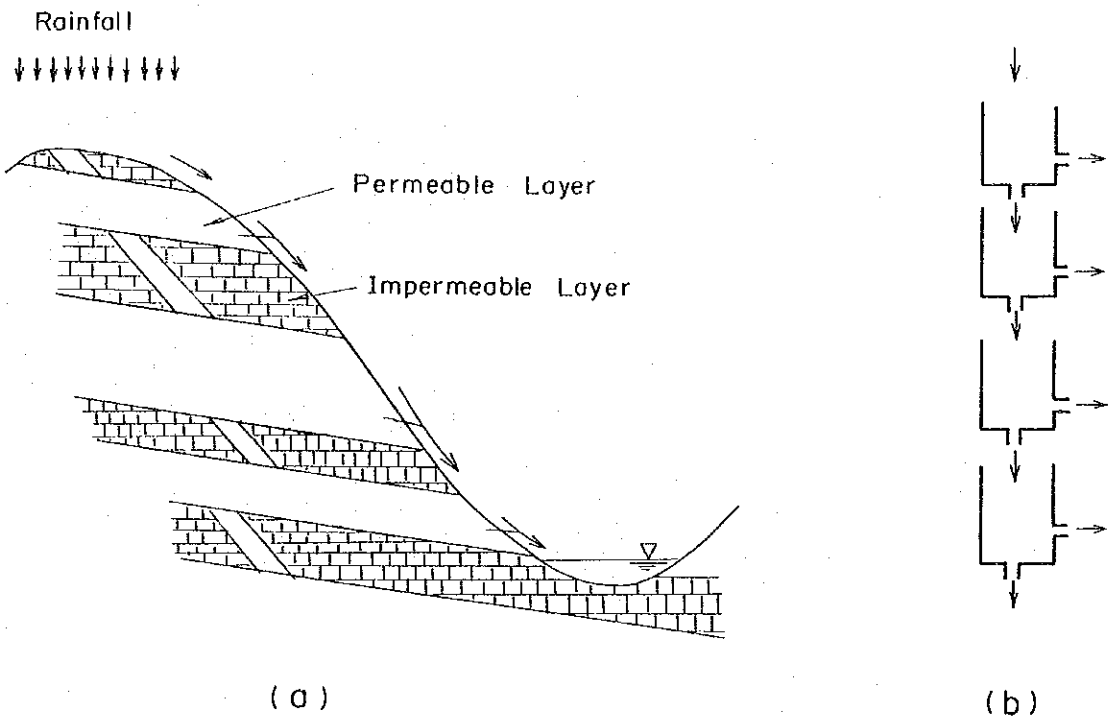


Fig. 4.2 Tank Model, Analogy to the Ground

