4. Lugeon Test Data

Project for Mater Plan Study on Hydropower Development

JICA STUDY TEAM

Ayago Pre-feasibility Study: Geological Investigations

GEOTECH SOLUTIONS (U) LTD

LUGEON TEST

PMHU-10-022

FRM. 20.043 rev 0

Location	EASTING	NORTHING	ELEVATION
Right Bank intake area	381890.352	259900.428	866.647

Borehole No.	B1	(Investigation hole)

Date:	25-Sep-10			Test No.	1	From	5.0	m	to	10.0	m
Time of start:	13:10	Time of finish:	14:30								

Pressure Gauge Height - C (cm) — 80

Length of Test Section- L (cm) — 500

Dia of Test Section 2r (mm) — 7.6

Time for each period (min) — 10

Stage method — down stage

Packer: Single [√] Double [ ]

Water table depth

a) Water table B$_1$ (cm) — nil

b) Centre of Test Section B$_2$ (cm) — 750

WATER PRESSURE IN HEAD CALCULATION:

H = A + B + C - Hf

Hf (friction loss of energy in injection pipe) = 10 cm/m

866.647

Water table

Pressure gauge

C

Water Meter

B$_1$

B$_2$

L

2r

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	5624.5				water test done by single
1	1370	750	1000	5630.7	6.20	0.62	1.24	packer
2	4370	750	4000	5653.8	23.10	2.31	1.16	"
3	7370	750	7000	5692.4	38.60	3.86	1.10	"
4	10370	750	10000	5747.3	54.90	5.49	1.10	"
5	7370	750	7000	5786.5	39.20	3.92	1.12	"
6	4370	750	4000	5808.6	22.10	2.21	1.11	"
7	1370	750	1000	5813.4	4.80	0.48	0.96	"
							1.11	

Interpretation: Tight rock

Permeability k = $(q \times 10^3 \times \ln(L/r)) / (2\pi LH \times 60)$

Q = liter/min

r = 3.8

Lugeon value (Lu) = $q \times 10^6 / LH$

LUGEON CHART

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure [kgf/cm^2]
1	1.61E-05	1.24	1
2	1.49E-05	1.16	4
3	1.43E-05	1.10	7
4	1.42E-05	1.10	10
5	1.45E-05	1.12	7
6	1.43E-05	1.11	4
7	1.24E-05	0.96	1

Signature of in-charge

LUGEON TEST

PMHU-10-022

FRM. 20.044   rev 0

Location	EASTING	NORTHING	ELEVATION
Right Bank intake area	381890.352	258900.428	866.647
Borehole No.	**B1**	(Investigation hole)	
Date:	25-Sep-10		
Time of start:	17:20	Time of finish:	18:40

Test No. 2 From 10.0 m to 15.0 m

Pressure Gauge Height - C (cm)	90
Length of Test Section- L (cm)	500
Dia of Test Section 2r (mm)	7.6
Time for each period (min)	10
Stage method	down stage
Packer: Single ☐ Double ☐	
Water table depth	
a) Water table B_1 (cm)	1390
b) Centre of Test Section B_2 (cm)	1250

Hose pipe length (m) = 120

Hf = 1200 cm

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	6125.4				water test done by single
1	730	1390	1000	6137.3	11.80	1.18	2.38	packer
2	3730	1390	4000	6184.2	46.90	4.69	2.34	"
3	6730	1390	7000	6267.0	82.80	8.28	2.37	"
4	9730	1390	10000	6384.9	117.90	11.79	2.36	"
5	6730	1390	7000	6466.1	81.20	8.12	2.32	"
6	3730	1390	4000	6511.8	45.70	4.57	2.28	"
7	730	1390	1000	6523.3	11.50	1.15	2.30	"
							2.34	

Interpretation: Tight rock

Permeability x = (q x 10⁻³ ln(L/r)) / (2πL x 60)

Q =

r = 3.8

Lugeon value (Lu) = q x 10⁷ / LH

LUGEON CHART

Period/ Step	Permeability [K]	Lugeon value (Lu)	Pressure (kg/cm²)
1	3.08E-05	2.38	1
2	3.04E-05	2.34	4
3	3.06E-05	2.37	7
4	3.05E-05	2.36	10
5	3.00E-05	2.32	7
6	2.96E-05	2.28	4
7	2.98E-05	2.30	1

Signature of in-charge:

JICA STUDY TEAM

Ayago Pre-feasibility Study:
Geological Investigations

GEOTECH SOLUTIONS [U] LTD

Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Right Bank intake area	381890.352	258900.428	866.647	**LUGEON TEST**	
Borehole No.	B1	(Investigation hole)			FRM 20.948 rev 0
Date:	26-Sep-10			Test No. 3 From 15.0 m to 20.0 m	
Time of start:	7:30	Time of finish:	8:50		

Pressure Gauge Height - C (cm)	80
Length of Test Section- L (cm)	500
Dia of Test Section 2r (mm)	7.6
Time for each period (min)	10
Stage method	down stage
Packer: Single ☐ Double ☐	
Water table depth	
a) Water table B_1 (cm)	1390
b) Centre of Test Section B_2 (cm)	1750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	6732.6				water test done by single
1	730	1390	1000	6746.4	13.80	1.38	2.76	packer
2	3730	1390	4000	6802.3	55.90	5.59	2.80	"
3	6730	1390	7000	6900.7	88.40	8.84	2.81	"
4	9730	1390	10000	7041.8	141.10	14.11	2.82	"
5	6730	1390	7000	7139.1	97.30	9.73	2.78	"
6	3730	1390	4000	7195.2	56.10	5.61	2.80	"
7	730	1390	1000	7209.1	13.90	1.39	2.78	"
							2.79	

Interpretation:	Tight rock

Permeability = (q x 10' x ln(r)) / (2πLH x 60)

$Q = $ lit/min $r = $ 3.8

Lugeon value (Lu) = q x 10' / LH

LUGEON CHART

Period/ Step	Permeability [K]	Lugeon value (Lu)	Pressure (kg/cm²)
1	3.57E-05	2.76	1
2	3.62E-05	2.80	4
3	3.64E-05	2.81	7
4	3.65E-05	2.82	10
5	3.60E-05	2.78	7
6	3.63E-05	2.80	4
7	3.60E-05	2.78	1

Signature of in-charge

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Location	EASTING	NORTHING	ELEVATION				PMHU-10-022
Right Bank intake area	381890.382	258900.428	866.647		**LUGEON TEST**		
Borehole No.	B1	(Investigation hole)				FRM 20.046	rev 0
Date:	26-Sep-10			Test No. 4 From 20.0 m to 25.0 m			
Time of start:	13:25	Time of finish:	14:45				

Pressure Gauge Height - C (cm) 80

Length of Test Section- L (cm) 500

Dia of Test Section 2r (mm) 7.8

Time for each period (min) 10

Stage method down stage

Packer: Single ☑ Double ☐

Water table depth

a) Water table B₁ (cm) 1390

b) Centre of Test Section B₂ (cm) 2250

WATER PRESSURE IN HEAD CALCULATION:

H = A + B + C - Hf

Hf (friction loss of energy in injection pipe) = 10 cm/m

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	7340.2				water test done by single
1	730	1390	1000	7356.4	16.20	1.62	3.24	packer
2	3730	1390	4000	7422.1	65.70	6.57	3.29	"
3	6730	1390	7000	7536.5	114.40	11.44	3.27	"
4	9730	1390	10000	7700.7	164.20	16.42	3.28	"
5	6730	1390	7000	7814.5	113.80	11.38	3.25	"
6	3730	1390	4000	7879.6	65.10	6.51	3.26	"
7	730	1390	1000	7895.7	16.10	1.61	3.22	"
							3.26	

Interpretation: Tight rock

Permeability κ = q x 10⁻³ (H/L/) / (2πrL x 60)

Q = lit/min

r = 3.8

Lugeon value (Lu) = q x 10² / LH

LUGEON CHART

Period/ Step	Permeability [K]	Lugeon value (Lu)	Pressure (kgf/cm²)
1	4.19E-05	3.24	1
2	4.25E-05	3.29	4
3	4.23E-05	3.27	7
4	4.25E-05	3.28	10
5	4.21E-05	3.25	7
6	4.21E-05	3.26	4
7	4.17E-05	3.22	1

Signature of in-charge

Location	EASTING	NORTHING	ELEVATION				PMHU-10-022
Left Bank intake area	381280.110	289538.09	856.536	**LUGEON TEST**			
Borehole No.	B2	(Investigation hole)				FRM 20.840	rev 0
Date:	13-Sep-10			Test No. 1 From 5.0 m to 10.0 m			
Time of start:	16:10	Time of finish:	17:30				

Pressure Gauge Height - C (cm)   90

Length of Test Section- L (cm)   500
Dia of Test Section 2r (mm)   7.6

Time for each period (min)   10

Stage method   down stage

Packer: Single [ ]   Double [ ]

Water table depth

a) Water table B₁ (cm)   nil

b) Centre of Test Section B₂ (cm)   750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

856.5

B₁

Water table

L

2r

Pressure gauge

C

Water Meter

Hose pipe length (m) = 120

Hf = 1200 cm

B₂

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	4239.6				water test done by single
1	1370	750	1000	4248.3	8.70	0.87	1.74	packer
2	4370	750	4000	4282.5	34.20	3.42	1.71	"
3	7370	750	7000	4342.7	60.20	6.02	1.72	"
4	10370	750	10000	4429.1	86.40	8.64	1.73	"
5	7370	750	7000	4489.4	60.30	6.03	1.72	"
6	4370	750	4000	4523.7	34.30	3.43	1.72	"
7	1370	750	1000	4532.2	8.50	0.85	1.70	"
							1.72	

Interpretation: Laminar flow

Permeability $k =$ (q x 10' x ln(r/1) / (2πLt x 60)

Q =   lit/min   r =   3.8

Lugeon value (LU) = q x 10³ / Lh

Period/ Step	Permeability [k]	Lugeon value (LU)	Pressure [kg/cm]
1	2.25E-05	1.74	1
2	2.21E-05	1.71	4
3	2.23E-05	1.72	7
4	2.24E-05	1.73	10
5	2.23E-05	1.72	7
6	2.22E-05	1.72	4
7	2.20E-05	1.70	1

LUGEON CHART

Signature of Incharge

JICA STUDY TEAM

Ayago Pre-feasibility Study:
Geological Investigations

GEOTECH SOLUTIONS [U] LTD

PMHU-10-022

Location	EASTING	NORTHING	ELEVATION			
Left Bank intake area	381280.110	289538.09	856.536	**LUGEON TEST**		
Borehole No.	B2	(Investigation hole)			FRM. 20.041	rev 0
Date:	14-Sep-10			Test No. 2 From 10.0 m to 15.0 m		
Time of start:	7:55	Time of finish:	9:15			

Pressure Gauge Height - C (cm) 90

Length of Test Section- L (cm) 500

Dia of Test Section 2r (mm) 7.8

Time for each period (min) 10

Stage method down stage

Packer: Single ☑ Double ☐

Water table depth

a) Water table B_1 (cm) 900

b) Centre of Test Section B_2 (cm) 1250

856.5

B_1

Water table

B_2

L

2r

Hose pipe length (m) = 120

Hf = 1200 cm

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	4720.8				water test done by single packer
1	1220	900	1000	4731.5	10.70	1.07	2.14	
2	4220	900	4000	4775.1	43.60	4.36	2.18	"
3	7220	900	7000	4852.7	77.60	7.76	2.22	"
4	10220	900	10000	4963.4	110.70	11.07	2.21	"
5	7220	900	7000	5035.9	72.50	7.25	2.07	"
6	4220	900	4000	5076.5	40.60	4.06	2.03	"
7	1220	900	1000	5086.6	10.10	1.01	2.02	"
							2.12	

Interpretation: Laminar flow

Permeability k = q x 10⁴ x ln(l/r) / (2π x L x H)

Q =

Lugeon value (Lu) = q x 10⁵ / LH

r = 3.8

LUGEON CHART

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	2.77E-05	2.14	1
2	2.82E-05	2.18	4
3	2.87E-05	2.22	7
4	2.87E-05	2.21	10
5	2.68E-05	2.07	7
6	2.63E-05	2.03	4
7	2.61E-05	2.02	1

Signature of incharge

JICA STUDY TEAM			**Ayago Pre-feasibility Study: Geological Investigations**	**GEOTECH SOLUTIONS [U] LTD**

Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Left Bank intake area	381280.110	289538.09	856.536	**LUGEON TEST**	
Borehole No.	**B2**	(Investigation hole)			FRM 20.042 rev 0
Date:	14-Sep-10			Test No. 3 From 15.0 m to 20.0 m	
Time of start:	14:25	Time of finish:	15:45		

Pressure Gauge Height - C (cm)   90

Length of Test Section- L (cm)   500

Dia of Test Section 2r (mm)   7.6

Time for each period (min)   10

Stage method   down stage

Packer: Single ☐   Double ☐

Water table depth

a) Water table B₁ (cm)   900

b) Centre of Test Section B₂ (cm)   1750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

856.5   B₁   Water table   L   2r   C   B₂

Pressure gauge   Water Meter

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	5216.5				water test done by single
1	1220	900	1000	5220.4	3.90	0.39	0.78	packer
2	4220	900	4000	5236.5	16.10	1.61	0.81	"
3	7220	900	7000	5264.4	27.90	2.79	0.80	"
4	10220	900	10000	5307.4	43.00	4.30	0.86	"
5	7220	900	7000	5336.5	29.10	2.91	0.83	"
6	4220	900	4000	5352.6	16.10	1.61	0.81	"
7	1220	900	1000	5356.6	4.00	0.40	0.80	"
							0.81	

Interpretation: Laminar flow

Permeability k =   (q x 10² x ln(L/r)) / (2π x L x 60)

$Q = \frac{litre}{min}$ r =   3.8

Lugeon value (Lu) = q x 10² / 10L

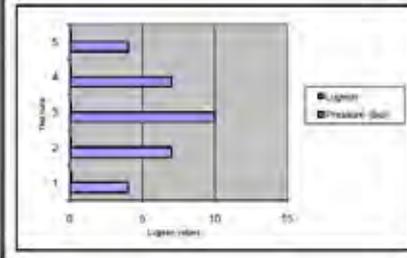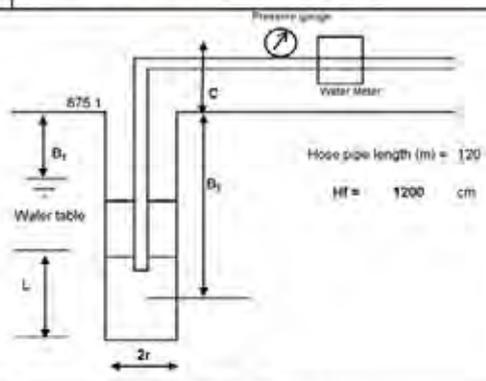| Period/ Step	Permeability (k)	Lugeon value (Lu)	Pressure (kg/cm²)
1	1.01E-05	0.78	1
2	1.04E-05	0.81	4
3	1.03E-05	0.80	7
4	1.11E-05	0.86	10
5	1.06E-05	0.83	7
6	1.04E-05	0.81	4
7	1.04E-05	0.80	1

LUGEON CHART

Signature of Incharge

Project for Water Plan Study on Hydropower Development

JICA STUDY TEAM

Ayago Pre-feasibility Study: Geological Investigations

GEOTECH SOLUTIONS [U] LTD

Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381 183.964	289365.73	875.125	**LUGEON TEST**	
Borehole No.	**BS**	(Investigation hole)			FRM 20.001 rev 0
Date:	9-Aug-10			Test No. 1 From 10.0 m to 15.0 m	
Time of start:	13:05	Time of finish:	14:25		

Pressure Gauge Height - C (cm) : 90

Length of Test Section- L (cm) : 500

Dia of Test Section 2r (mm) : 7.6

Time for each period (min) : 10

Stage method : down stage

Packer: Single ☑ Double ☐

Water table depth

a) Water table B₁ (cm) : nil

b) Centre of Test Section B₂ (cm) : 1250

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	2210.2				water test done by single
1	870	1250	1000	2224.8	14.60	1.46	2.92	packer
2	3870	1250	4000	2280.1	55.30	5.53	2.76	.
3	6870	1250	7000	2372.0	91.90	9.19	2.63	.
4	9870	1250	10000	2505.5	133.50	13.35	2.67	.
5	6870	1250	7000	2600.2	94.70	9.47	2.71	.
6	3870	1250	4000	2654.6	54.40	5.44	2.72	.
7	870	1250	1000	2668.0	13.40	1.34	2.68	.
							2.73	

Interpretation: Laminar flow

Permeability x = q x 10⁻⁴ x ln(l/r) / (2πL x 60)

Q = lit/min

r = 3.8

Lugeon value (Lu) = q x 10⁷ / LH

Period/ Step	Permeability [K]	Lugeon value (Lu)	Pressure (kg/cm²)
1	3.78E-05	2.92	1
2	3.58E-05	2.76	4
3	3.40E-05	2.63	7
4	3.46E-05	2.67	10
5	3.50E-05	2.71	7
6	3.52E-05	2.72	4
7	3.47E-05	2.68	1

LUGEON CHART

Signature of Incharge

		Project for Mater Plan Study on Hydropower Development			**GEOTECH**	
JICA STUDY TEAM		**Ayago Pre-feasibility Study: Geological Investigations**			**SOLUTIONS [U] LTD**	

Location	EASTING	NORTHING	ELEVATION			PMHU-10-022
Powerhouse Area	381183.964	259385.73	875.125	**LUGEON TEST**		
Borehole No.	**BS**	(Investigation hole)			**FRM 20.002**	rev 0
Date:	9-Aug-10			Test No. 2 From 15.0 m to 20.0 m		
Time of start:	17:15	Time of finish:	18:35			

Pressure Gauge Height - C (cm) 80

Length of Test Section- L (cm) 500

Dia of Test Section 2r (mm) 7.6

Time for each period (min) 10

Stage method .... down stage

Packer: Single ☐ Double ☐

Water table depth

a) Water table B_1 (cm) .... nil

b) Centre of Test Section B_2 (cm) 1750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

875.1 | C | Pressure gauge | Water Meter

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate, q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	2714.0				water test done by single
1	370	1750	1000	2722.8	8.80	0.88	1.78	packer
2	3370	1750	4000	2755.2	32.40	3.24	1.62	
3	6370	1750	7000	2813.7	58.50	5.85	1.67	"
4	9370	1750	10000	2898.0	84.30	8.43	1.69	"
5	6370	1750	7000	2956.5	58.50	5.85	1.67	"
6	3370	1750	4000	2988.4	31.90	3.19	1.60	"
7	370	1750	1000	2996.3	7.90	0.79	1.58	"
							1.65	

Interpretation: Laminar flow

Permeability k =

$Q = $ r = 3.8

Lugeon value (Lu) = q × 10⁷ / LH

LUGEON CHART

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure [kbar]
1	2.28E-05	1.76	1
2	2.10E-05	1.62	4
3	2.16E-05	1.67	7
4	2.18E-05	1.69	10
5	2.16E-05	1.67	7
6	2.06E-05	1.60	4
7	2.05E-05	1.58	1

Signature of incharge

Project for Mater Plan Study on Hydropower Development				GEOTECH SOLUTIONS (U) LTD	
JICA STUDY TEAM		Ayago Pre-feasibility Study: Geological Investigations			

Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381183.964	259365.73	875.125	**LUGEON TEST**	
Borehole No.	B5	(Investigation hole)			FRM. 20.003 rev 0
Date:	10-Aug-10		Test No. 3 From 20.0 m to 25.0 m		
Time of start:	7:15	Time of finish: 8:15			

Pressure Gauge Height - C (cm) 80

Length of Test Section- L (cm) 500

Dia of Test Section 2r (mm) 7.6

Time for each period (min) 10

Stage method .... down stage

Packer: Single [ ] Double [ ]

Water table depth

a) Water table B₁ (cm) 2320

b) Centre of Test Section B₂ (cm) 2250

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

875.1

C

Water Meter

B₁

B₂

Water table

L

Hose pipe length (m) = 120

Hf = 1200 cm

2r

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	3012.4				water test done by single
1	2800	2320	4000	3035.2	22.80	2.28	1.14	packer
2	5800	2320	7000	3073.6	38.40	3.84	1.10	"
3	8800	2320	10000	3132.8	59.20	5.92	1.18	"
4	5800	2320	7000	3170.5	37.70	3.77	1.08	"
5	2800	2320	4000	3191.4	20.90	2.00	1.05	"
							1.11	

Interpretation: Laminar flow

LUGEON CHART

Permeability $k = (q \times 10^3 \times \ln(L/r)) / (2\pi L \times 60)$

$Q = $ litre/min $\qquad r = 3.8$

Lugeon value (Lu) = $q \times 10^3 / LH$

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kgf/cm²)
1	1.48E-05	1.14	4
2	1.42E-05	1.10	7
3	1.53E-05	1.18	10
4	1.39E-05	1.08	7
5	1.36E-05	1.05	4

Signature of in-charge

Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381183.964	259365.73	875.125	**LUGEON TEST**	
Borehole No.	B5	(Investigation hole)			FRM. 20.004 / rev 0
Date:	10-Aug-10			Test No. 4 From 25.0 m to 30.0 m	
Time of start:	13:10	Time of finish:	14:10		

Pressure Gauge Height - C (cm)   80

Length of Test Section- L (cm)   500

Dia of Test Section 2r (mm)   7.6

Time for each period (min)   10

Stage method   down stage

Packer: Single ☑   Double ☐

Water table depth

a) Water table B₁ (cm)   2320

b) Centre of Test Section B₂ (cm)   2750

WATER PRESSURE IN HEAD CALCULATION:

H = A + B + C - Hf

Hf (friction loss of energy in injection pipe) = 10 cm/m

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	3240.5				water test done by single
1	2800	2320	4000	3246.0	5.50	0.55	0.28	packer
2	5800	2320	7000	3253.2	7.20	0.72	0.21	"
3	8800	2320	10000	3265.1	11.90	1.19	0.24	"
4	5800	2320	7000	3272.4	7.30	0.73	0.21	"
5	2800	2320	4000	3277.0	4.60	0.46	0.23	"
							0.23	

Interpretation: Tight rock

Permeability k = (q x 10⁻³ x ln(l/r)) / (2πL x 60)

Q =   ltr/min   L = 3.8

Lugeon value (Lu) = q x 10² / LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	3.56E-06	0.28	4
2	2.66E-06	0.21	7
3	3.06E-06	0.24	10
4	2.70E-06	0.21	7
5	2.98E-06	0.23	4

Signature of Geologist

LUGEON CHART

JICA STUDY TEAM

Ayago Pre-feasibility Study:
Geological Investigations

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Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381183.964	259365.73	875.125	**LUGEON TEST**	
Borehole No.	B5	(Investigation hole)			FRM. 20.006 rev 0
Date:	10-Aug-10		Test No. 5 From 30.0 m to 35.0 m		
Time of start:	17:20	Time of finish:	18:20		

Pressure Gauge Height - C (cm) 80

Length of Test Section- L (cm) 500

Dia of Test Section 2r (mm) 7.6

Time for each period (min) 10

Stage method down stage

Packer: Single ☑ Double ☐

Water table depth

a) Water table B₁ (cm) 2320

b) Centre of Test Section B₂ (cm) 3250

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

875.1

Hose pipe length (m) = 120

$Hf =$ 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (litr/min)	Lugeon value [Lu]	Remarks
0	0	0	0	3280.0				water test done by single
1	2800	2320	4000	3281.5	1.50	0.15	0.08	packer
2	5800	2320	7000	3283.7	2.20	0.22	0.06	"
3	8800	2320	10000	3286.4	2.70	0.27	0.05	"
4	5800	2320	7000	3288.0	1.60	0.16	0.05	"
5	2800	2320	4000	3289.2	1.20	0.12	0.06	"
							0.06	

Interpretation: Tight rock

Permeability $k =$ (q x 10⁻ x ln(L/r)) / (2πL x 60)

$Q =$ litres/min $t =$ 3.8

Lugeon value (Lu) = q x 10⁻ / L H

LUGEON CHART

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	9.71E-07	0.08	4
2	8.14E-07	0.06	7
3	6.99E-07	0.05	10
4	5.92E-07	0.05	7
5	7.77E-07	0.06	4

Signature of in-charge

Project for Water Plan Study on Hydropower Development

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Ayago Pre-feasibility Study: Geological Investigations

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Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381183.964	259365.73	875.125	**LUGEON TEST**	
Borehole No.	B5	(Investigation hole)			FRM. 20.006 rev 0
Date:	11-Aug-10			Test No. 6 From 35.0 m to 40.0 m	
Time of start:	7:10	Time of finish:	8:10		

Pressure Gauge Height - C (cm) — 80

Length of Test Section- L (cm) — 500

Dia of Test Section 2r (mm) — 7.6

Time for each period (min) — 10

Stage method — down stage

Packer: Single [✓] Double [ ]

Water table depth

a) Water table B₁ (cm) — 2320

b) Centre of Test Section B₂ (cm) — 3750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

875.1 C Water Meter

Hose pipe length (m) = 120

$Hf =$ 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (ltr/min)	Lugeon value [Lu]	Remarks
0	0	0	0	3310.2				water test done by single
1	2800	2320	4000	3311.8	1.60	0.16	0.08	packer
2	5800	2320	7000	3314.2	2.40	0.24	0.07	"
3	8800	2320	10000	3317.8	3.60	0.36	0.07	"
4	5800	2320	7000	3320.5	2.70	0.27	0.08	"
5	2800	2320	4000	3321.6	1.10	0.11	0.05	"
							0.07	

Interpretation: Tight rock

Permeability k = (q x 10⁻³ x ln(L/r)) / (2πLt x 60)

$Q =$ ltr/min $t =$ 3.8

Lugeon value (Lu) = q x 10³ / LH

Period/ Step	Permeability (k)	Lugeon value (Lu)	Pressure (kgf/cm²)
1	1.04E-06	0.08	4
2	8.88E-07	0.07	7
3	9.32E-07	0.07	10
4	9.88E-07	0.08	7
5	7.12E-07	0.05	4

Signature of in-charge

LUGEON CHART

Project for Water Plan Study on Hydropower Development			
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Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381183.984	259365.73	875.125	**LUGEON TEST**	
Borehole No.	**B5**	(Investigation hole)			FRM. 20.007 rev 0
Date:	11-Aug-10			Test No. 7 From 40.0 m to 45.0 m	
Time of start:	13:20	Time of finish:	14:20		

Pressure Gauge Height - C (cm)   80

Length of Test Section- L (cm)   500
Dia of Test Section 2r (mm)   7.6

Time for each period (min)   10

Stage method   down stage

Packer: Single [x]   Double [ ]

Water table depth

a) Water table B₁ (cm)   2320

b) Centre of Test Section B₂ (cm)   4250

WATER PRESSURE IN HEAD CALCULATION:

H = A + B + C - Hf

Hf (friction loss of energy in injection pipe) = 10 cm/m

875.1   C   Water Meter

B₁   Hose pipe length (m) = 120

B₂   Hf = 1200 cm

Water table

L

2r

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (ltr/min)	Lugeon value [Lu]	Remarks
0	0	0	0	3350.0				water test done by single
1	2800	2320	4000	3351.8	1.80	0.18	0.09	packer
2	5800	2320	7000	3354.4	2.60	0.26	0.07	"
3	8800	2320	10000	3356.7	2.30	0.23	0.05	"
4	5800	2320	7000	3358.7	2.00	0.20	0.06	"
5	2800	2320	4000	3359.7	1.00	0.10	0.05	"
							0.06	

Interpretation: Tight rock

Permeability k = (q x 10⁻⁶ ln(r/r)) / (2πLt × 60)

Q = ltr/min   t = 3.8

Lugeon value (Lu) = q x 10⁴/LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure [kg/cm²]
1	1.18E-06	0.09	4
2	9.62E-07	0.07	7
3	5.95E-07	0.05	10
4	7.40E-07	0.06	7
5	6.47E-07	0.05	4

LUGEON CHART

Signature of geology:

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Location	EASTING	NORTHING	ELEVATION	PMHU-10-022
Powerhouse Area	381183.984	259365.73	875.125	**LUGEON TEST**
Borehole No.	**B5**	(Investigation hole)		FRM 20.006 rev 0
Date:	11-Aug-10		Test No. 8 From 45.0 m to 50.0 m	
Time of start:	17:25	Time of finish: 18:25		

Pressure Gauge Height - C (cm) 80

Length of Test Section- L (cm) 500

Dia of Test Section 2r (mm) 7.6

Time for each period (min) 10

Stage method down stage

Packer: Single ☑ Double ☐

Water table depth

a) Water table B₁ (cm) 2320

b) Centre of Test Section B₂ (cm) 4750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	3467.4				water test done by single
1	2800	2320	4000	3469.8	2.40	0.24	0.12	packer
2	5800	2320	7000	3473.2	3.40	0.34	0.10	"
3	8800	2320	10000	3477.9	4.70	0.47	0.08	"
4	5800	2320	7000	3480.3	2.40	0.24	0.07	"
5	2800	2320	4000	3482.3	2.00	0.20	0.10	"
							0.10	

Interpretation: Tight rock

Permeability k = (q x 10⁴ x ln(r/r)) / (2πLr x 60)

$Q =$ litre/min $r =$ 3.8

Lugeon value (Lu) = q x 10⁵ / LH

LUGEON CHART

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	1.58E-06	0.12	4
2	1.26E-06	0.10	7
3	1.22E-06	0.08	10
4	8.88E-07	0.07	7
5	1.29E-06	0.10	4

Signature of geologist

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Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381183.964	259365.73	875.125	**LUGEON TEST**	
Borehole No.	B5	(Investigation hole)			FRM. 20.009 rev 0
Date:	12-Aug-10		Test No. 9 From 50.0 m to 55.0 m		
Time of start:	7:15	Time of finish: 8:15			

Pressure Gauge Height - C (cm) 80

Length of Test Section- L (cm) 500

Dia of Test Section 2r (mm) 7.6

Time for each period (min) 10

Stage method .... down stage

Packer: Single [ ] Double [ ]

Water table depth

a) Water table B₁ (cm) 2320

b) Centre of Test Section B₂ (cm) 5250

WATER PRESSURE IN HEAD CALCULATION:

H = A + B + C - Hf

Hf (friction loss of energy in injection pipe) = 10 cm/m

875.1   C   Water Meter

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm] A	Static water head [cm] B	Water pressure in head [cm] H	Meter reading [litres]	Water take [litres]	Water injection Rate q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	25.5				water test done by single
1	2800	2320	4000	27.8	2.30	0.23	0.12	packer
2	5800	2320	7000	31.2	3.40	0.34	0.10	"
3	8800	2320	10000	36.4	5.20	0.52	0.10	"
4	5800	2320	7000	39.8	3.40	0.34	0.10	"
5	2800	2320	4000	41.7	1.90	0.19	0.10	"
							0.10	

Interpretation: Tight rock

Permeability k = (q × 10⁻¹ × ln(L/r)) / (2πLH × 60)

Q = litre/min   r = 3.8

Lugeon value (Lu) = q × 10² / LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	1.49E-06	0.12	4
2	1.26E-06	0.10	7
3	1.35E-06	0.10	10
4	1.26E-06	0.10	7
5	1.23E-06	0.10	4

Signature of in-charge

LUGEON CHART

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Location	EASTING	NORTHING	ELEVATION	PMHU-10-022
Powerhouse Area	381183.964	259365.73	875.125	**LUGEON TEST**
Borehole No.	B5	(Investigation hole)		FRM 20.010 rev 0
Date:	12-Aug-10		Test No. 10 From 55.0 m to 60.0 m	
Time of start:	13:15	Time of finish: 14:15		

Pressure Gauge Height - C (cm)   80

Length of Test Section- L (cm)   500

Dia of Test Section 2r (mm)   7.6

Time for each period (min)   10

Stage method   down stage

Packer: Single ☑   Double ☐

Water table depth

a) Water table B₁ (cm)   2320

b) Centre of Test Section B₂ (cm)   5750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (ltr/min)	Lugeon value [Lu]	Remarks
0	0	0	0	52.8				water test done by single
1	2800	2320	4000	55.5	2.70	0.27	0.14	packer
2	5800	2320	7000	59.7	4.20	0.42	0.12	"
3	8800	2320	10000	67.0	7.30	0.73	0.15	"
4	5800	2320	7000	72.1	5.10	0.51	0.15	"
5	2800	2320	4000	74.8	2.70	0.27	0.14	"
							0.14	

Interpretation: Tight rock

Permeability k =   (q x 10⁻¹ x ln(L/r)) / (2πLH x 60)

Q =   litre/min   r = 3.8

Lugeon value (Lu) = q x 10⁵ / LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kgf/cm²)
1	1.78E-06	0.14	4
2	1.55E-06	0.12	7
3	1.89E-06	0.15	10
4	1.89E-06	0.15	7
5	1.78E-06	0.14	4

Signature of in-charge

LUGEON CHART

Signature of in-charge

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Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381183.984	259365.73	875.125	**LUGEON TEST**	
Borehole No.	B5	(Investigation hole)			FRM 20.011 rev 0
Date:	12-Aug-10		Test No. 11 From 60.0 m to 65.0 m		
Time of start:	17:20	Time of finish:	18:20		

Pressure Gauge Height - C (cm)   80

Length of Test Section- L (cm)   500

Dia of Test Section 2r (mm)   7.6

Time for each period (min)   10

Stage method   down stage

Packer: Single ☑   Double ☐

Water table depth

a) Water table B₁ (cm)   2320

b) Centre of Test Section B₂ (cm)   6250

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	95.6				water test done by single
1	2800	2320	4000	98.4	2.80	0.28	0.14	packer
2	5800	2320	7000	103.5	5.10	0.51	0.15	"
3	8800	2320	10000	109.3	5.80	0.58	0.12	"
4	5800	2320	7000	112.5	3.20	0.32	0.09	"
5	2800	2320	4000	114.1	1.60	0.16	0.08	"
							0.11	

Interpretation: Tight rock

Permeability k =   (q x 10⁻³ x ln(L/r)) / (2πrH x 60)

Q = litre/min r = 3.8

Lugeon value (Lu) = q x 10² / LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	1.61E-06	0.14	4
2	1.89E-06	0.15	7
3	1.50E-06	0.12	10
4	1.18E-06	0.09	7
5	1.04E-06	0.08	4

LUGEON CHART

Signature of in-charge

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Location	EASTING	NORTHING	ELEVATION	**LUGEON TEST**	PMHU-10-022
Powerhouse Area	381183.964	259365.73	875.125		
Borehole No.	**B5**	(Investigation hole)			FRM 20.012 rev 0
Date:	13-Aug-10			Test No. 12 From 65.0 m to 70.0 m	
Time of start:	7:15	Time of finish:	8:15		

Pressure Gauge Height - C (cm) 80

Length of Test Section- L (cm) 500

Dia of Test Section 2r (mm) 7.6

Time for each period (min) 10

Stage method down stage

Packer: Single ☑ Double ☐

Water table depth

a) Water table B₁ (cm) 2320

b) Centre of Test Section B₂ (cm) 6750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

875.1

B₁

Water table

B₂

L

2r

C

Water Meter

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (ltr/min)	Lugeon value [Lu]	Remarks
0	0	0	0	150.4				water test done by single
1	2800	2320	4000	157.7	7.30	0.73	0.36	packer
2	5800	2320	7000	166.5	8.80	0.88	0.25	"
3	8800	2320	10000	170.3	3.80	0.38	0.08	"
4	5800	2320	7000	173.2	2.90	0.29	0.08	"
5	2800	2320	4000	174.2	1.00	0.10	0.05	"
							0.17	

Interpretation: Tight rock

Permeability k = (q x 10² x ln(L/r)) / (2πLH x 60)

Q = litre/min   r = 3.8

Lugeon value (Lu) = q x 10² / LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	4.72E-06	0.36	4
2	3.25E-06	0.25	7
3	9.84E-07	0.08	10
4	1.07E-06	0.08	7
5	6.47E-07	0.05	4

LUGEON CHART

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Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381183.964	259365.73	875.125	**LUGEON TEST**	
Borehole No.	**B5**	(Investigation hole)			FRM. 20.013 rev 0
Date:	13-Aug-10			Test No. 13 From 70.0 m to 75.0 m	
Time of start:	13:25	Time of finish:	14:25		

Pressure Gauge Height - C (cm)   80

Length of Test Section- L (cm)   500

Dia of Test Section 2r (mm)   7.6

Time for each period (min)   10

Stage method   down stage

Packer: Single ☑   Double ☐

Water table depth

a) Water table B₁ (cm)   2320

b) Centre of Test Section B₂ (cm)   7250

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (litr/min)	Lugeon value [Lu]	Remarks
0	0	0	0	210.2				water test done by single
1	2800	2320	4000	212.5	2.30	0.23	0.12	packer
2	5800	2320	7000	216.3	3.80	0.38	0.11	"
3	8800	2320	10000	221.4	5.10	0.51	0.10	"
4	5800	2320	7000	225.6	4.20	0.42	0.12	"
5	2800	2320	4000	227.8	2.20	0.22	0.11	"
							0.11	

Interpretation: Tight rock

Permeability k = (q x 10⁻¹ x ln(r/r)) / (2πLt x 60)

Q = litre/min   t = 3.8

Lugeon value (Lu) = q x 10² / Lt H

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	1.49E-06	0.12	4
2	1.41E-06	0.11	7
3	1.32E-06	0.10	10
4	1.55E-06	0.12	7
5	1.42E-06	0.11	4

LUGEON CHART

Signature of in-charge

Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381183.964	259365.73	875.125	**LUGEON TEST**	
Bornhole No.	**B5**	(Investigation hole)			FRM 20.014 rev 0
Date:	13-Aug-10		Test No. 14 From 75.0 m to 80.0 m		
Time of start:	17:30	Time of finish: 18:30			

Pressure Gauge Height - C (cm)   80

Length of Test Section- L (cm)   500

Dia of Test Section 2r (mm)   7.6

Time for each period (min)   10

Stage method   down stage

Packer: Single [·]   Double [ ]

Water table depth

a) Water table B_1 (cm)   2320

b) Centre of Test Section B_1 (cm)   7750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

875.1 B_1 C   Water Meter
Water table B_1
Hose pipe length (m) = 120
L   Hf = 1200 cm
2r

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (ltr/min)	Lugeon value [Lu]	Remarks
0	0	0	0	250.3				water test done by single
1	2800	2320	4000	252.0	1.70	0.17	0.08	packer
2	5800	2320	7000	254.7	2.70	0.27	0.08	"
3	8800	2320	10000	259.6	4.90	0.49	0.10	"
4	5800	2320	7000	262.2	2.60	0.26	0.07	"
5	2800	2320	4000	263.5	1.30	0.13	0.07	"
							0.08	

Interpretation: Tight rock				**LUGEON CHART**	

Permeability k =   (q x 10⁻¹ x ln(L/r)) / (2πH x 60)

Q =   ltr/min   t = 3.8

Lugeon value (Lu) = q x 10³ / LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)		
1	1.10E-06	0.08	4		
2	9.99E-07	0.08	7		
3	1.27E-06	0.10	10		
4	9.82E-07	0.07	7		
5	8.41E-07	0.07	4		

Signature of in-charge

Project for Water Plan Study on Hydropower Development		GEOTECH SOLUTIONS (U) LTD
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Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381183.964	259365.73	875.125	**LUGEON TEST**	
Borehole No.	B5	(Investigation hole)			FRM 20.016 rev 0
Date:	14-Aug-10		Test No. 15 From 80.0 m to 85.0 m		
Time of start:	7:10	Time of finish:	8:10		

Pressure Gauge Height - C (cm)   80

Length of Test Section- L (cm)   500

Dia of Test Section 2r (mm)   7.6

Time for each period (min)   10

Stage method   down stage

Packer: Single ☑   Double ☐

Water table depth

a) Water table B_1 (cm)   2320

b) Centre of Test Section B_2 (cm)   8250

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	294.8				water test done by single
1	2800	2320	4000	297.1	2.30	0.23	0.12	packer
2	5800	2320	7000	300.8	3.70	0.37	0.11	"
3	8800	2320	10000	306.2	5.40	0.54	0.11	"
4	5800	2320	7000	309.8	3.60	0.36	0.10	"
5	2800	2320	4000	311.8	2.00	0.20	0.10	"
							0.11	

Interpretation: Tight rock

Permeability $k = (q \times 10^3 \times \ln(L/r)) / (2\pi L \times 60)$

$Q = $ litre/min $r = $ 3.8

Lugeon value (Lu) = q $\times 10^5 / LH$

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kgf/cm²)
1	1.48E-06	0.12	4
2	1.37E-06	0.11	7
3	1.40E-06	0.11	10
4	1.33E-06	0.10	7
5	1.29E-06	0.10	4

LUGEON CHART

Signature of in-charge

Project for Water Plan Study on Hydropower Development			**GEOTECH SOLUTIONS [U] LTD**
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Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381183.964	259365.73	875.125	**LUGEON TEST**	
Borehole No.	B5	(Investigation hole)			FRM 20.016 rev 0
Date:	14-Aug-10			Test No. 16 From 85.0 m to 90.0 m	
Time of start:	13:15	Time of finish:	14:15		