Fig. 4-3 Estimated and Observed Runoff of Yuam River

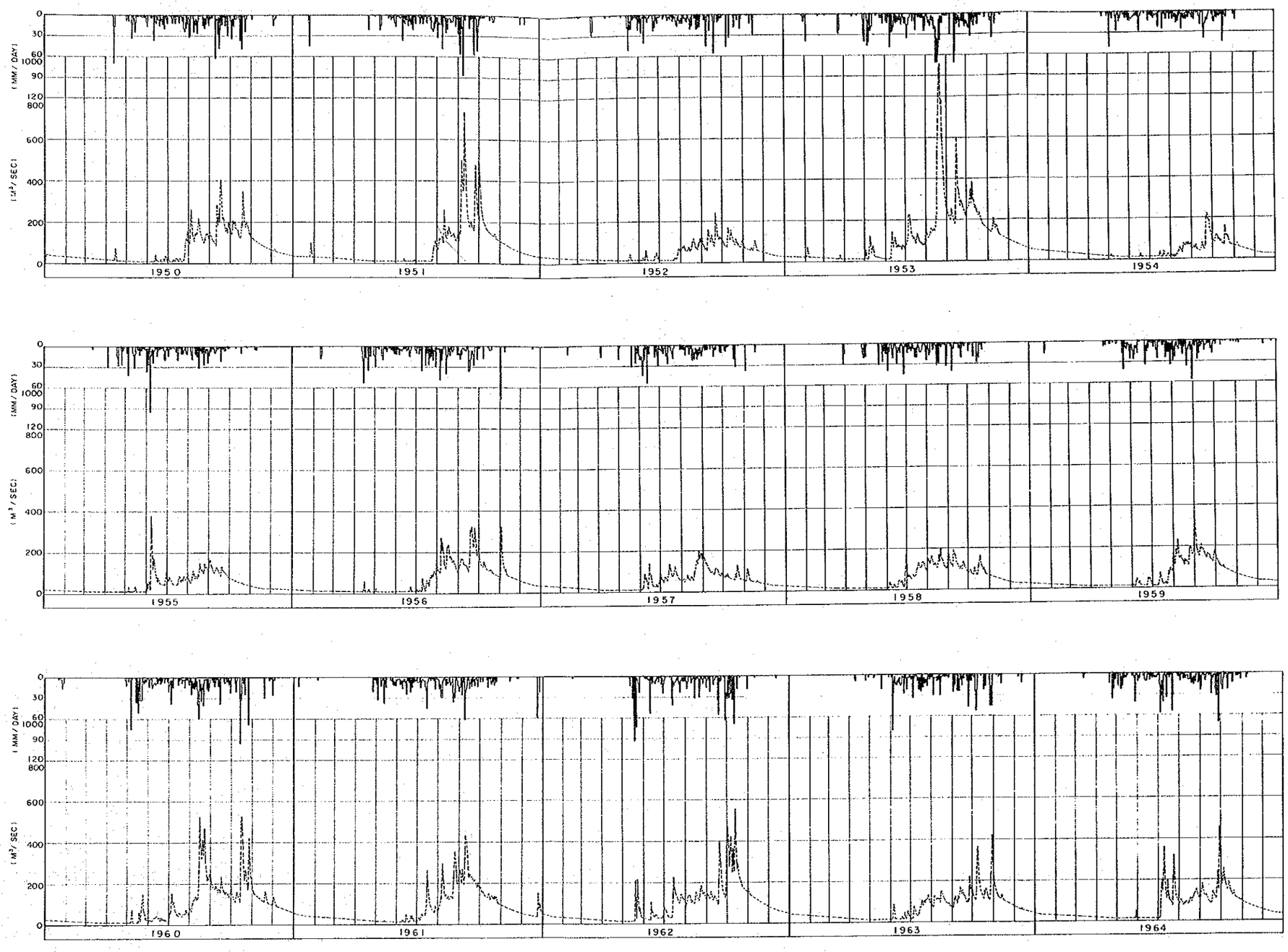
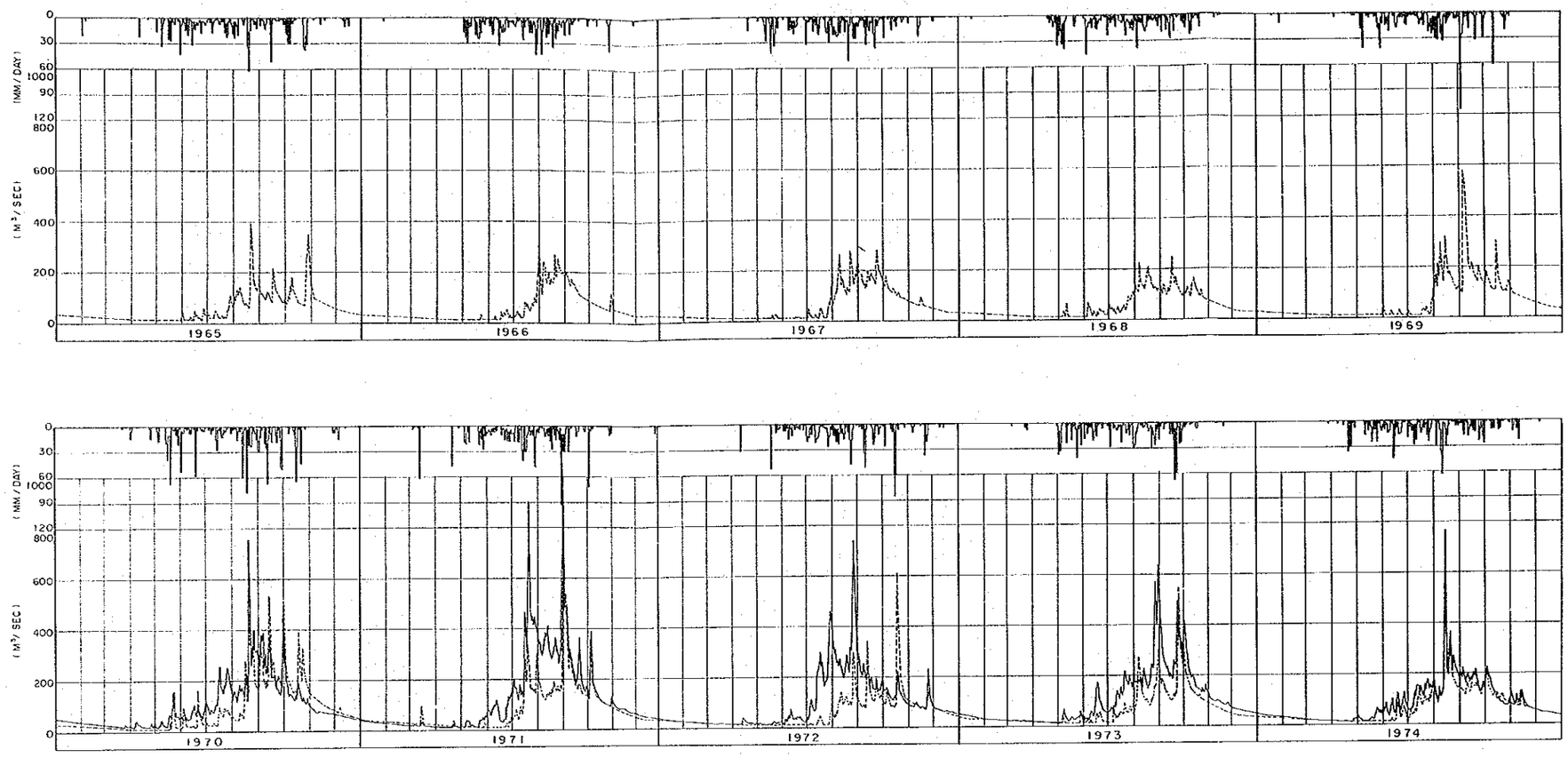