Pressure Gauge Height - C (cm)   80

Length of Test Section- L (cm)   500

Dia of Test Section 2r (mm)   7.6

Time for each period (min)   10

Stage method   down stage

Packer: Single [x]   Double [ ]

Water table depth

a) Water table B₁ (cm)   2320

b) Centre of Test Section B₂ (cm)   8750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

875.1   C   Water Meter

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (ltr/min)	Lugeon value [Lu]	Remarks
0	0	0	0	356.2				water test done by single
1	2800	2320	4000	357.8	1.60	0.16	0.08	packer
2	5800	2320	7000	360.4	2.60	0.26	0.07	"
3	8800	2320	10000	364.5	4.10	0.41	0.08	"
4	5800	2320	7000	366.7	2.20	0.22	0.06	"
5	2800	2320	4000	368.0	1.30	0.13	0.07	"
							0.07	

Interpretation: Tight rock

Permeability k =   (q x 10⁻¹ x ln(L/r)) / (2πL x 60)

Q = ltr/min   r = 3.8

Lugeon value (Lu) = q x 10⁷ / LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure [kg/cm²]
1	1.04E-06	0.08	4
2	9.62E-07	0.07	7
3	1.06E-06	0.08	10
4	8.14E-07	0.06	7
5	8.41E-07	0.07	4

Signature of geologist

LUGEON CHART

JICA STUDY TEAM

Ayago Pre-feasibility Study: Geological Investigations

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PMHU-10-022

Location	EASTING	NORTHING	ELEVATION
Powerhouse Area	381183.964	259365.73	875.125

Borehole No. **B5** (Investigation hole)

LUGEON TEST

FRM. 20.017   rev 0

Date:	14-Aug-10		Test No. 17 From 90.0 m to 95.0 m
Time of start:	17:20	Time of finish: 18:20	

Pressure Gauge Height - C (cm)   80

Length of Test Section- L (cm)   500

Dia of Test Section 2r (mm)   7.6

Time for each period (min)   10

Stage method   down stage

Packer: Single ☑   Double ☐

Water table depth

a) Water table B_1 (cm)   2320

b) Centre of Test Section B_2 (cm)   9250

WATER PRESSURE IN HEAD CALCULATION:

H = A + B + C - Hf

Hf (friction loss of energy in injection pipe) = 10 cm/m

875.1

B_1

Water table

B_2

L

2r

C

Water Meter

Pressure gauge

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (ltr/min)	Lugeon value [Lu]	Remarks
0	0	0	0	392.4				water test done by single
1	2800	2320	4000	393.2	0.80	0.08	0.04	packer
2	5800	2320	7000	394.7	1.50	0.15	0.04	"
3	8800	2320	10000	397.8	3.10	0.31	0.06	"
4	5800	2320	7000	399.3	1.50	0.15	0.04	"
5	2800	2320	4000	400.0	0.70	0.07	0.03	"
							0.04	

Interpretation: Tight rock

Permeability k =   (q × 10⁷ × ln(r/L)) / (2πL × 60)

Q = litr/min   t = 3.8

Lugeon value (Lu) = q × 10² / LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	8.18E-07	0.04	4
2	5.55E-07	0.04	7
3	8.03E-07	0.06	10
4	5.55E-07	0.04	7
5	4.53E-07	0.03	4

Signature of in-charge:

LUGEON CHART

Lugeon
Pressure (bar)

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Ayago Pre-feasibility Study:
Geological Investigations

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Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381183.964	259365.73	875.125	**LUGEON TEST**	
Borehole No.	B5	(Investigation hole)			FRM: 20.018	rev 0
Date:	15-Aug-10			Test No. 18 From 95.0 m to 100.0 m	
Time of start:	8:50	Time of finish:	9:50		

Pressure Gauge Height - C (cm) — 80

Length of Test Section- L (cm) — 500
Dia of Test Section 2r (mm) — 7.6

Time for each period (min) — 10

Stage method — down stage

Packer: Single ☑ Double ☐

Water table depth

a) Water table B₁ (cm) — 2320

b) Centre of Test Section B₂ (cm) — 9750

875.1

B₁

Water table

L

C

Water Meter

Hose pipe length (m) = 120

Hf = 1200 cm

2r

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	422.3				water test done by single
1	2800	2320	4000	423.6	1.30	0.13	0.07	packer
2	5800	2320	7000	424.5	0.90	0.09	0.03	"
3	8800	2320	10000	426.5	2.00	0.20	0.04	"
4	5800	2320	7000	427.8	1.30	0.13	0.04	"
5	2800	2320	4000	428.3	0.50	0.05	0.03	"
							0.04	

Interpretation: Tight rock

Permeability k = [q × 10⁻¹ × ln(L/r)] / (2πLH × 60)

Q = litre/min   r = 3.8

Lugeon value (Lu) = q × 10³ / L H

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure [kg/cm²]
1	8.41E-07	0.07	4
2	3.33E-07	0.03	7
3	5.18E-07	0.04	10
4	4.81E-07	0.04	7
5	3.24E-07	0.03	4

LUGEON CHART

Signature of in-charge

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Ayago Pre-feasibility Study: Geological Investigations

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PMHU-10-022

LUGEON TEST

FRM: 20.019   rev 0

Location	EASTING	NORTHING	ELEVATION
Powerhouse Area	381183.964	259365.73	875.125

Borehole No.	B5	(Investigation hole)

Date:	15-Aug-10			Test No. 19 From 100.0 m to 105.0 m
Time of start:	16:20	Time of finish:	17:20	

Pressure Gauge Height - C (cm)   80

Length of Test Section- L (cm)   500

Dia of Test Section 2r (mm)   7.6

Time for each period (min)   10

Stage method   down stage

Packer: Single [x]   Double [ ]

Water table depth

a) Water table B₁ (cm)   2320

b) Centre of Test Section B₂ (cm)   10250

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

875.1

C

Water Meter

Hose pipe length (m) = 120

Hf = 1200 cm

B₁

B₂

Water table

L

2r

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (ltr/min)	Lugeon value [Lu]	Remarks
0	0	0	0	465.1				water test done by single
1	2800	2320	4000	466.4	1.30	0.13	0.06	packer
2	5800	2320	7000	468.1	1.70	0.17	0.05	"
3	8800	2320	10000	470.5	2.40	0.24	0.05	"
4	5800	2320	7000	472.2	1.70	0.17	0.05	"
5	2800	2320	4000	473.3	1.10	0.11	0.06	"
							0.06	

Interpretation: Tight rock

Permeability k =   (q × 10⁻¹ × ln(L/r)) / (2πL × 60)

Q =   ltr/min

i =   3.8

Lugeon value (Lu) = q × 10² / (L × H)

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	8.41E-07	0.06	4
2	6.29E-07	0.05	7
3	6.21E-07	0.05	10
4	6.29E-07	0.05	7
5	7.12E-07	0.06	4

Signature of in-charge

LUGEON CHART

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Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381183.964	259365.73	875.125	**LUGEON TEST**	
Borehole No.	B5	(Investigation hole)			FRM 20.020 rev 0
Date:	16-Aug-10			Test No. 20 From 105.0 m to 110.0 m	
Time of start:	11:10	Time of finish:	12:10		

Pressure Gauge Height - C (cm) 80

Length of Test Section- L (cm) 500

Dia of Test Section 2r (mm) 7.6

Time for each period (min) 10

Stage method down stage

Packer: Single [ ] Double [ ]

Water table depth

a) Water table B₁ (cm) 2320

b) Centre of Test Section B₂ (cm) 10750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (ltr/min)	Lugeon value [Lu]	Remarks
0	0	0	0	510.2				water test done by single
1	2800	2320	4000	511.5	1.30	0.13	0.07	packer
2	5800	2320	7000	512.9	1.40	0.14	0.04	"
3	8800	2320	10000	514.8	1.90	0.19	0.04	"
4	5800	2320	7000	516.0	1.20	0.12	0.03	"
5	2800	2320	4000	516.5	0.50	0.05	0.03	"
							0.04	

Interpretation: Tight rock

Permeability k = (q x 10⁻¹ x ln(L/r)) / (2πLt x 60)

Q = litre/min   t = 3.8

Lugeon value (Lu) = q x 10³ / LH

LUGEON CHART

Period/ Step	Permeability (k)	Lugeon value (Lu)	Pressure (kgf/cm²)
1	8.41E-07	0.07	4
2	5.18E-07	0.04	7
3	4.92E-07	0.04	10
4	4.44E-07	0.03	7
5	3.24E-07	0.03	4

Signature of in-charge

Project for Water Plan Study on Hydropower Development				GEOTECH SOLUTIONS [U] LTD	
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Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381183.984	259365.73	875.125	**LUGEON TEST**	
Borehole No.	B5	(Investigation hole)			FRM. 20.021 rev 0
Date:	16-Aug-10		Test No. 21 From 110.0 m to 115.0 m		
Time of start:	16:15	Time of finish: 17:15			

Pressure Gauge Height - C (cm)   80

Length of Test Section- L (cm)   500

Dia of Test Section 2r (mm)   7.6

Time for each period (min)   10

Stage method   down stage

Packer: Single [✓]   Double [ ]

Water table depth

a) Water table B₁ (cm)   2320

b) Centre of Test Section B₂ (cm)   11250

WATER PRESSURE IN HEAD CALCULATION:

H = A + B + C - Hf

Hf (friction loss of energy in injection pipe) = 10 cm/m

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm] A	Static water head [cm] B	Water pressure in head [cm] H	Meter reading [litres]	Water take [litres]	Water injection Rate q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	582.7				water test done by single
1	2800	2320	4000	584.2	1.50	0.15	0.08	packer
2	5800	2320	7000	585.5	1.30	0.13	0.04	"
3	8800	2320	10000	588.0	2.50	0.25	0.05	"
4	5800	2320	7000	589.8	1.80	0.18	0.05	"
5	2800	2320	4000	590.5	0.70	0.07	0.04	"
							0.08	

Interpretation: Tight rock

Permeability k = (q × 10⁻¹ × ln(r/r)) / (2πLt × 60)

Q = litre/min   t = 3.8

Lugeon value (Lu) = q × 10² / (Lt)

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	9.71E-07	0.08	4
2	4.81E-07	0.04	7
3	6.47E-07	0.05	10
4	6.86E-07	0.05	7
5	4.53E-07	0.04	4

LUGEON CHART

Signature of geologist

JICA STUDY TEAM

Ayago Pre-feasibility Study:
Geological Investigations

GEOTECH SOLUTIONS [U] LTD

Location	EASTING	NORTHING	ELEVATION			PMHU-10-022
Powerhouse Area	381512.473	259123.827	868.827	**LUGEON TEST**		
Borehole No.	B5	(Investigation hole)			FRM. 20.022	rev 0
Date:	26-Aug-10			Test No. 1 From 10.0 m to 15.0 m		
Time of start:	7:05	Time of finish:	8:25			

Pressure Gauge Height - C (cm) 90

Length of Test Section- L (cm) 500

Dia of Test Section 2r (mm) 7.8

Time for each period (min) 10

Stage method down stage

Packer: Single ☐ Double ☐

Water table depth

a) Water table B_1 (cm) nil

b) Centre of Test Section B_2 (cm) 1250

WATER PRESSURE IN HEAD CALCULATION:

H = A + B + C - Hf

Hf (friction loss of energy in injection pipe) = 10 cm/m

868.827

B_1

Water table

B_2

L

2r

Pressure gauge

C

Water Meter

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	670.4				water test done by single
1	870	1250	1000	682.5	12.10	1.21	2.42	packer
2	3870	1250	4000	725.2	42.70	4.27	2.14	"
3	6870	1250	7000	800.8	75.60	7.56	2.16	"
4	9870	1250	10000	908.1	107.30	10.73	2.15	"
5	6870	1250	7000	982.4	74.30	7.43	2.12	"
6	3870	1250	4000	1024.7	42.30	4.23	2.12	"
7	870	1250	1000	1035.3	10.60	1.06	2.12	"
							2.17	

Interpretation: Laminar flow

LUGEON CHART

Permeability $k = q \times 10^3 \times \ln(L/r) / (2\pi \times L \times 60)$

Q = lit/min   r = 3.8

Lugeon value (Lu) = q x 10^n / LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure [kg/cm²]
1	3.13E-05	2.42	1
2	2.76E-05	2.14	4
3	2.80E-05	2.16	7
4	2.78E-05	2.15	10
5	2.75E-05	2.12	7
6	2.74E-05	2.12	4
7	2.74E-05	2.12	1

Signature of Incharge

Project for Water Plan Study on Hydropower Development				GEOTECH SOLUTIONS [U] LTD	
JICA STUDY TEAM		**Ayago Pre-feasibility Study: Geological Investigations**			

Location	EASTING	NORTHING	ELEVATION	**LUGEON TEST**	PMHU-10-022
Powerhouse Area	381512.473	259123.827	868.827		
Borehole No.	B5	(Investigation hole)			FRM 20.023 rev 0
Date:	26-Aug-10			Test No. 2 From 15.0 m to 20.0 m	
Time of start:	15:30	Time of finish:	16:50		

Pressure Gauge Height - C (cm) 90

Length of Test Section - L (cm) 500

Dia of Test Section 2r (mm) 7.6

Time for each period (min) 10

Stage method down stage

Packer: Single ☐ Double ☐

Water table depth

a) Water table B₁ (cm) 1780

b) Centre of Test Section B₂ (cm) 1750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	1164.2				water test done by single
1	360	1760	1000	1173.7	9.50	0.95	1.90	packer
2	3360	1760	4000	1210.9	37.20	3.72	1.86	"
3	6360	1760	7000	1276.5	65.60	6.56	1.87	"
4	9360	1760	10000	1370.8	94.30	9.43	1.89	"
5	6360	1760	7000	1436.2	65.40	6.54	1.87	"
6	3360	1760	4000	1473.6	37.40	3.74	1.87	"
7	360	1760	1000	1482.2	8.60	0.86	1.72	"
							1.85	

Interpretation: Laminar Flow

Permeability k = q x 10² x ln(L/r) / (2πL x 60)

$Q =$ lit/min   r = 3.8

Lugeon value (Lu) = q x 10² / LH

Period/ Step	Permeability [K]	Lugeon value (Lu)	Pressure (kg/cm²)
1	2.46E-05	1.90	1
2	2.41E-05	1.86	4
3	2.43E-05	1.87	7
4	2.44E-05	1.89	10
5	2.42E-05	1.87	7
6	2.42E-05	1.87	4
7	2.23E-05	1.72	1

LUGEON CHART

Signature of in-charge

JICA STUDY TEAM

**Ayago Pre-feasibility Study:
Geological Investigations**

**GEOTECH
SOLUTIONS [U] LTD**

Location	EASTING	NORTHING	ELEVATION							PMHU-10-022
Powerhouse Area	381512.473	259123.827	868.827	**LUGEON TEST**						
Borehole No.	B5	(Investigation hole)							FRM. 20.024	rev 0
Date:	27-Aug-10			Test No.	3	From	20.0	m	to 25.0 m	
Time of start:	8:10	Time of finish:	9:30							

Pressure Gauge Height - C (cm)   90

Length of Test Section- L (cm)   500

Dia of Test Section 2r (mm)   7.6

Time for each period (min)   10

Stage method   down stage

Packer: Single ☐   Double ☐

Water table depth

a) Water table B_1 (cm)   1760

b) Centre of Test Section B_2 (cm)   2250

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

868.827

B_1

Water table

L

2r

C

B_2

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	1512.6				water test done by single
1	360	1760	1000	1517.9	5.30	0.53	1.06	packer
2	3360	1760	4000	1538.9	21.00	2.10	1.05	.
3	6360	1760	7000	1576.7	37.80	3.78	1.08	.
4	9360	1760	10000	1635.4	58.70	5.87	1.17	.
5	6360	1760	7000	1672.4	37.00	3.70	1.06	.
6	3360	1760	4000	1693.0	20.60	2.06	1.03	.
7	360	1760	1000	1698.2	5.20	0.52	1.04	.
							1.07	

Interpretation: Laminar flow

Permeability $k = q \times 10^3 \times \ln(L/r) / (2\pi L \times H)$

$Q =$ litre/min $r = 3.8$

Lugeon value (Lu) = q x 10³ / L H

LUGEON CHART

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	1.37E-05	1.06	1
2	1.36E-05	1.05	4
3	1.40E-05	1.08	7
4	1.52E-05	1.17	10
5	1.37E-05	1.06	7
6	1.33E-05	1.03	4
7	1.35E-05	1.04	1

■Lugeon
■Pressure (bar)

Signature of in-charge

JICA STUDY TEAM

Ayago Pre-feasibility Study: Geological Investigations

GEOTECH SOLUTIONS (U) LTD

Location	EASTING	NORTHING	ELEVATION					PMHU-10-022
Powerhouse Area	381512.473	259123.827	868.827	**LUGEON TEST**				
Borehole No.	B5	(Investigation hole)					FRM. 20.028	rev 0
Date:	27-Aug-10			Test No. 4 From 25.0 m to 30.0 m				
Time of start:	17:15	Time of finish:	18:35					

Pressure Gauge Height - C (cm) 90

Length of Test Section- L (cm) 500

Dia of Test Section 2r (mm) 7.6

Time for each period (min) 10

Stage method down stage

Packer: Single ☑ Double ☐

Water table depth

a) Water table B_1 (cm) 1760

b) Centre of Test Section B_2 (cm) 2750

WATER PRESSURE IN HEAD CALCULATION:

H = A + B + C - Hf

Hf (friction loss of energy in injection pipe) = 10 cm/m

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	1780.2				water test done by single
1	360	1760	1000	1782.8	2.70	0.27	0.54	packer
2	3360	1760	4000	1794.2	11.30	1.13	0.56	"
3	6360	1760	7000	1812.8	18.60	1.88	0.53	"
4	9360	1760	10000	1840.4	27.60	2.76	0.55	"
5	6360	1760	7000	1859.3	18.90	1.89	0.54	"
6	3360	1760	4000	1870.1	10.80	1.08	0.54	"
7	360	1760	1000	1872.8	2.70	0.27	0.54	"
							0.54	

Interpretation: Laminar flow

LUGEON CHART

Permeability $k = q \times 10^{-3} \times \ln(L/r) / (2\pi L \times 90)$

$Q = $ lit/min $r = $ 3.8

Lugeon value (Lu) = $q \times 10^5 / LH$

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	6.90E-06	0.54	1
2	7.31E-06	0.56	4
3	6.88E-06	0.53	7
4	7.14E-06	0.55	10
5	6.99E-06	0.54	7
6	6.99E-06	0.54	4
7	6.99E-06	0.54	1

Signature of in-charge

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Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381512.473	259123.827	868.827	**LUGEON TEST**	
Borehole No.	B5	(Investigation hole)			FRM. 20.028 rev 0
Date:	4-Sep-10			Test No. 5 From 30.0 m to 35.0 m	
Time of start:	11:05	Time of finish:	12:25		

Pressure Gauge Height - C (cm) — 90

Length of Test Section- L (cm) — 500

Dia of Test Section 2r (mm) — 7.8

Time for each period (min) — 10

Stage method — down stage

Packer: Single ☐ Double ☐

Water table depth

a) Water table B₁ (cm) — 1760

b) Centre of Test Section B₂ (cm) — 3250

Pressure gauge

868.827

Hose pipe length (m) = 120

Hf = 1200 cm

Water table

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	1950.1				water test done by single
1	360	1760	1000	1954.7	4.60	0.46	0.92	packer
2	3360	1760	4000	1972.3	17.60	1.76	0.88	"
3	6360	1760	7000	2003.4	31.10	3.11	0.89	"
4	9360	1760	10000	2048.2	44.80	4.48	0.90	"
5	6360	1760	7000	2078.9	30.70	3.07	0.88	"
6	3360	1760	4000	2096.1	17.20	1.72	0.86	"
7	360	1760	1000	2100.3	4.20	0.42	0.84	"
							0.88	

Interpretation: Laminar flow

LUGEON CHART

Permeability k = q x 10⁻² x ln(l/r) / (2πL x 60)

Q = lit/min

r = 3.8

Lugeon value (Lu) = q x 10² / LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	1.19E-05	0.92	1
2	1.14E-05	0.88	4
3	1.15E-05	0.89	7
4	1.16E-05	0.90	10
5	1.14E-05	0.88	7
6	1.11E-05	0.86	4
7	1.09E-05	0.84	1

Signature of in-charge

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Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381512.473	259123.827	868.827	**LUGEON TEST**	
Borehole No.	**B5**	(Investigation hole)			FRM. 20.027 rev 0
Date:	4-Sep-10			Test No. 6 From 35.0 m to 40.0 m	
Time of start:	17:10	Time of finish:	18:30		

Pressure Gauge Height - C (cm) 80

Length of Test Section- L (cm) 500

Dia of Test Section 2r (mm) 7.6

Time for each period (min) 10

Stage method down stage

Packer: Single [ ] Double [ ]

Water table depth

a) Water table B₁ (cm) 1780

b) Centre of Test Section B₂ (cm) 3750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

868.827

B₁

Water table

L

2r

Pressure gauge

C

Water Meter

Hose pipe length (m) = 120

Hf = 1200 cm

B₂

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	2225.6				water test done by single
1	360	1780	1000	2230.9	5.30	0.53	1.06	packer
2	3360	1780	4000	2252.7	21.80	2.18	1.09	"
3	6360	1780	7000	2287.3	34.60	3.46	0.99	"
4	9360	1780	10000	2340.0	52.70	5.27	1.05	"
5	6360	1780	7000	2378.1	38.10	3.81	1.03	"
6	3360	1780	4000	2395.7	19.60	1.98	0.98	"
7	360	1780	1000	2400.6	4.90	0.49	0.98	"
							1.03	

Interpretation: Laminar flow

Permeability k = (q x 10⁻³ x ln(l/r)) / (2πL x 80)

$Q =$ litr/min $r =$ 3.8

Lugeon value (Lu) = q x 10⁷ / (LH)

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kgf/cm²)
1	1.37E-05	1.06	1
2	1.41E-05	1.09	4
3	1.28E-05	0.99	7
4	1.36E-05	1.05	10
5	1.34E-05	1.03	7
6	1.27E-05	0.98	4
7	1.27E-05	0.98	1

LUGEON CHART

Signature of in-charge

JICA STUDY TEAM

Ayago Pre-feasibility Study:
Geological Investigations

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Location	EASTING	NORTHING	ELEVATION							PMHU-10-022
Powehouse Area	381512.473	259123.827	868.827	**LUGEON TEST**						
Borehole No.	B5	(Investigation hois)							FRM 20.028	rev 0
Date:	5-Sep-10			Test No. 7 From 40.0 m to 45.0 m						
Time of start:	7:40	Time of finish:	9:00							

Pressure Gauge Height - C (cm)　　　90

Length of Test Section- L (cm)　　　500
Dia of Test Section 2r (mm)　　　7.6

Time for each period (min)　　　10

Stage method　　　down stage

Packer:　Single ☐　Double ☐

Water table depth

a) Water table B₁ (cm)　　　1760

b) Centre of Test Section B₂ (cm)　　　4250

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	2485.4				water test done by single
1	360	1760	1000	2487.5	2.10	0.21	0.42	packer
2	3360	1760	4000	2496.3	8.80	0.88	0.44	.
3	6360	1760	7000	2511.9	15.60	1.56	0.45	.
4	9360	1760	10000	2535.8	23.90	2.39	0.48	.
5	6360	1760	7000	2552.0	16.20	1.62	0.46	.
6	3360	1760	4000	2560.8	8.80	0.88	0.44	.
7	360	1760	1000	2562.9	2.10	0.21	0.42	.
							0.44	

Interpretation: Laminar flow

LUGEON CHART

Permeability k = q x 10⁻² x ln(r/r) / (2πL x 60)

Q = lit/min　　　r = 3.8

Lugeon value (Lu) = q x 10³ / LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	5.44E-06	0.42	1
2	5.70E-06	0.44	4
3	5.77E-06	0.45	7
4	6.18E-06	0.48	10
5	5.99E-06	0.46	7
6	5.70E-06	0.44	4
7	5.44E-06	0.42	1

■ Lugeon
■ Pressure (bar)

Signature of in-charge

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Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381512.473	259123.827	868.827	**LUGEON TEST**	
Borehole No.	BS	(Investigation hole)			FRM. 20.029 rev 0
Date:	5-Sep-10			Test No. 9 From 45.0 m to 50.0 m	
Time of start:	13:15	Time of finish:	14:35		

Pressure Gauge Height - C (cm)   80

Length of Test Section- L (cm)   500
Dia of Test Section 2r (mm)   7.8

Time for each period (min)   10

Stage method   down stage

Packer: Single ☐   Double ☐

Water table depth

a) Water table B₁ (cm)   1760

b) Centre of Test Section B₂ (cm)   4750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	2623.8				water test done by single
1	360	1760	1000	2625.1	1.30	0.13	0.28	packer
2	3360	1760	4000	2629.6	4.50	0.45	0.23	"
3	6360	1760	7000	2638.5	8.90	0.89	0.25	"
4	9360	1760	10000	2651.6	13.10	1.31	0.26	"
5	6360	1760	7000	2660.0	8.40	0.84	0.24	"
6	3360	1760	4000	2664.6	4.60	0.46	0.23	"
7	360	1760	1000	2665.7	1.10	0.11	0.22	"
							0.24	

Interpretation: Laminar flow

LUGEON CHART

Permeability k =   q x 10⁻⁶ x ln(L/r) / (2π L x H)

$Q = $ lit/min   r = 3.8

Lugeon value (Lu) = q x 10² / (L x)

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	3.37E-06	0.26	1
2	2.91E-06	0.23	4
3	3.29E-06	0.25	7
4	3.39E-06	0.26	10
5	3.11E-06	0.24	7
6	2.96E-06	0.23	4
7	2.85E-06	0.22	1

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Geological Investigations

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Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381512.473	259123.827	868.827	**LUGEON TEST**	
Borehole No.	B5	(Investigation hole)			FRM 20.030 rev 0
Date:	5-Sep-10			Test No. 9 From 50.0 m to 55.0 m	
Time of start:	17:20	Time of finish:	18:40		

Pressure Gauge Height - C (cm)   90

Length of Test Section- L (cm)   500

Dia of Test Section 2r (mm)   7.6

Time for each period (min)   10

Stage method   down stage

Packer: Single ☑   Double ☐

Water table depth

a) Water table B_1 (cm)   1760

b) Centre of Test Section B_2 (cm)   5250

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

868.827 B_1 Water table B_2 L   2r

Pressure gauge   C   Water Meter

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water Injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	2789.6				water test done by single
1	360	1760	1000	2790.4	0.80	0.08	0.18	packer
2	3360	1760	4000	2793.3	2.90	0.29	0.15	"
3	6360	1760	7000	2799.2	5.90	0.59	0.17	"
4	9360	1760	10000	2807.9	8.70	0.87	0.17	"
5	6360	1760	7000	2813.6	5.70	0.57	0.16	"
6	3360	1760	4000	2816.4	2.80	0.28	0.14	"
7	360	1760	1000	2817.1	0.70	0.07	0.14	"
							0.16	

Interpretation: Tight rock

Permeability k = q x 10⁻³ x ln(L/r) / (2πLH·60)

Q = lit/sec   r = 3.8

Lugeon value (Lu) = q x 10³ / LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kgf/cm²)
1	2.07E-06	0.16	1
2	1.86E-06	0.15	4
3	2.18E-06	0.17	7
4	2.25E-06	0.17	10
5	2.11E-06	0.16	7
6	1.81E-06	0.14	4
7	1.81E-06	0.14	1

LUGEON CHART

Signature of in-charge

Project for Water Plan Study on Hydropower Development		**GEOTECH**
JICA STUDY TEAM	**Ayago Pre-feasibility Study: Geological Investigations**	**SOLUTIONS [U] LTD**

Location	EASTING	NORTHING	ELEVATION				PMHU-10-022
Powerhouse Area	381512.473	259123.827	868.827	**LUGEON TEST**			
Borehole No.	**B5**	(Investigation hole)					FRM 20.031 rev 0
Date:	6-Sep-10			Test No.	10 From	55.0 m to 60.0 m	
Time of start:	7:25	Time of finish:	8:45				

Pressure Gauge Height - C (cm) 90

Length of Test Section- L (cm) 500

Dia of Test Section 2r (mm) 7.6

Time for each period (min) 10

Stage method down stage

Packer: Single [ ] Double [ ]

Water table depth

a) Water table B₁ (cm) 1760

b) Centre of Test Section B₂ (cm) 5750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	2920.5				water test done by single
1	360	1760	1000	2920.8	0.30	0.03	0.06	packer
2	3360	1760	4000	2922.5	1.70	0.17	0.08	"
3	6360	1760	7000	2924.9	2.40	0.24	0.07	"
4	9360	1760	10000	2928.6	3.70	0.37	0.07	"
5	6360	1760	7000	2931.1	2.50	0.25	0.07	"
6	3360	1760	4000	2932.4	1.30	0.13	0.07	"
7	360	1760	1000	2932.7	0.30	0.03	0.06	"
							0.07	

Interpretation: Tight rock

Permeability = q(x 10⁻³ x PG/H) / (2π(L x 90)

$Q =$ _____

$r = 3.8$

Lugeon value (Lu) = q x 10³ / LH

LUGEON CHART

Period/ Step	Permeability [K]	Lugeon value (Lu)	Pressure [kg/cm²]
1	7.77E-07	0.06	1
2	1.10E-06	0.08	4
3	8.86E-07	0.07	7
4	9.58E-07	0.07	10
5	9.25E-07	0.07	7
6	8.41E-07	0.07	4
7	7.77E-07	0.06	1

Signature of in-charge

JICA STUDY TEAM

Ayago Pre-feasibility Study:
Geological Investigations

GEOTECH SOLUTIONS [U] LTD

Location	EASTING	NORTHING	ELEVATION				PMHU-10-022
Powerhouse Area	381512.473	259123.827	868.827	**LUGEON TEST**			
Borehole No.	B5	(Investigation hole)				FRM 20.032	rev 0
Date:	6-Sep-10			Test No. 11 From 60.0 m to 65.0 m			
Time of start:	13:10	Time of finish:	14:30				

Pressure Gauge Height - C (cm) — 80

Length of Test Section- L (cm) — 500

Dia of Test Section 2r (mm) — 7.6

Time for each period (min) — 10

Stage method — down stage

Packer: Single ☐ Double ☐

Water table depth

a) Water table B₁ (cm) — 1760

b) Centre of Test Section B₂ (cm) — 6250

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Pressure gauge

Water Meter

868.827

B₁

Water table

B₂

C

L

2r

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	3052.6				water test done by single
1	360	1760	1000	3052.8	0.20	0.02	0.04	packer
2	3360	1760	4000	3053.9	1.10	0.11	0.05	"
3	6360	1760	7000	3055.8	1.90	0.19	0.05	"
4	9360	1760	10000	3058.5	2.70	0.27	0.05	"
5	6360	1760	7000	3059.9	1.40	0.14	0.04	"
6	3360	1760	4000	3060.7	0.80	0.08	0.04	"
7	360	1760	1000	3060.9	0.20	0.02	0.04	"
							0.05	

Interpretation: Tight rock

LUGEON CHART

Permeability k = q x 10⁻³ x (ln(L/r)) / (2πLH)

Q = lit/min   r = 3.8

Lugeon value (Lu) = q x 10³ / LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	5.18E-07	0.04	1
2	7.12E-07	0.05	4
3	7.03E-07	0.05	7
4	6.99E-07	0.05	10
5	5.18E-07	0.04	7
6	5.16E-07	0.04	4
7	5.18E-07	0.04	1

Signature of in-charge

JICA STUDY TEAM

Ayago Pre-feasibility Study:
Geological Investigations

GEOTECH
SOLUTIONS [U] LTD

PMHU-10-022

Location	EASTING	NORTHING	ELEVATION
Powerhouse Area	381512.473	259123.827	868.827

LUGEON TEST

FRM 20.033 rev 0

Borehole No.	B5	(Investigation hole)

Date:	6-Sep-10		Test No. 12 From 65.0 m to 70.0 m
Time of start:	17:15	Time of finish: 18:35	

Pressure Gauge Height - C (cm) 90

Length of Test Section- L (cm) 500
Dia of Test Section 2r (mm) 7.6

Time for each period (min) 10

Stage method down stage

Packer: Single ☑ Double ☐

Water table depth

a) Water table B₁ (cm) 1760

b) Centre of Test Section B₂ (cm) 6750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Hose pipe length (m) = 120
Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water Injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	3143.2				water test done by single
1	360	1760	1000	3143.5	0.30	0.03	0.06	packer
2	3360	1760	4000	3144.8	1.30	0.13	0.07	"
3	6360	1760	7000	3147.3	2.50	0.25	0.07	"
4	9360	1760	10000	3151.6	4.30	0.43	0.09	"
5	6360	1760	7000	3154.4	2.80	0.28	0.08	"
6	3360	1760	4000	3155.7	1.30	0.13	0.06	"
7	360	1760	1000	3156.0	0.30	0.03	0.06	"
							0.07	

Interpretation: Tight rock

LUGEON CHART

Permeability $k = q \cdot 10^3 \times \ln(L/r) / (2 \pi L \times 60)$

$Q = \frac{litres}{sec}$ $r = 3.8$

Lugeon value (Lu) = q x 10³ / LH

Period/ Step	Permeability [K]	Lugeon value (Lu)	Pressure (kg/cm²)
1	7.77E-07	0.06	1
2	8.41E-07	0.07	4
3	9.25E-07	0.07	7
4	1.11E-06	0.09	10
5	1.04E-06	0.08	7
6	8.41E-07	0.06	4
7	7.77E-07	0.06	1

Signature of in-charge

Project for Mater Plan Study on Hydropower Development			
JICA STUDY TEAM		Ayago Pre-feasibility Study: Geological Investigations	**GEOTECH SOLUTIONS [U] LTD**

Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381512.473	259123.827	868.827	**LUGEON TEST**	
Borehole No.	B6	(Investigation hole)			FRM 20.034 rev 0
Date:	7-Sep-10			Test No. 13 From 70.0 m to 75.0 m	
Time of start:	7:10	Time of finish:	8:30		

Pressure Gauge Height - C (cm)   80

Length of Test Section- L (cm)   500

Dia of Test Section 2r (mm)   7.8

Time for each period (min)   10

Stage method   down stage

Packer: Single ☐   Double ☐

Water table depth

a) Water table B₁ (cm)   1760

b) Centre of Test Section B₂ (cm)   7250

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

868.827

B₁

Water table

L

2r

Pressure gauge

C

Water Meter

Hose pipe length (m) = 120

Hf = 1200 cm

B₂

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	3212.4				water test done by single
1	360	1760	1000	3212.9	0.50	0.05	0.10	packer
2	3360	1760	4000	3215.3	2.40	0.24	0.12	"
3	6360	1760	7000	3218.6	3.30	0.33	0.09	"
4	9360	1760	10000	3224.2	5.60	0.56	0.11	"
5	6360	1760	7000	3227.7	3.50	0.35	0.10	"
6	3360	1760	4000	3229.6	1.90	0.19	0.10	"
7	360	1760	1000	3230.1	0.50	0.05	0.10	"
							0.10	

Interpretation: Tight rock

Permeability k =   (q x 10⁻³ x ln(r/l)) / (2π L x 60)

Q =

Lugeon value (Lu) = q x 10³ / LH

r = 3.8

Period/ Step	Permeability [K]	Lugeon value (Lu)	Pressure (kg/cm²)
1	1.29E-06	0.10	1
2	1.55E-06	0.12	4
3	1.22E-06	0.09	7
4	1.45E-06	0.11	10
5	1.29E-06	0.10	7
6	1.23E-06	0.10	4
7	1.29E-06	0.10	1

LUGEON CHART

Signature of in-charge

JICA STUDY TEAM	Ayago Pre-feasibility Study: Geological Investigations	GEOTECH SOLUTIONS (U) LTD

Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381512.473	259123.827	868.827	**LUGEON TEST**	
Borehole No.	B5	(Investigation hole)			FRM 20.036 rev 0
Date:	7-Sep-10			Test No. 14 From 75.0 m to 80.0 m	
Time of start:	13:20	Time of finish:	14:40		

Pressure Gauge Height - C (cm)   80

Length of Test Section- L (cm)   500

Dia of Test Section 2r (mm)   7.8

Time for each period (min)   10

Stage method   down stage

Packer: Single ☐   Double ☐

Water table depth

a) Water table B₁ (cm)   1780

b) Centre of Test Section B₂ (cm)   7750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	3380.7				water test done by single
1	360	1760	1000	3380.9	0.20	0.02	0.04	packer
2	3360	1760	4000	3381.8	0.90	0.09	0.05	"
3	6360	1760	7000	3383.6	1.80	0.18	0.05	"
4	9360	1760	10000	3386.5	2.90	0.29	0.06	"
5	6360	1760	7000	3388.2	1.70	0.17	0.05	"
6	3360	1760	4000	3389.0	0.80	0.08	0.04	"
7	360	1760	1000	3389.2	0.20	0.02	0.04	"
							0.05	

Interpretation: Tight rock

LUGEON CHART

Permeability k = q x 10⁻⁷ x ln(L/r) / (2πLH)

$Q = $ lit/min $r = $ 3.8

Lugeon value (Lu) = q x 10⁵ / LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	5.18E-07	0.04	1
2	5.82E-07	0.05	4
3	6.66E-07	0.05	7
4	7.51E-07	0.06	10
5	6.29E-07	0.05	7
6	5.18E-07	0.04	4
7	5.18E-07	0.04	1

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Ayago Pre-feasibility Study: Geological Investigations

GEOTECH SOLUTIONS [U] LTD

Location	EASTING	NORTHING	ELEVATION				PMHU-10-022
Powerhouse Area	381512.473	259123.827	868.827	**LUGEON TEST**			
Borehole No.	B8	(Investigation hole)				FRM 20.038	rev 0
Date:	7-Sep-10			Test No. 15 From 80.0 m to 85.0 m			
Time of start:	17:20	Time of finish:	18:40				

Pressure Gauge Height - C (cm) 90

Length of Test Section- L (cm) 500

Dia of Test Section 2r (mm) 7.8

Time for each period (min) 10

Stage method down stage

Packer: Single ☐ Double ☐

Water table depth

a) Water table B₁ (cm) 1760

b) Centre of Test Section B₂ (cm) 8250

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Hose pipe length (m) = 120

Hf = 1200 cm

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	3572.5				water test done by single
1	360	1760	1000	3572.8	0.30	0.03	0.06	packer
2	3360	1760	4000	3574.1	1.30	0.13	0.06	"
3	6360	1760	7000	3576.5	2.40	0.24	0.07	"
4	9360	1760	10000	3579.7	3.20	0.32	0.06	"
5	6360	1760	7000	3581.8	2.10	0.21	0.06	"
6	3360	1760	4000	3583.0	1.20	0.12	0.06	"
7	360	1760	1000	3583.3	0.30	0.03	0.06	"
							0.06	

Interpretation: Tight rock

LUGEON CHART

Permeability = q × 10⁻⁴ × ln(L/r) / (2πL × 80)

$Q = $ litres

$r = $ 3.8

Lugeon value (Lu) = q × 10³ / LH

Period/ Step	Permeability [K]	Lugeon value (Lu)	Pressure (kg/cm²)
1	7.77E-07	0.06	1
2	8.41E-07	0.06	4
3	8.86E-07	0.07	7
4	8.28E-07	0.06	10
5	7.77E-07	0.06	7
6	7.77E-07	0.06	4
7	7.77E-07	0.06	1

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JICA STUDY TEAM

Ayago Pre-feasibility Study: Geological Investigations

GEOTECH SOLUTIONS [U] LTD

Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381512.473	259123.827	868.827	**LUGEON TEST**	
Borehole No.	B5	(Investigation hole)			FRM 20.037 rev 0
Date:	8-Sep-10			Test No. 16 From 85.0 m to 90.0 m	
Time of start:	7:15	Time of finish:	8:35		

Pressure Gauge Height - C (cm) 90

Length of Test Section- L (cm) 500

Dia of Test Section 2r (mm) 7.8

Time for each period (min) 10

Stage method down stage

Packer: Single ☐ Double ☐

Water table depth

a) Water table B_1 (cm) 1780

b) Centre of Test Section B_2 (cm) 8750

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

868.827

B_1

Water table

L

2r

Pressure gauge

C

Water Meter

Hose pipe length (m) = 120

Hf = 1200 cm

B_2

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	3717.4				water test done by single
1	360	1760	1000	3717.7	0.30	0.03	0.06	packer
2	3360	1760	4000	3718.4	0.70	0.07	0.04	"
3	6360	1760	7000	3719.9	1.50	0.15	0.04	"
4	9360	1760	10000	3722.2	2.30	0.23	0.05	"
5	6360	1760	7000	3723.7	1.50	0.15	0.04	"
6	3360	1760	4000	3724.3	0.60	0.06	0.03	"
7	360	1760	1000	3724.5	0.20	0.02	0.04	"
							0.04	

Interpretation: Tight rock

LUGEON CHART

Permeability k = q/(10^? x ln(L/r)) / (2πL x 60)

Q = lit/min   r = 3.8

Lugeon value (Lu) = q x 10^? / LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	7.77E-07	0.06	1
2	4.53E-07	0.04	4
3	5.55E-07	0.04	7
4	5.98E-07	0.06	10
5	5.55E-07	0.04	7
6	3.88E-07	0.03	4
7	5.18E-07	0.04	1