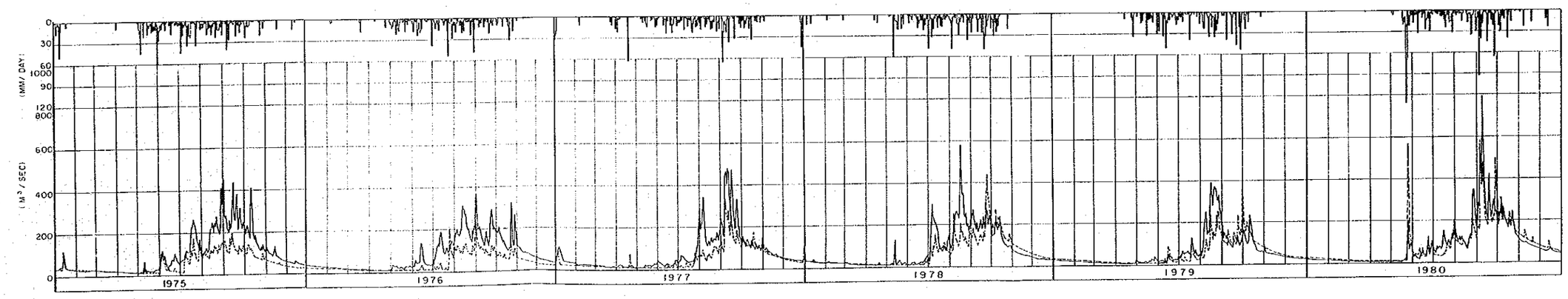
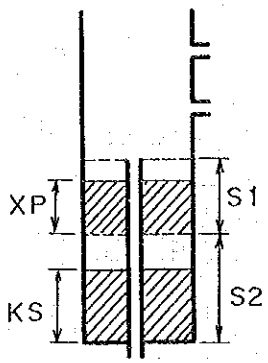