Signature of in-charge

JICA STUDY TEAM

Ayago Pre-feasibility Study: Geological Investigations

GEOTECH SOLUTIONS [U] LTD

Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381512.473	259123.827	868.827	**LUGEON TEST**	
Borehole No.	B5	(Investigation hole)			FRM 20.038 rev 0
Date:	8-Sep-10			Test No. 17 From 90.0 m to 95.0 m	
Time of start:	13:25	Time of finish:	14:45		

Pressure Gauge Height - C (cm)	80
Length of Test Section- L (cm)	500
Dia of Test Section 2r (mm)	7.8
Time for each period (min)	10
Stage method	down stage
Packer: Single ☐ Double ☐	
Water table depth	
a) Water table B₁ (cm)	1760
b) Centre of Test Section B₂ (cm)	9250

868.827 — Hose pipe length (m) = 120

Hf = 1200 cm

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	3886.1				water test done by single
1	360	1760	1000	3886.2	0.10	0.01	0.02	packer
2	3360	1760	4000	3886.7	0.50	0.05	0.03	"
3	6360	1760	7000	3887.6	0.90	0.09	0.03	"
4	9360	1760	10000	3889.2	1.60	0.16	0.03	"
5	6360	1760	7000	3889.9	0.70	0.07	0.02	"
6	3360	1760	4000	3890.3	0.40	0.04	0.02	"
7	360	1760	1000	3890.4	0.10	0.01	0.02	"
							0.02	

Interpretation:	Tight rock

LUGEON CHART

Permeability k = q(q x 10⁻³ x ln(L/r)) / (2πL x 80)

Q = lit/min   r = 3.8

Lugeon value (Lu) = q x 10⁵ / LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	2.59E-07	0.02	1
2	3.24E-07	0.03	4
3	3.33E-07	0.03	7
4	4.14E-07	0.03	10
5	2.59E-07	0.02	7
6	2.59E-07	0.02	4
7	2.59E-07	0.02	1

Signature of in-charge

JICA STUDY TEAM

Ayago Pre-feasibility Study:
Geological Investigations

GEOTECH
SOLUTIONS [U] LTD

Location	EASTING	NORTHING	ELEVATION		PMHU-10-022
Powerhouse Area	381512.473	259123.827	868.827	**LUGEON TEST**	
Borehole No.	B5	(Investigation hole)			FRM 20.038 rev 0
Date:	8-Sep-10			Test No. 19 From 95.0 m to 100.0 m	
Time of start:	17:10	Time of finish:	18:30		

Pressure Gauge Height - C (cm)	90
Length of Test Section- L (cm)	500
Dia of Test Section 2r (mm)	7.6
Time for each period (min)	10
Stage method	down stage
Packer: Single ☐ Double ☐	
Water table depth	
a) Water table B_1 (cm)	1760
b) Centre of Test Section B_2 (cm)	9750

Hose pipe length (m) = 120
Hf = 1200 cm

WATER PRESSURE IN HEAD CALCULATION:

$H = A + B + C - Hf$

Hf (friction loss of energy in injection pipe) = 10 cm/m

Period/ Step	Gauge Pressure [cm]: A	Static water head [cm]: B	Water pressure in head [cm]: H	Meter reading [litres]	Water take [litres]	Water injection Rate: q (lit/min)	Lugeon value [Lu]	Remarks
0	0	0	0	4028.4				water test done by single
1	360	1760	1000	4028.6	0.20	0.02	0.04	packer
2	3360	1760	4000	4029.2	0.60	0.06	0.03	"
3	6360	1760	7000	4030.3	1.10	0.11	0.03	"
4	9360	1760	10000	4032.0	1.70	0.17	0.03	"
5	6360	1760	7000	4033.0	1.00	0.10	0.03	"
6	3360	1760	4000	4033.5	0.50	0.05	0.03	"
7	360	1760	1000	4033.6	0.10	0.01	0.02	"
							0.03	

Interpretation: Tight rock

Permeability $k = q \times 10^3 \times \ln(L/r) / (2\pi L \times H)$

$Q = $ litres/min $r = $ 3.8

Lugeon value (Lu) = q x 10³ / LH

Period/ Step	Permeability [k]	Lugeon value (Lu)	Pressure (kg/cm²)
1	5.18E-07	0.04	1
2	3.88E-07	0.03	4
3	4.07E-07	0.03	7
4	4.40E-07	0.03	10
5	3.70E-07	0.03	7
6	3.24E-07	0.03	4
7	2.59E-07	0.02	1

LUGEON CHART

Signature of in-charge

5. Water Level Monitoring Data

Geological Investigations for Project for Hydropower Development in Uganda
Pre-feasibility Study Stage

Daily River Water Level Readings for Ayago Hydro Electric Power Project

Staff Gauge Location   Easting: 381433.877   Northing: 259368.566
                         Zero Reading = 845.575

Area: intake   Year: 2010

	July	Aug	Sept	Oct
1	~	-	846.025	846.075
2	~	-	846.075	846.065
3	-	-	846.055	846.055
4	~	~	846.055	846.065
5	~	-	846.045	846.065
6	~	~	846.045	846.075
7	~	-	846.025	846.075
8	-	-	846.025	-
9	~	~	846.015	-
10	~	-	846.005	-
11	-	-	846.015	-
12	~	-	846.045	-
13	~	-	846.055	846.055
14	)	-	846.055	
15	~	845.995	846.045	
16	~	846.015	846.075	
17	-	846.005	846.075	
18	~	846.005	846.065	
19	~	846.015	846.075	
20	~	846.025	846.075	
21	~	846.035	846.075	
22	-	845.985	846.055	
23	~	846.005	846.055	
24	~	846.005	846.035	
25	-	845.995	846.045	
26	~	846.005	846.045	
27	~	846.005	846.055	
28		846.025	846.065	
29	~	846.025	846.065	
30	~	846.025	846.075	
31	~	846.025		

River elevations in meters

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Geological Investigations for Project for Hydropower Development in Uganda
Pre-feasibility Study Stage

Daily River Water Level Readings for Ayago Hydro Electric Power Project

Staff Gauge Location   Easting: **374078.159**   Northing: **260866.002**

         Zero Reading = **764.034**

Area: **outlet**   Year: **2010**

	July	Aug	Sept	Oct
1	-	-	764.814	764.834
2	-	-	764.834	764.834
3	-	-	764.824	764.824
4	-	-	764.824	764.824
5	-	-	764.814	764.824
6	-	-	764.804	764.824
7	-	-	764.804	764.834
8	-	-	764.814	-
9	-	-	764.814	-
10	-	-	764.814	-
11	-	-	764.824	-
12	-	-	764.824	-
13	-	-	764.814	764.814
14	-	-	764.814	
15	-	764.804	764.814	
16	-	764.804	764.824	
17	-	764.804	764.824	
18	-	764.814	764.824	
19	-	764.814	764.824	
20	-	764.804	764.834	
21	-	764.804	764.834	
22	-	764.794	764.834	
23	-	764.794	764.834	
24	-	764.794	764.834	
25	-	764.794	764.824	
26	-	764.794	764.824	
27	-	764.794	764.824	
28	-	764.804	764.824	
29	-	764.804	764.824	
30	-	764.804	764.834	
31	-	764.804		

River elevations in meters

JICA Study Team   GeoTech Solutions (U) Ltd

Ground water measurements in drilled boreholes for Ayago Hydro Electric Power Project

Bore hole number	Water level reading from hole collar (m)	Date of measurement
B1	13.9	26-Sep-10
B2	8.3	14-Sep-10
"	9.0	15-Sep-10
B3	14.8	23-Aug-10
"	15.2	24-Aug-10
B4	10.5	10-Sep-10
"	11.3	11-Sep-10
B5	22.2	10-Aug-10
"	22.4	11-Aug-10
"	22.4	12-Aug-10
"	22.8	13-Aug-10
"	22.8	14-Aug-10
"	23.2	15-Aug-10
"	23.2	16-Aug-10
B6	17.2	27-Aug-10
"	17.4	28-Aug-10
"	17.4	29-Aug-10
"	17.4	30-Aug-10
"	17.4	31-Aug-10
"	17.4	1-Sep-10
"	17.5	2-Sep-10
"	17.5	3-Sep-10
"	17.5	4-Sep-10
"	17.5	5-Sep-10
"	17.5	6-Sep-10
"	17.6	7-Sep-10
"	17.6	8-Sep-10
B7	20.1	19-Sep-10
"	20.1	20-Sep-10
B8	11.7	22-Sep-10

JICA Study Team   GeoTech Solutions (U) Ltd

6. Field Photographs

General Photos

General road condition of gravel road in the park after the turning on the Kampala-Karuma
Location: E: 411122, N: 234029 (approximately)

Main camp for geological investigations team on the southern bank
Location: E: 380516, N: 259029

General Photos

"Ayago" sign post on the Karuma - Packwach Highway

Backfilling of a mud pit for a completed borehole
Location: E: 381184, N: 259336

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Staff gauges

Dragging of staff gauge to outlet location

Dragging of staff gauge into the river

Staff gauges

Positioning of staff gauge in the river
Location E: 374078.159, N: 260866.002, Zero Reading = 764.034
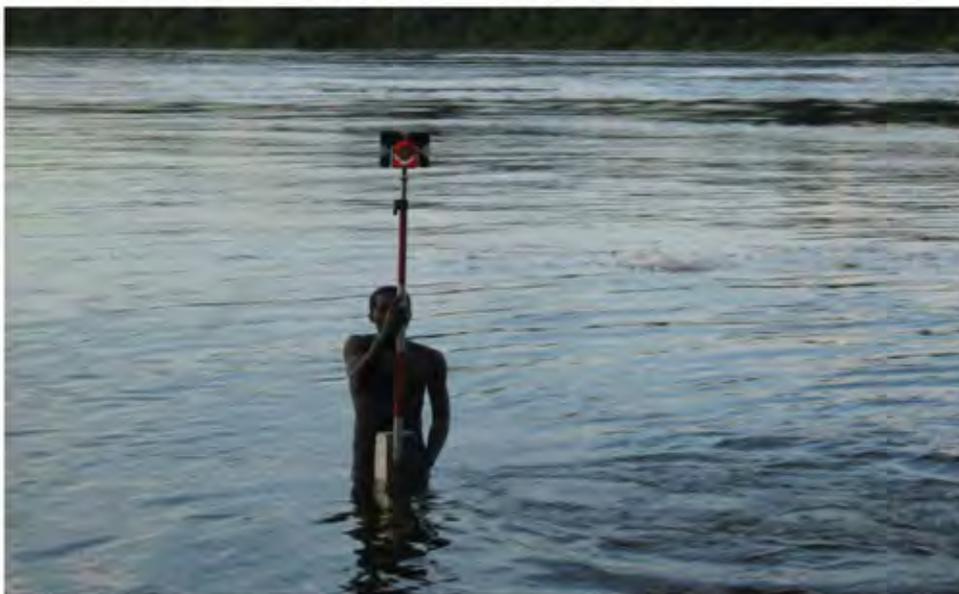
Surveying of installed staff gauge location, and the river water level
Location E: 374078.159, N: 260866.002, Zero Reading = 764.034

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Staff gauges

Installed staff gauge location at inlet area

Location   E: 381433.877
            N: 259368.566
            Zero Reading = 845.575

Site condition photographs at drill points

Site conditions at borehole: B1
Location: E: 381809.352, N: 259900.428, Ground Elevation: 866.647

Site conditions at borehole: B2
Location: E: 381260.110, N: 259538.086, Ground Elevation: 856.536

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Site condition photographs at drill points

Site conditions at borehole: B3
Location: E: 381294.839, N: 259412.349, Ground Elevation: 862.146

Site conditions at borehole: B4
Location: E: 381591.382, N: 259190.542, Ground Elevation: 864.924

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Site condition photographs at drill points

Site conditions at borehole: B5
Location: E: 381183.963, N: 259365.727, Ground Elevation: 875.125

Site conditions at borehole: B6
Location: E: 381512.473, N: 259123.827, Ground Elevation: 868.827

Site condition photographs at drill points

Site conditions at borehole: B7
Location: E: 374078.159, N: 260757.248, Ground Elevation: 795.664

Site conditions at borehole: B8
Location: E: 374252.443, N: 260823.751, Ground Elevation: 796.535

Geological

Location of photos is shown in Geological Map

P1: Foliation in a weathered rock outcrop
Location E: 375105, N: 260720 (approximately)

P2: Jointing in a rock outcrop
Location E: 374231, N: 260901 (approximately)

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Geological

Location of photos is shown in Geological Map

P3: Micro folding in a rock outcrop
    Location E: 381298, N: 259500 (approximately)

P4: Stream channels, common towards the river banks
    Location E: 374386, N: 260794 (approximately)

Geological

Location of photos is shown in Geological Map

P5: Dry seasonal stream channel exposing rock
Location E: 380884, N: 250067 (approximately)

Water level measurements in a borehole after installation of screen PVC at Drilling Point B-2
Location: E: 381260.110, N: 259538.086, Ground Elevation: 856.536

7. Laboratory Test Results

CENTRAL MATERIALS LABORATORY

PROJECT : AYAGO HYDRO ELECTRIC POWER
CLIENT : M/S GEOTECH SOLUTIONS (U) LTD.
DATE : 8 OCTOBER 2010

TEST RESULTS FOR POTENTIAL ALKALI-SILICA REACTIVITY OF AGGREGATES (CHEMICAL METHOD) FOR A SAMPLE OF ROCK CORE (TESTED IN ACCORDANCE WITH PROCEDURES IN ASTM C289-94)

SOURCE OF ROCK CORES - B-5

PARAMETER	TEST METHOD	RESULTS
Reduction in alkalinity, RC (ppm)	Titration	358
Dissolved silica, Sc, (ppm)	Spectrophotometry	58

Remarks: The tests were done jointly by the Central Materials Laboratory and the Government Analytical Laboratory.

Interpretation of Results: From the Graph (photocopy attached)

Rc - Y axis
Sc - X axis

P, the point of intersection, lies in the area where the aggregates are considered innocuous on the basis of reduction in alkalinity and dissolved silica.
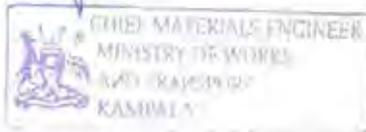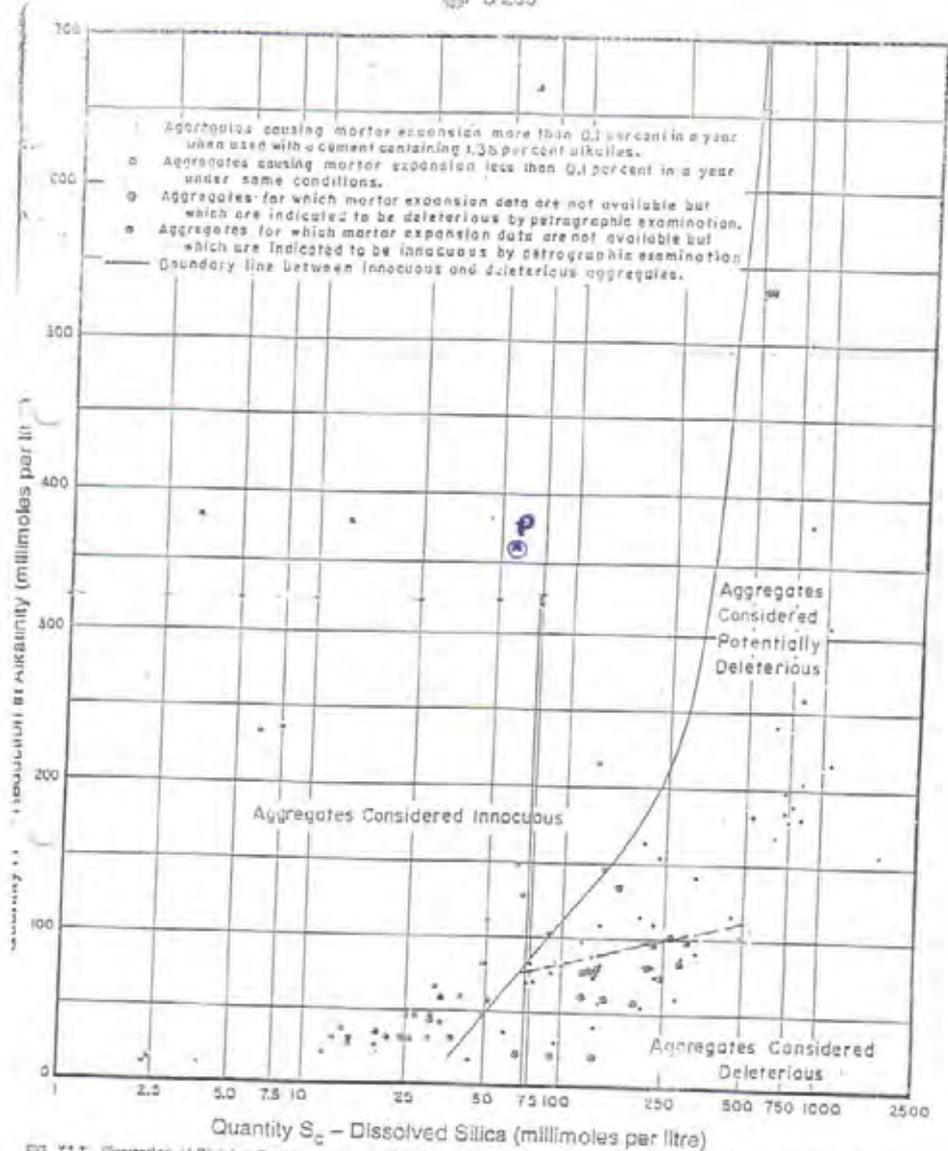
FIG. X1.1 Illustration of Division Between Innocuous and Deleterious Aggregates on Basis of Reduction in Alkalinity Test
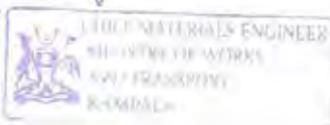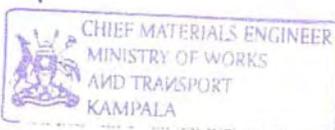
CENTRAL MATERIALS LABORATORY

PROJECT : AYAGO HYDRO ELECTRIC POWER
CLIENT : M/S GEOTECH SOLUTIONS (U) LTD.
DATE : 8 OCTOBER 2010

A. TEST RESULTS FOR LOS ANGELES ABRASION VALUE FOR A
SAMPLE OF ROCK CORES

SAMPLE LABEL BOREHOLE NUMBER	LOS ANGELES ABRASION VALUE (%)	PERMISSIBLE LIMITS BS 812 (CONCRETE WORKS)
B-5	40	50 Maximum

B. TEST RESULTS FOR SODIUM SULPHATE SOUNDNESS VALUE

SAMPLE LABEL BOREHOLE NUMBER	SODIUM SULPHATE SOUNDNESS VALUE (%)	PERMISSIBLE LIMITS BS 812 (CONCRETE WORKS)
B-5	1.5	12 Maximum

CENTRAL MATERIALS LABORATORY
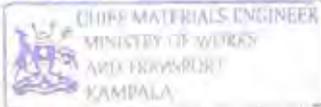
PROJECT   :   AYAGO HYDRO ELECTRIC POWER
CLIENT   :   M/S GEOTECH SOLUTIONS (U) LTD.
DATE   :   8 OCTOBER 2010

TEST RESULTS FOR WATER ABSORPTION FOR ROCK CORE

SAMPLE LABEL BOREHOLE NUMBER		WATER ABSORPTION (%)
B1	W1	0.22
	W2	0.15
B2	W1	0.08
	W2	0.09
B3	W1	0.08
	W2	0.11
B4	W1	0.05
	W2	0.05
B5	W1	0.13
	W2	0.06
	W3	0.19
B6	W1	0.05
	W2	0.09
B8	W1	0.21
	W2	0.61

CHIEF MATERIALS ENGINEER
MINISTRY OF WORKS
AND TRANSPORT
KAMPALA

CENTRAL MATERIALS LABORATORY

PROJECT : AYAGO HYDRO ELECTRIC POWER
CLIENT : M/S GEOTECH SOLUTIONS (U) LTD.
DATE : 8 OCTOBER 2010

TEST RESULTS FOR A SAMPLE OF ROCK CORE
UNCONFINED COMPRESSIVE STRENGTH TESTS AND BULK SPECIFIC
GRAVITY SPECIMEN

DIAMETER   =   61mm
SPECIMEN LENGTH =   75mm

APPROIMATE LENGTH: DIAMETER RATIO = 1.2:1

SAMPLE LABEL	BOREHOLE NUMBER	UNCONFINED COMPRESSIVE STRENGTH (N/mm^2)	BULK SPECIFIC GRAVITY (AVERAGE)
B1	U1	22.99	2.83
	U2	22.99	
B2	U1	37.14	2.87
	U2	28.29	
B3	U1	21.22	
	U2	43.86	2.86
	U3	42.44	
B4	U1	22.99	
	U2	38.91	2.75
	U3	49.52	
B5	U1	10.61	
	U2	22.99	3.34
	U3	26.53	
	U4	12.36	
B6	U1	53.05	
	U2	31.83	3.12
	U3	37.14	
	U4	56.59	
B8	U1	22.64	2.88
	U2	21.22	

CHIEF MATERIALS ENGINEER
MINISTRY OF WORKS
AND TRANSPORT
KAMPALA

CENTRAL MATERIALS LABORATORY

PROJECT   :   AYAGO HYDRO ELECTRIC POWER
CLIENT   :   M/S GEOTECH SOLUTIONS (U) LTD.
DATE   :   11 OCTOBER 2010

TEST RESULTS FOR AGGREGATE SAMPLES

SOURCE OF AGGREGATES: POSSIBLE QUARRY SITE NYAKYANIKA –
MASINDI (M/S DOTT SERVICES QUARRY)

AGGREGATE SIZE	PARAMETERS			
	LOS ANGELES ABRASION VALUE (%)	WATER ABSORPTION (%)	BULK DENSITY (g/cc)	SODIUM SULPHATE SOUNDNESS (%)
14/20mm	30	0.3	2.65	1.3
10/14mm	30	0.3	2.63	1.2
Permissible Limits: BS 812 (Concrete Works)	50 Maximum	2 Maximum	-	12 Maximum

CHIEF MATERIALS ENGINEER
MINISTRY OF WORKS
AND TRANSPORT
KAMPALA

Recieved
Patrick
14/10/10

Appendix D

Strategic Environmental Assessment Report

TABLE OF CONTENTS

Abbreviations

CR	Critically Endangered (IUCN Red List)
CPI	Community Protected Areas Institutions
EIA	Environmental Impact Assessment
EN	Endangered (IUCN Red List)
EX	Extinct (IUCN Red List)
IDP	Internally Displaced Persons
IUCN	the International Union for Conservation of Nature
JICA	Japan International Cooperation Agency
LC	Least Concern (IUCN Red List)
LRA	Lord Resistance Army
MFNP	Murchison Falls National Park
MFPA	Murchison Falls Protected Area
NEMA	The National Environment Management Authority
NT	Near Threatened
SEA	Strategic Environmental Assessment
UBOS	Uganda Bureau of Statistics
UWA	Uganda Wildlife Authority
VU	Vulnerable (IUCN Red List)

Appendix D

Strategic Environmental Assessment Report

1   Introduction

1.1   Objectives

The objectives of this study are to assess the impact of the power source and proposed project sites in Uganda from positive and negative points of view and to identify one prospective site for follow-up site survey.

1.2   Method

Impact assessments are conducted based on the Strategic Impact Assessment (SEA) method, because this stage is before feasibility study, and the project site and design have not yet been decided. There are three SEAs stages in this study. The first stage is for seven alternative power sources, the second stage is for seven potential sites, and the third stage is for three candidate layouts. All the alternatives are analyzed from economic, environmental, and social points of view. Available quantitative data are evaluated. First and second analyses are based on document survey, and third analyses are based on the site survey.

1.3   Schedule

The first stage was conducted from November 2009 to January 2010, the second stage from November 2009 to February 2010, and the third stage from February 2010 to January 2011. Two stakeholder meetings are held for each stage, one for discussion on TOR/SEA and the second for discussion on result of SEAs. Site survey of the third stage was conducted from July to October 2010.

Table 1.3-1 Schedule of the three SEAs

	2009		2010												2011	
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
1 Scenario Review Stage																
(a) Confirmation of scenarios		▨														
(b) Scoping (Preparation of evaluation framework)		▨														
(c) 1st SHM (discussion on the evaluation framework)		▲														
(d) confirmation of electricity demand		▨														
(e) Information collection		▨														
(f) Impact Assessment			▨													
(g) 2nd SHM (Discussion on the evaluation result)				▲												
(h) Information disclosure	△	△		△									△			
2 Site Selection Stage																
(a) Confirmation of potential points (Long List)		▨														
(b) Scoping (Preparation of evaluation framework)		▨														
(c) 1st SHM (Discussion on the evaluation framework)		▲														
(d) Information collection		▨														
(e) Impact Assessment (Long list)			▨													
(i) 2nd SHM (Discussion on the evaluation result)				▲												
(j) Information disclosure	△	△		△									△			
3 Site Survey Stage																
(a) Confirmation of the possible layouts				▨												
(b) Scoping (Preparation of Evaluation Framework)				▨												
(c) 2nd SHM (Discussion on the evaluation framework)				▲												
(d) Site survey									▨	▨	▨	▨				
(e) Impact Assessment																
(f) 3rd SHM (Discussion on the evaluation result)															▲	
(g) Information disclosure				△									△		△	△
4 Master Plan Preparation Stage																
(a) Preparation on TOR/EIA of F/S stage														▨		
(b) Preparation on Environmental and Social checklist														▨		
(c) Preparation of guideline for SHM														▨		

2 Regulatory Requirements

2.1 SEA for 1st and 2nd stages

The SEA study on stage 1 and stage 2 is based on the following guidelines.

- GUIDELINES FOR STRATEGIC ENVIRONMENT ASSESSMENT (SEA) (December 2006, NATIONAL ENVIRONMENT MANAGEMENT AUTHORITY)
- The Constitution of Uganda (1995, article 39: Every Ugandan has a right to a clean and healthy environment)
- The National Environment Policy, 1994, Energy Policy, Renewable energy policy and various sectoral policies
- National Environment Act CAP 153
- JICA (April 2004) "Japan International Cooperation Agency Guidelines for Environmental and Social Considerations"

2.2 EIA for site survey

The EIA procedure in stage 3 is based on following regulation and guidelines.

- NATIONAL ENVIRONMENT MANAGEMENT AUTHORITY (June 2004) "ENVIRONMENTAL IMPACT ASSESSMENT GUIDELINES FOR THE ENERGY SECTOR"
- National Environment Management Authority (July 1997) "GUIDELINES FOR ENVIRONMENTAL IMPACT ASSESSMENT IN UGANDA"

- The Environmental Impact Assessment Regulations, 1998, UPPC
- JICA (April 2004) "Japan International Cooperation Agency Guidelines for Environmental and Social Considerations"

After reviewing the project brief, this project is categorized as "no EIA needed" by NEMA. Therefore, JICA conducted SEA.

3   Existing Environmental and Social Conditions

3.1   Uganda

3.1.1   Physical Environment

3.1.1.1   Topography

Uganda is located around 1 degree north latitude and 32 degrees east longitude. Altitude in the country ranges from 621 m (Lake Albert) to 5,110 m (Mount Stanley). Land form in the central plain is gently undulating from south to north.
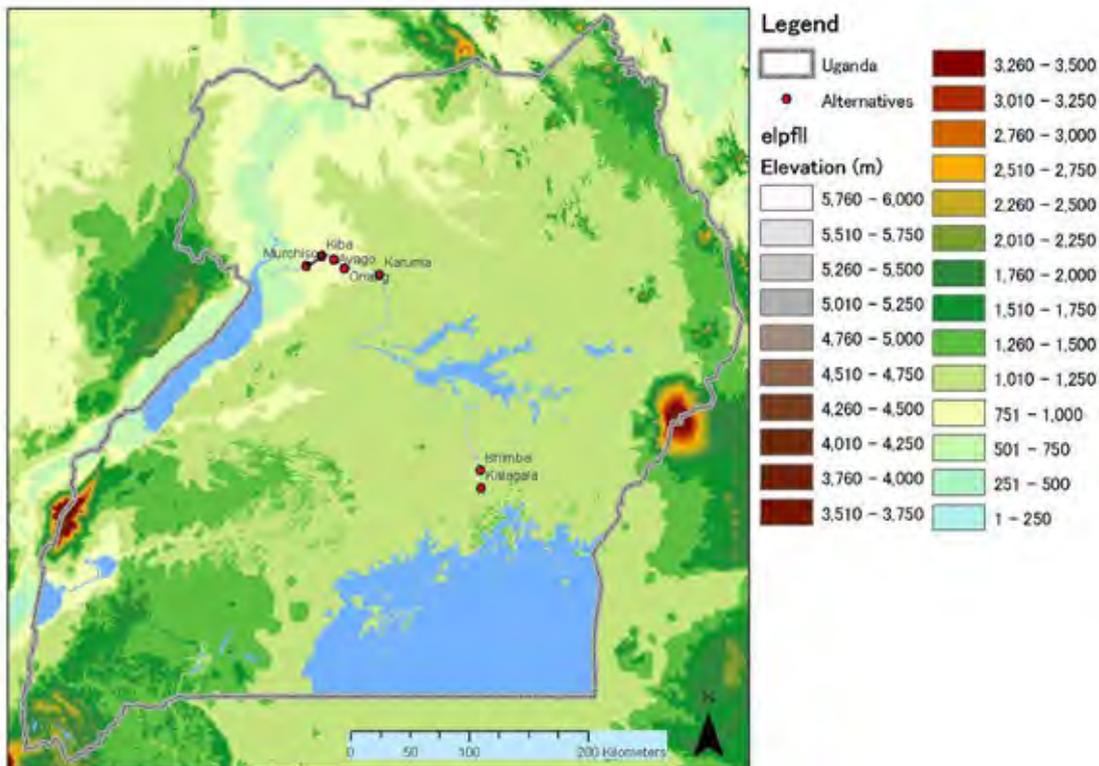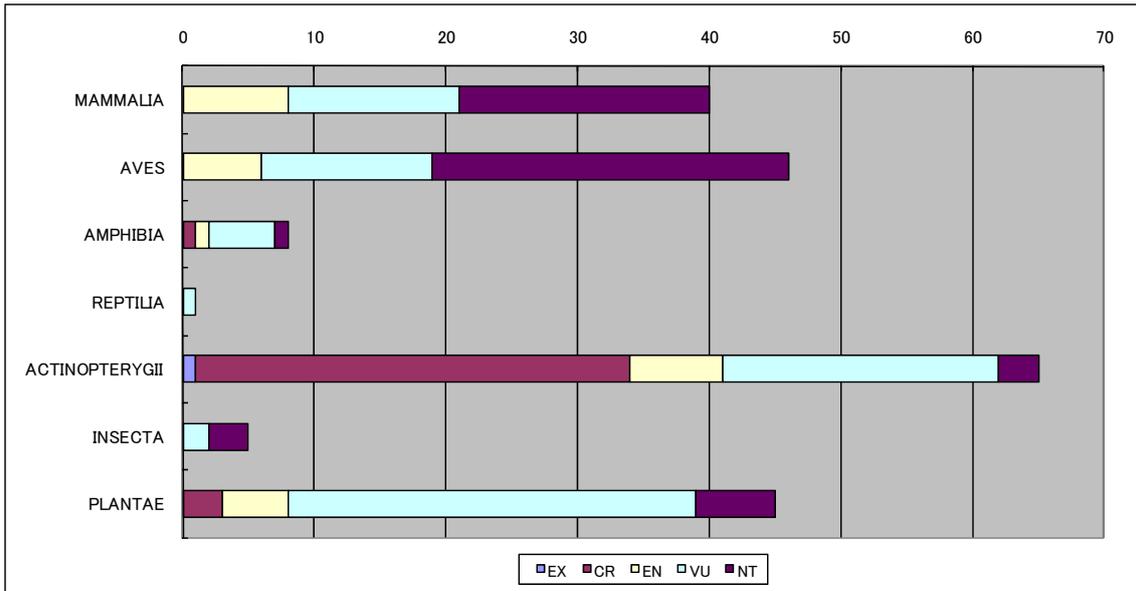

Figure 3.1-1   Topography

3.1.1.2   Hydrology

There are four large lakes in Uganda, Lake Victoria, Lake Choga, Lake Albert, and Lake Edward. The Victoria Nile starts at Lake Victoria, flows through Lake Choga and Lake Albert, and flows out to Sudan.

Figure 3.1-2 Hydrology

3.1.2 Natural Environment

3.1.2.1 Endangered Species

The number of IUCN red list species in Uganda is 1838, including Animalia and Plantae. The number of ACTINOPTERYGII categorized in CR (Critically Endangered) is relatively high. This is considered attributable to the impact on domestic species by Nile perch *(Lates niloticus)* stocked in Lake Victoria. Among mammals, 8 species, including mountain gorilla, are EN (Endangered), and 13 species, including Hippopotamus, are VU (Vulnerable).

Table 3.1-1 Number of IUCN Red List species in UGANDA

Kingdom	Class	EX	CR	EN	VU	NT	LC	Total
ANIMALIA	MAMMALIA			8	13	19	259	299
	AVES			6	13	27	872	918
	AMPHIBIA		1	1	5	1	52	60
	REPTILIA				1		17	18
	ACTINOPTERYGII	1	33	7	21	3	87	152
	INSECTA				2	3	220	225
	GASTROPODA		2	4	2	6	25	39
	BIVALVIA		1				5	6
	CRUSTACEA			2	2		7	11
PLANTAE			3	5	31	6	65	110
Grand Total		1	40	33	90	65	1,609	1,838

*Extinct (EX); Critically Endangered (CR); Endangered (EN); Vulnerable (VU); Near Threatened (NT); Least Concern (LC)

Source: IUCN Web site (http://www.iucnredlist.org/)

Source: IUCN Web site (http://www.iucnredlist.org/)

Figure 3.1-3   Number of IUCN Red List species in UGANDA

In terms of Mammal and Amphibian, the distribution of EN, VU, and NT of IUCN red list species are mainly concentrated around the lakes on the western side of the country.


Source: IUCN Web site (http://www.iucnredlist.org/)
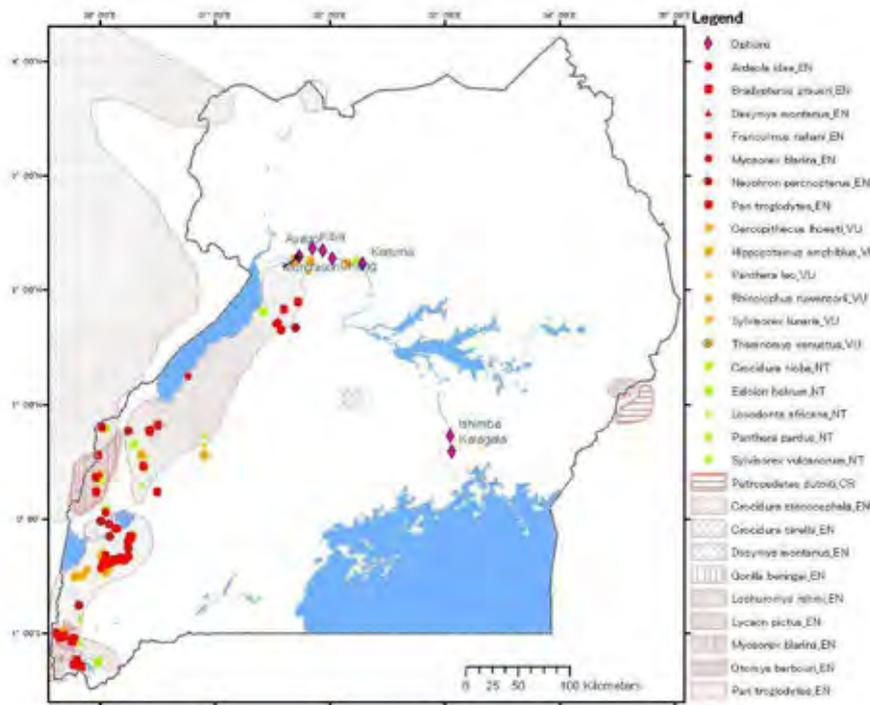
Figure 3.1-4   Distribution of endangered species (Mammal and Amphibian)

3.1.2.2　Protected Areas

Many kinds of protected areas, such as national parks, Wildlife Reserves, and Community Wildlife Management Areas, are in Uganda. The largest national park is Murchison Falls National Park, which is 3,867km^2, the same size as Saitama Prefecture (see エラー! 参照元が見つかりません。).
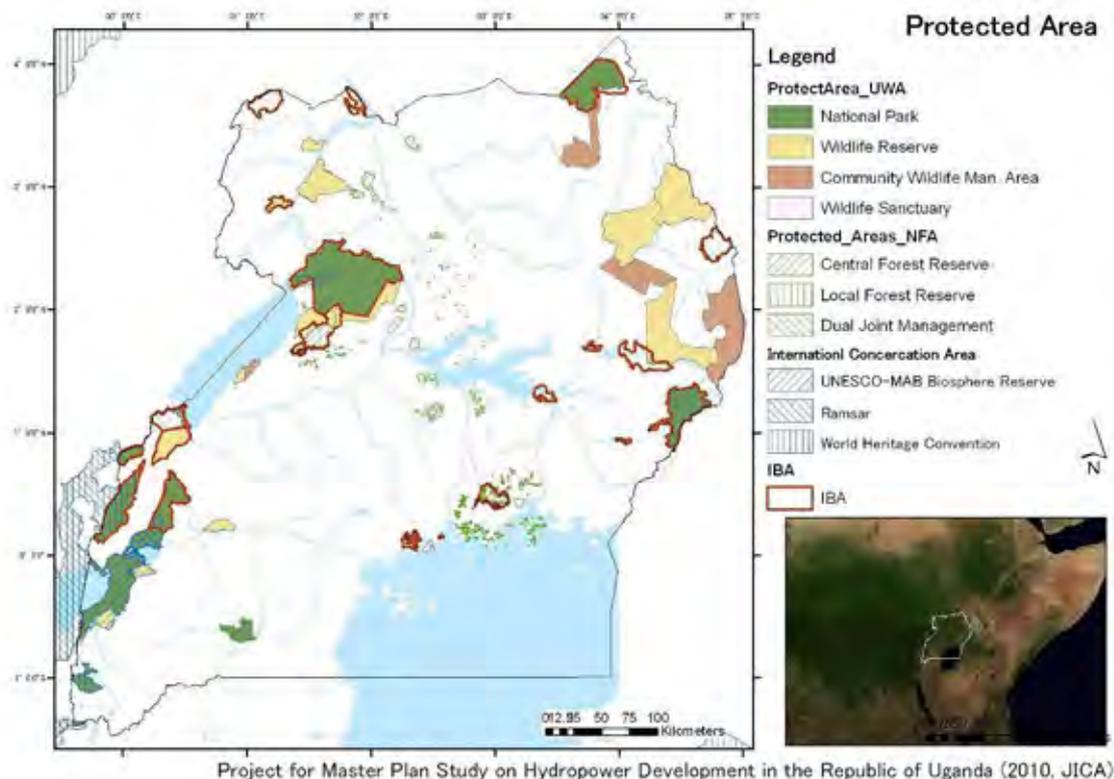
Figure 3.1-5　Protected Area in UGANDA

3.1.3　Social Environment

3.1.3.1　Administrative Boundaries

Administrative divisions in Uganda consist of Districts (Local Councils: LC5), Counties (LC4), Sub-counties (LC3), Parishes (LC2), and Villages (LC1) in rural areas, and Districts/Cities (LC5), Municipalities (LC4), Towns/Divisions (LC3), Wards (LC2), and Cells (LC1) in urban areas. Since establishment of the decentralization policy in 1991, the number of Districts has increased, reaching 80 in July 2006 (see Figure 3.1-6) and 112 in July 2010 (GIS data is not available).

Source: Uganda Bureau of Statistics

Figure 3.1-6   Administrative Boundaries by District, 2007

3.1.3.2   Population

The total population of Uganda in 2002 was 24,227,300 according to the census, and it was estimated at 32,360,558 in 2009. Population growth rate in 2009 was estimated at 2.692% per year. Population density is comparatively high on the north coast of Lake Victoria and lower in the northeast area (see Figure 3.1-7).