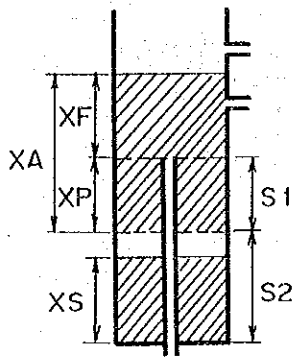
Fig. 4-3 Estimated and Observed Runoff of Yuam River (cont'd.)



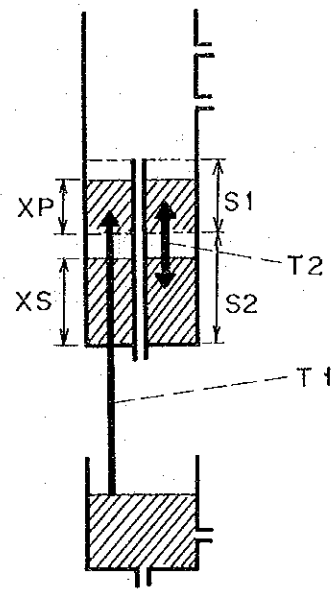




(1)



(2)



$$T1 = K1\left(1 - \frac{XP}{S1}\right)$$

$$T2 = K2\left(\frac{XP}{S1} - \frac{XS}{S2}\right)$$

(3)

S1 : Saturation Capacity of the primary soil moisture function

S2 : Saturation Capacity of the secondary soil moisture function

XP : Actual Storage in the primary soil moisture function

XS : Actual Storage in the secondary soil moisture function

XF : Free Water stored abone the primary soil moisture function, leaving the primary function full.

$XA = XP + XF$

Fig. 4.4 Detail of Soil Moisture Function

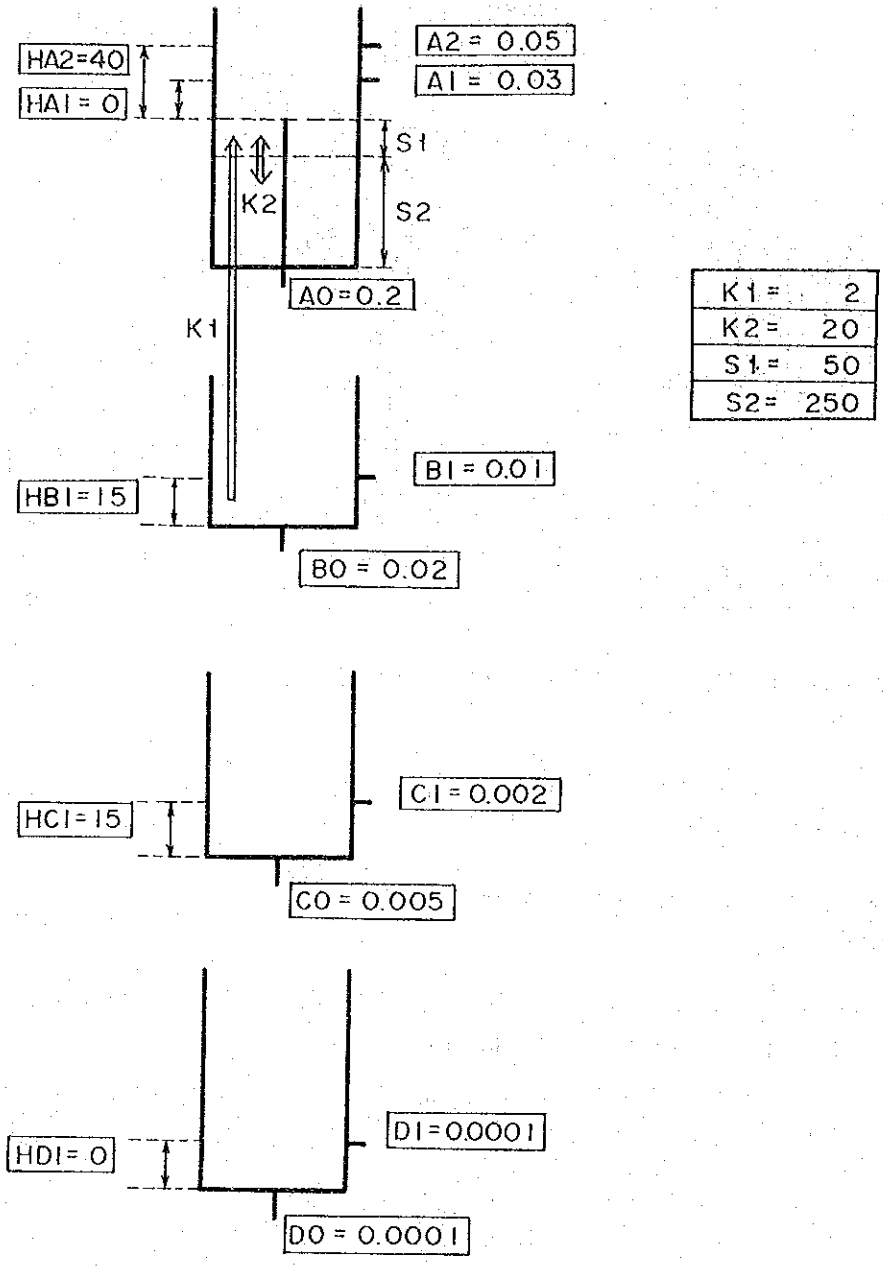


Fig. 4.5 Tank Model Eventually Employed in the Study