Source: Uganda Bureau of Statistics

Figure 3.1-7　Population Density (Person/Km2) by District, 2002

3.1.3.3　Ethnic Groups

The population of Uganda is made up of different ethnic groups. Fifty-six tribal groups are listed in the 1995 Constitution of Uganda. As the figure below shows, the Baganda, accounting for 17.7 percent, is the largest group, followed by the Banyankole (10.0%) and the Basoga (8.9%). The dominance of the Baganda has been observed since the 1948 Census.
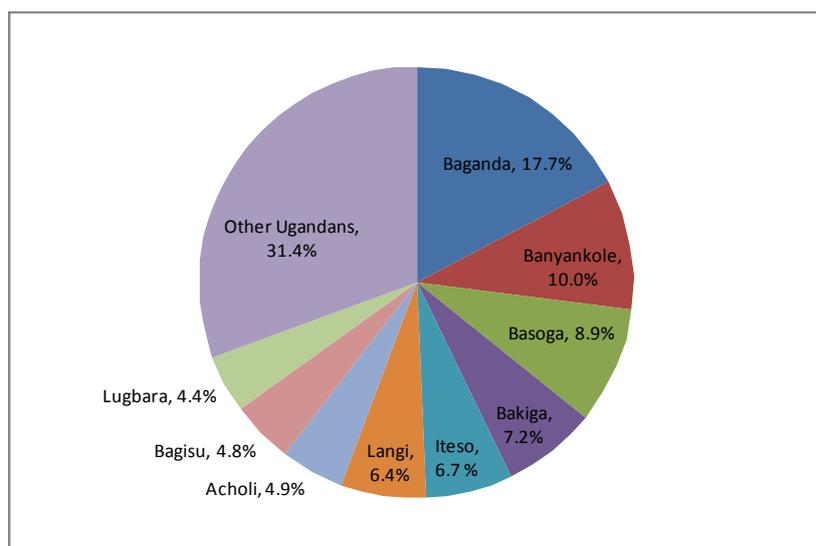
Source: 2002 Population and Housing Census

Figure 3.1-8　Distribution of Population by Ethnic Groups, 2002

Among other Ugandans, which account for 31.4 percent of total population, there are smaller ethnic groups. The table below shows fifteen ethnic groups that have populations less than 25,000.

Table 3.1-2   Populations of Small Number Ethnic Groups, 2002

Ethnic Group	Population	%Share of Ugandan Population
Vonoma	119	0.001
Napore	330	0.001
Nyangia	332	0.001
Mvuba	863	0.004
Jie	1,092	0.005
Mening	1,247	0.01
Ethur	2,342	0.01
Dodoth	2,545	0.01
Bahehe	3,358	0.01
Batwa	6,705	0.03
IK(Teuso)	8,497	0.04
Basongora	10,153	0.04
Lendu	11,155	0.05
Banyabindi	13,912	0.06
Babukusu	14,961	0.06
Chope	20,517	0.09
Batuku	20,532	0.09
Banyara	20,612	0.09
So(Tepeth)	21,527	0.09
All Groups	**160,799**	**0.692**

Source: 2002 Population and Housing Census

The ethnic groups are headed by traditional kings or chiefs, who are not politically elected but have a significant influence in community governance and moral formation. They play a major role in shaping the behaviours and ways of life of the people in the region. Therefore, it is essential for any hydropower development project to share information with ethnic leaders in order to avoid misunderstanding on the project and to get their opinions.

3.1.3.4 Land-use
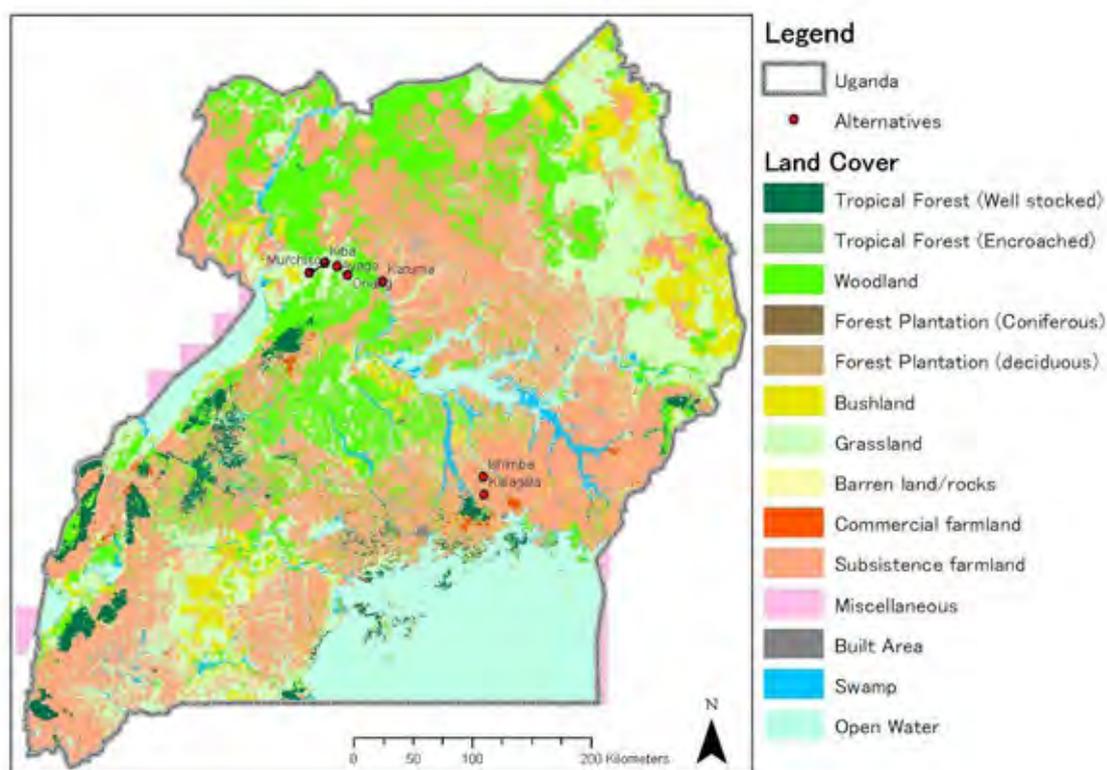

Source: National Forest Authority

Figure 3.1-9   Land Use

3.1.3.5 Economic Activities

3.1.3.5.1 Agriculture

Agriculture is the dominant economic activity in Uganda; its contribution to total GDP in 2008 was 21.5 percent (2009 Statistical Abstract). Most industries and services are dependent on the agricultural sector. The sector provides over 70 percent of the working population[1] (2002 Population and Housing Census). However, most farmers are subsistence farmers; they produce primarily for their own consumption but may sell some of the products. As the figure below shows, the majority of people in rural areas depend on subsistence agriculture, such as crop growing, livestock rearing, fishing, hunting, and gathering. The lowest percentage of subsistence farmers is found in the Central region, including   the Kampala and Wakiso Districts.

---

[1] All persons aged five years and above whose status is paid employee, self employed, or unpaid family worker.
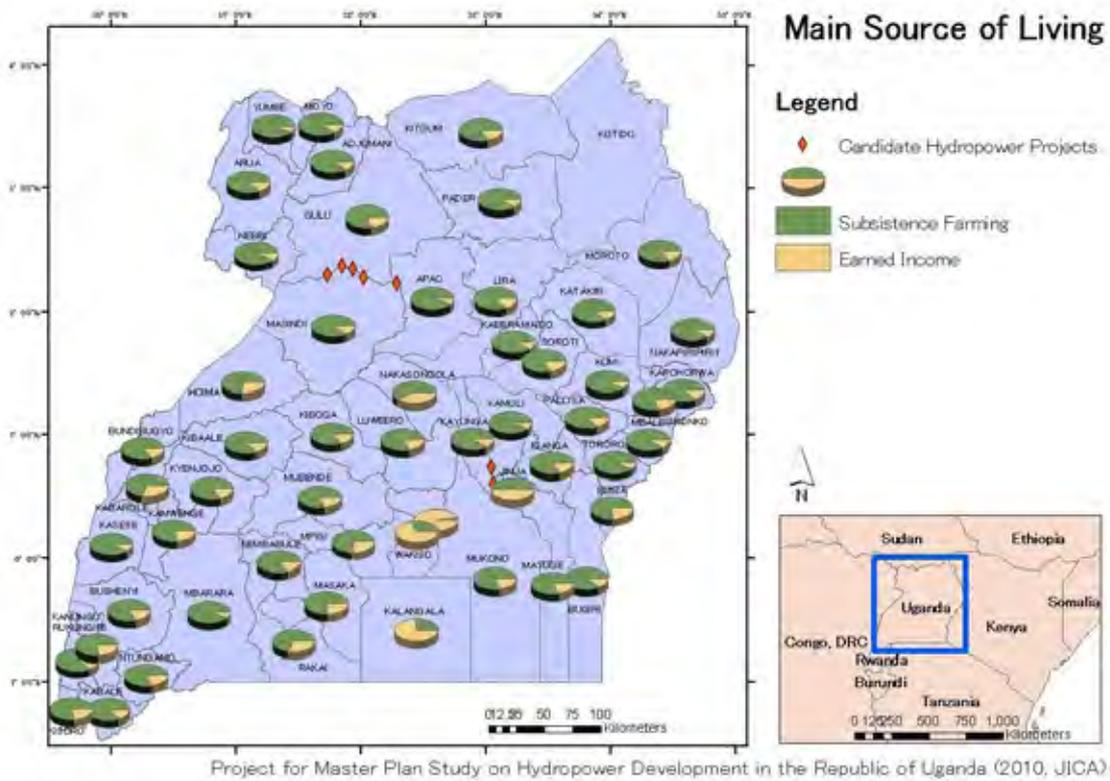
Source: 2002 Population and Housing Census

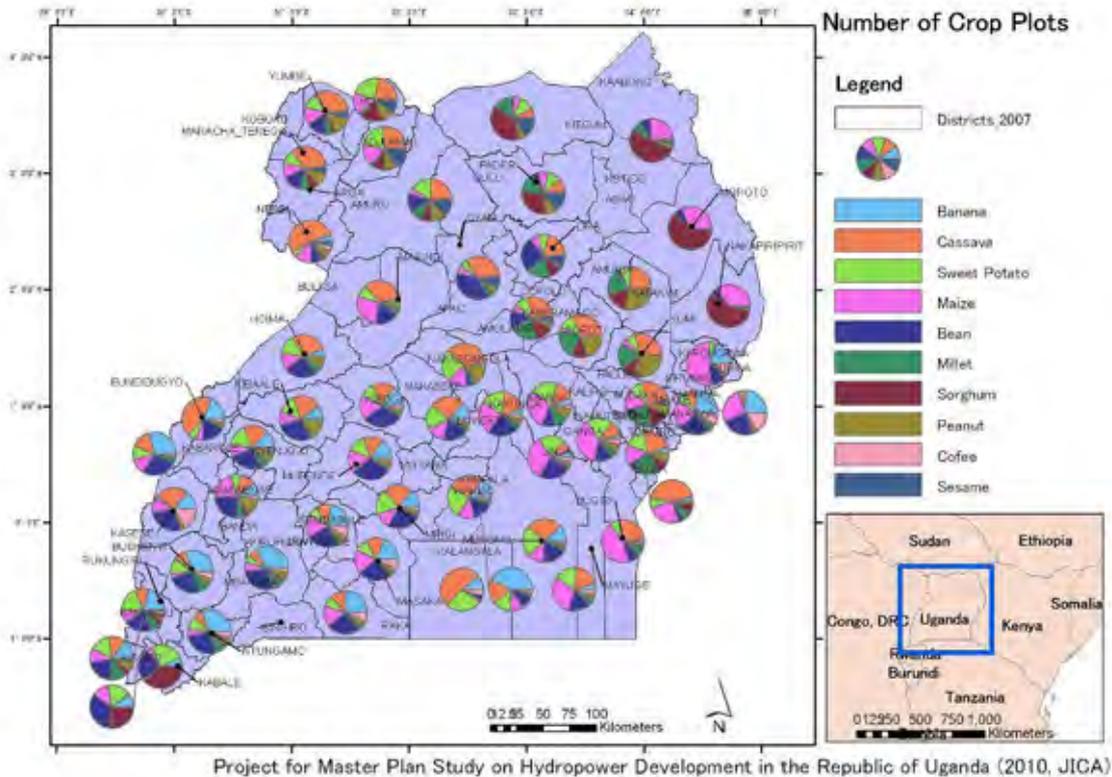**Figure 3.1-10   Main Source of Living by District, 2002**

The major agricultural products in Uganda include banana, cassava, sweet potato, maize, beans, millet, sorghum, peanuts, coffee, and sesame. The production of these crops, other than coffee, during 2003 to 2008 is shown in the table below.

Table 3.1-3　Production of Selected Food Crops 2003-2008

						(Thousand tonnes)
	2003	**2004**	**2005**	**2006**	**2007**	**2008**
Banana	9,700	9,686	9,380	9,052	9,233	9,371
Cassava	5,450	5,500	5,576	4,924	4,973	5,072
Maize	1,300	1,080	1,237	1,258	1,262	1,266
Millet	640	659	672	687	732	783
Sweet Potatoes	557	573	585	628	650	670
Sorghum	421	399	449	440	458	477
Beans	525	455	478	424	430	440
Peanuts	150	137	159	154	162	173
Sesame	120	125	161	166	168	173

Source: Uganda Bureau of Statistics

The distribution of these crops by number of plots by District is shown in the figure below. Banana, which has the largest production, is found mostly in the Central and Western regions. Coffee growing follows the same pattern, but has an extra concentration in the Eastern Districts around Mount Elgon. Coffee is the dominant export commodity, accounting for 23.4 percent of total value, US$1,724.3 million in 2008 (2009 Statistical Abstract). The growing of cassava, peanuts, sweet potato, and beans is more evenly distributed throughout the country. Maize is produced mostly in the Eastern region. Millet and sorghum are produced in the Eastern, Northern, and Western regions. Sesame is mostly grown in the Northern region.

Project for Master Plan Study on Hydropower Development in the Republic of Uganda (2010, JICA)

Source: Agricultural Statistics 2002

Figure 3.1-11　Number of Crop Plots by District, 2002

3.1.3.5.2 Livestock

Livestock production plays a key role in raising incomes of households and providing a source of protein to many people. Livestock products include milk, beef, pork, goat meat/mutton, and chicken. The table below shows major livestock in Uganda and their population trends. On average, the populations of cattle, sheep, goats, pigs, and poultry have increased over the period.

Table 3.1-4   Number of livestock 2003-2008

						(thousand animals)
	2003	**2004**	**2005**	**2006**	**2007**	**2008**
Cattle	6,519	6,567	6,770	6,973	7,182	7,398
Sheep	1,175	1,552	1,600	1,648	1,697	1,748
Goats	7,092	7,566	7,800	8,034	8,275	8,523
Pigs	1,778	1,940	2,000	2,060	2,122	2,186
Poultry	35,903	31,622	32,600	26,049	26,950	27,508

Source: Ministry of Agriculture, Animal Industry and Fisheries and Uganda Bureau of Statistics

The distribution of these livestock by District is shown in the figure below. It reveals that while indigenous cattle are distributed over all Districts, exotic/crossbreed cattle are concentrated in major urban areas, such as Kampala and Wakiso Districts, as well as in traditional cattle-rearing and milk-producing areas such as the Mbarara District. The relatively high concentration of exotic/crossbreed cattle are also found in typical pastoral areas in the Northeast.

As the figure shows, rearing of goats is common in most Districts in Uganda, whereas rearing of sheep is found mainly in the extreme Northeast and Northwest. Rearing of pigs is more concentrated in the Central and Western regions along Lake Victoria. Also, there is a high concentration of pig rearing in the Moyo District in the North and in Kumi District in the East.

As for poultry, 46.4 percent of total agricultural households keep local chicken, whereas only 0.7 percent keep exotic/crossbreed chicken (Agricultural Statistics 2002). The exotic/crossbreed chickens are concentrated in the Central region. This is due to the high demand for eggs and cooking chickens in the Kampala, Wakiso, and Mukono Districts. Local chickens are found all over the country.
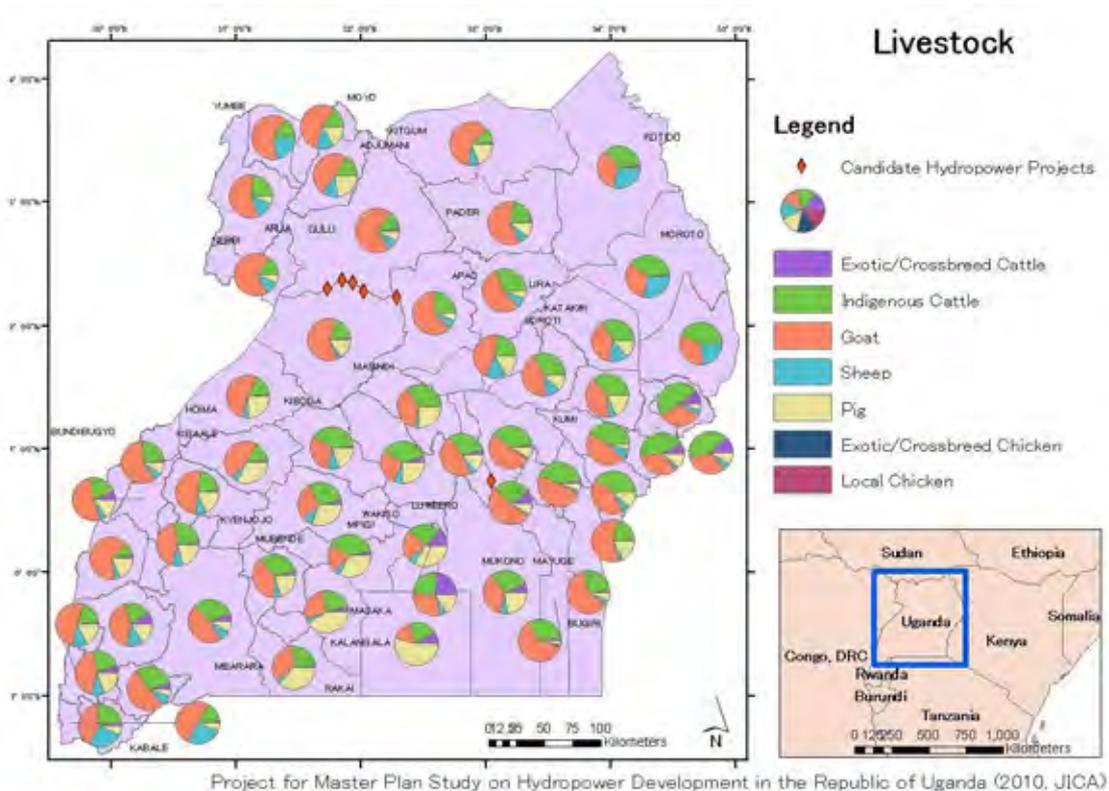
Source: Agricultural Statistics 2002

Figure 3.1-12   Number of Households with Livestock by District, 2002

3.1.3.5.3   Fishing

Fishing is carried out on almost all lakes in Uganda. Lake Victoria is the largest body of water in Uganda. As the table below shows, more than a half of fish are caught in Lake Victoria. Albert Nile (a part of the River Nile from Lake Victoria to Lake Albert) contributes only 1.3 percent of total catch.

Table 3.1-5   Fish Catch by Water Body 2003 – 2007

					(thousand tonnes)
	2003	**2004**	**2005**	**2006**	**2007**
Lake Victoria	175.3	253.3	253.3	215.9	223.1
Lake Albert	19.5	56.4	56.4	56.4	56.4
Albert Nile	5.6	6.4	5	5	5
Lake Kyoga	32.9	68.5	68.4	60	60
Lake Edward, George & Kazinga Channel	5.9	9.6	9.6	8.8	8.8
Other Waters	8.3	40.6	24.1	21.1	21
Total	**247.5**	**434.8**	**416.8**	**367.2**	**374.3**

Source: Fisheries Department, Ministry of Agriculture, Animal Industry and Fisheries

According to the Agricultural Statistics 2002, 0.2 percent of agricultural households reported carrying out fish farming with ponds. As the figure below shows, tilapia is the dominant fish in ponds in the country, followed by mirror carp and clarias (African catfish).
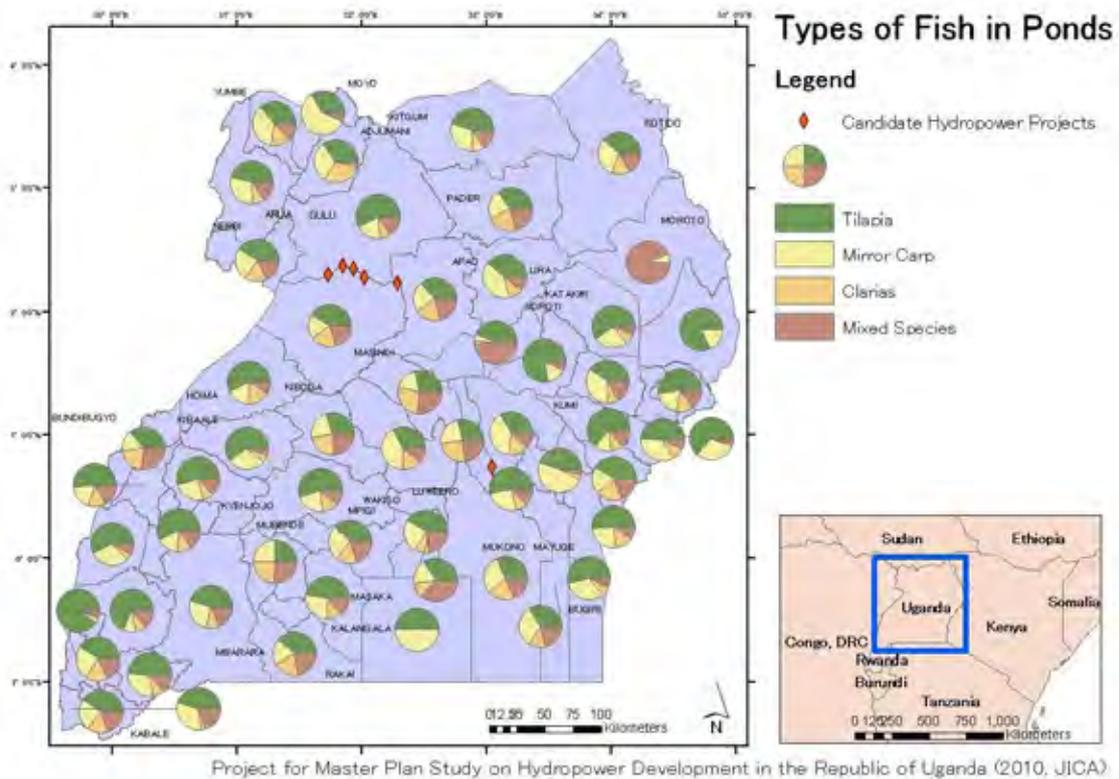
Source: Agricultural Statistics 2002

Figure 3.1-13   Types of Fish in Ponds by District, 2002

3.1.3.6   Education and Literacy

Uganda's education system includes formal and informal education. Formal education comprises training at primary school for seven years, secondary education for four years for "O (ordinary)" level and two years for "A (advanced)" level, and tertiary education from three to five years. Informal education trains beneficiaries in basic skills of education such as reading, writing, and numeracy.

The Government of Uganda introduced the Universal Primary Education (UPE) policy in 1997. The implementation of this policy has caused tremendous changes in primary enrolment, which has increased from 3.1 million in 1996 to 7.4 million in 2008 (2009 Statistical Abstract). The table below shows basic indicators of primary education in the country.

Table 3.1-6   Primary School Education Indicators in Uganda

	2008
Enrolment	7,471,000
Number of Primary Teachers	131,000
Number of Primary Schools	14,179
Pupil Teacher Ratio	57
Pupil Classroom Ratio	72
Gross Enrolment Rate	108
Gross Intake Rate	128
Net Enrolment Rate	89
Net Intake Rate	55

Source: Planning Unit, Ministry of Education and Sports

The Gross Enrolment Rate (GER)[2] and Gross Intake Rate (GIR)[3] are greater than 100. This means that more pupils enrolled in primary school before the age of six years or lasted beyond the age of twelve years in primary school. This frequently happens in rural areas in Uganda, where many pupils repeat the same grade due to exam failure.

The Net Enrolment Rate (NER)[4] can more accurately reflect participation than GER, because it refers to the proportion of the total enrolment of official school-age population to the corresponding age group. NER by District is shown the figure below. It reveals that the Central region has the highest participation, while the Northern region, including the Moroto and Nakapiripirit Districts, has the lowest (20.2 and 18.5 percent respectively).

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[2] Gross Enrolment Rate is the ratio of pupils in primary school (regardless of age) to the country total population aged six to twelve years.
[3] Gross Intake Rate is the ratio of pupils enrolled in primary one (P1) (regardless of age) to the country total population aged six years.
[4] Net Enrolment Rate is the ratio of pupils in primary school aged six to twelve to the country total population aged six to twelve years. Net Intake Rate is the ratio of the pupils aged six in primary one (P1) to the country total population aged six years.
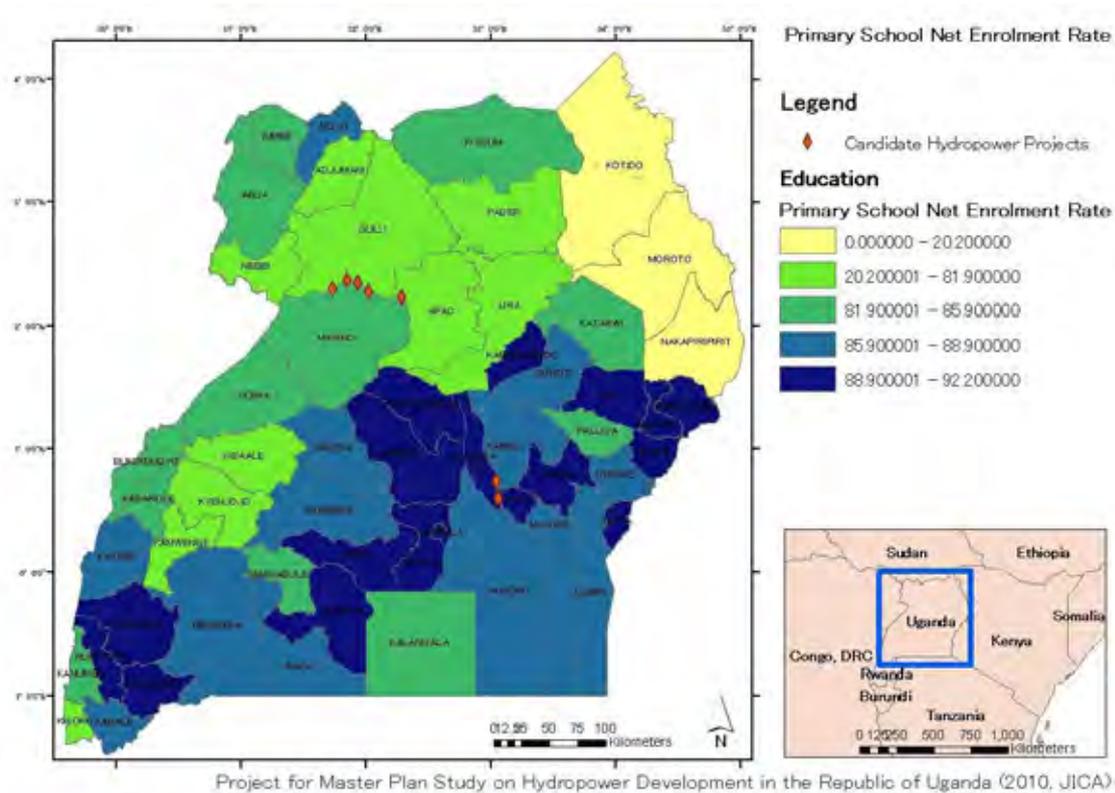
Figure 3.1-14   Primary School Net Enrolment Rate by District

According to the 2002 Population and Housing Census, about one-fifth (19 percent) of all persons aged 6 years and above had never attended school, while nearly two-fifths left school before 2002, and 41 percent were attending school. The proportion that had never been to school was much higher among females (25 percent) than males (14 percent).

Literacy is defined as the ability to read with understanding and write meaningfully in any language. In 2002, the literacy rate for persons aged 10 years and above was 70 percent. This was a great improvement compared with the level of 54 percent in 1991. However, wide gender disparities still exist in literacy rate, with 77 percent of males being literate compared to 62 percent of females. The figure below shows that gender disparity in literacy rates exists in all age groups except ten to fourteen years.
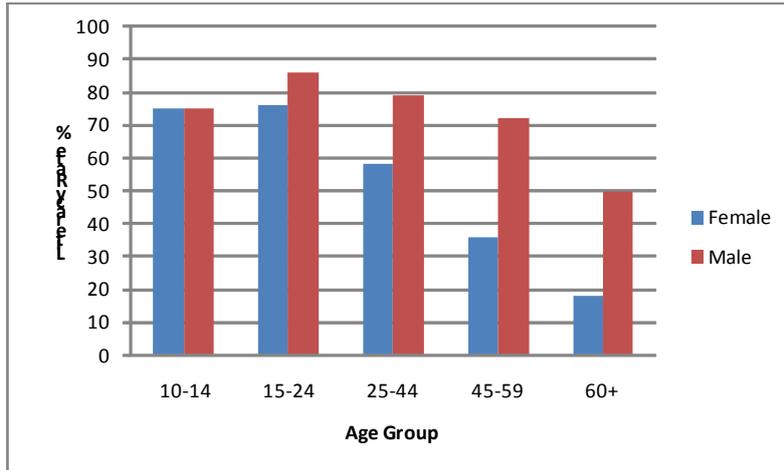
Source: 2002 Population and Housing Census

Figure 3.1-15   Literacy Rate by Age and Gender

As the figure below shows, the Central region has the highest literacy at 82 percent, while the Northern region has the lowest at 60 percent. The Eastern and Western regions recorded literacy rates of 63 percent and 70 percent respectively. Literacy rates are similar among males and females in the Central region.
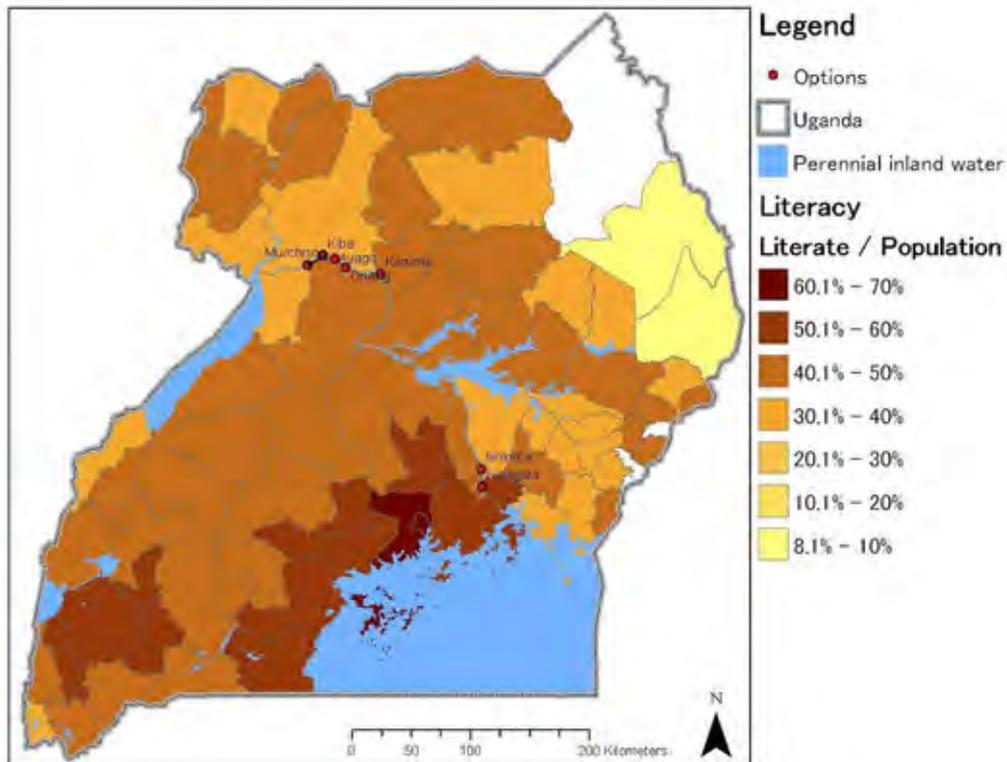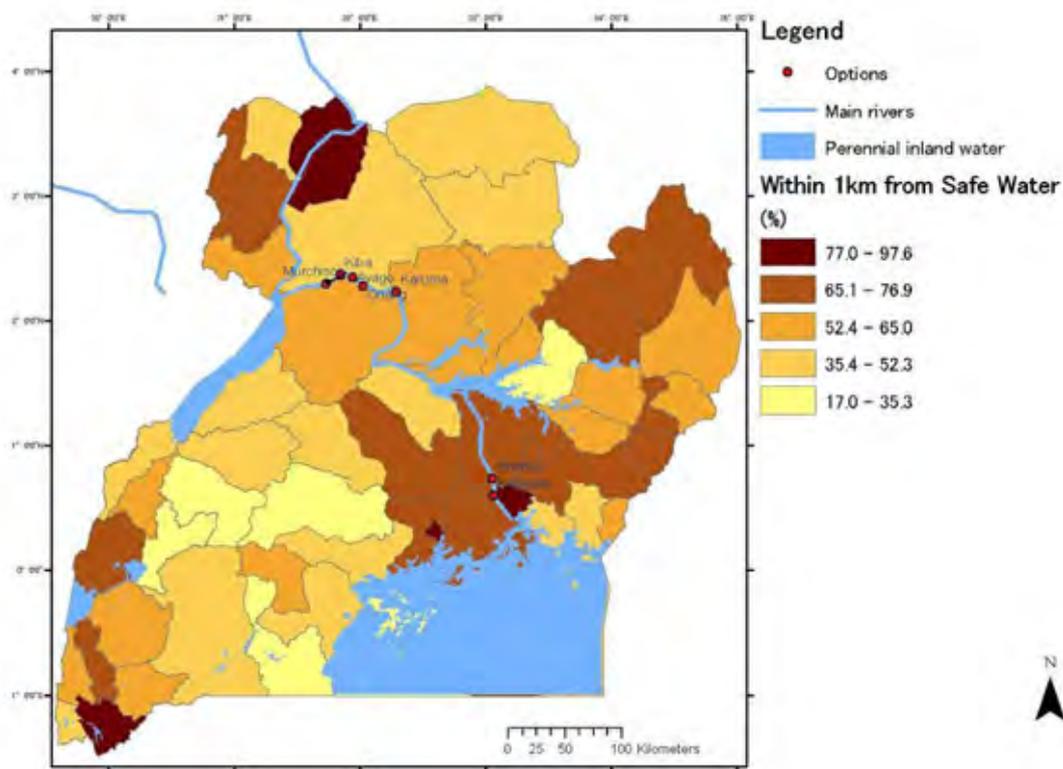

Source: 2002 Population and Housing Census

Figure 3.1-16   Literacy Rate by District, 2002

3.1.3.7   Health and Sanitation

Access to safe water and good sanitation are very crucial to the health of people. The 2002 Census showed that 61 percent of households had access to safe water, as compared to 26 percent in 1991. According to the figure below, access to safe water is much higher (96 percent on average) in urban areas, such as Kampala and Jinja, than in rural areas (76 percent on average).

Source: 2002 Population and Housing Census

Figure 3.1-17   Household within 1 km from Safe Water by District, 2002

The distance to a health facility has a strong impact on access to health care. Health facilities include hospitals and health centres; a health centre is intended to cover a given administrative area. The figure below shows the proportion of the households which are within five kilometres from a health facility. It reveals that the proportion is lower in the Northern region (around 66 percent) and higher in the Central region (78 percent).
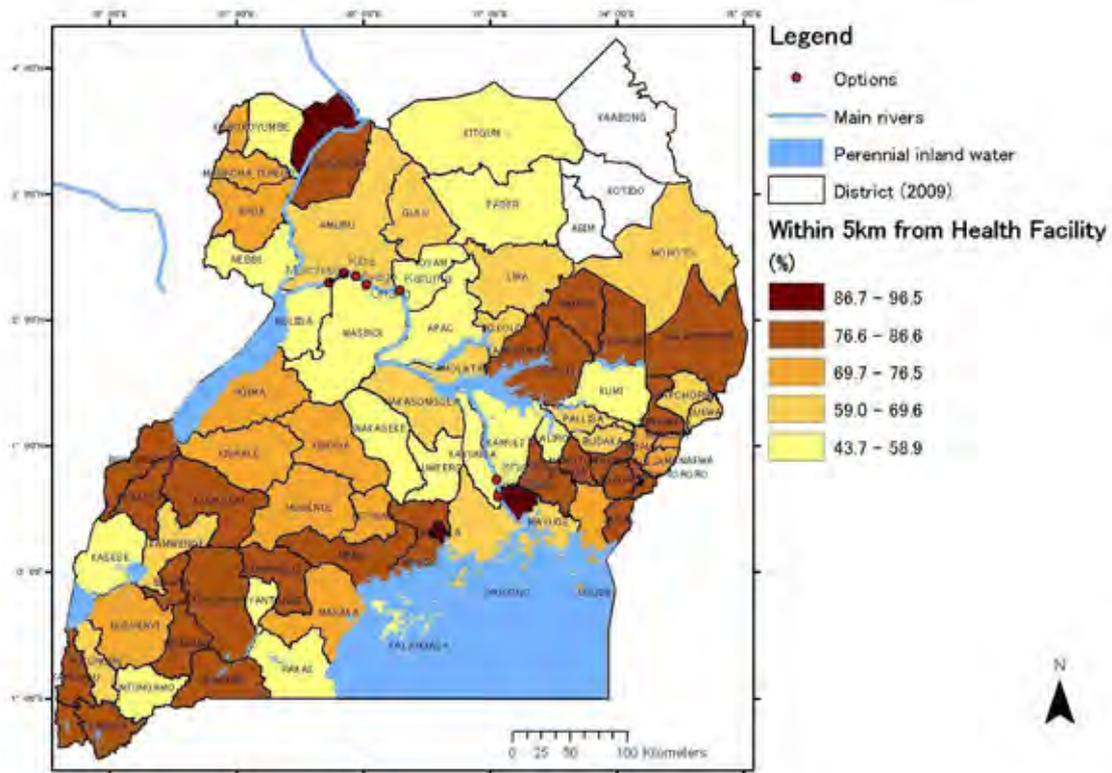
Source: 2002 Population and Housing Census

Figure 3.1-18   Household within 5 km from Health Facility by District, 2002

Findings of the 2002 Census indicate that toilet coverage was not universal in Uganda. Nearly one-third of households did not have a toilet facility (14 percent were using an uncovered pit latrine and 17 percent had no facility at all). There has been an improvement in the pit latrine coverage at the national level, from 58 percent in 2006 to 63 percent in 2008. The figure below presents pit latrine coverage by District.
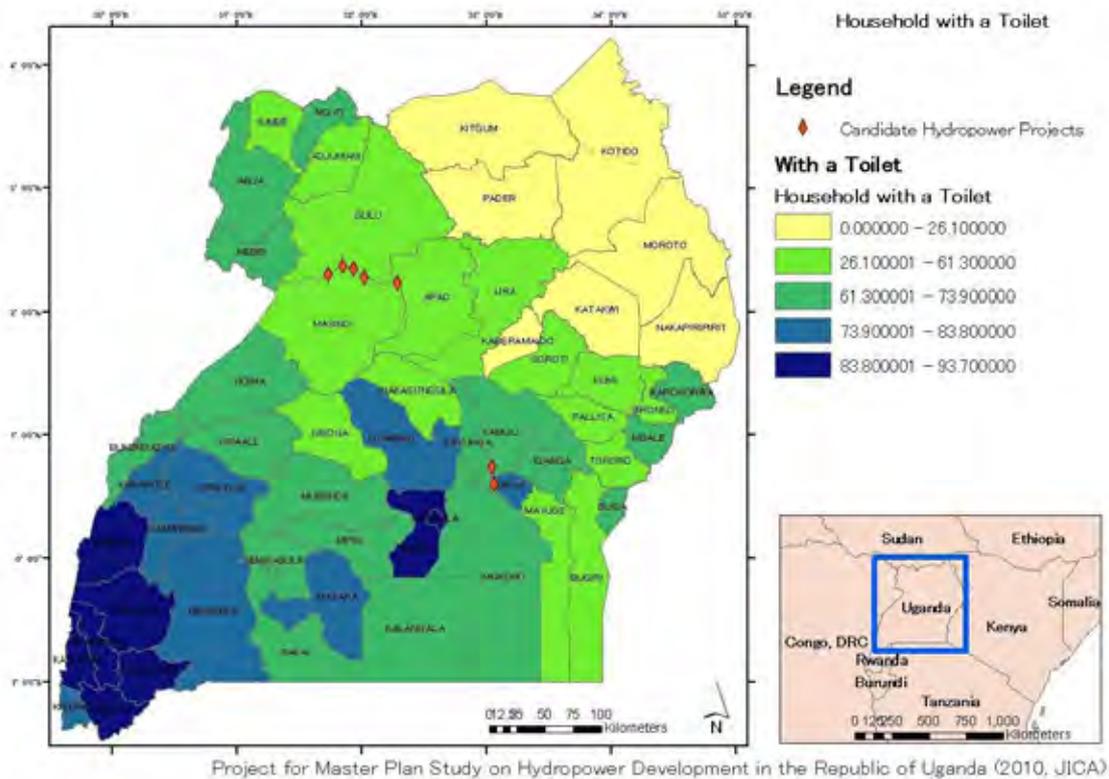
Source: 2002 Population and Housing Census

Figure 3.1-19   Households with a Toilet by District, 2002

3.1.3.8   Tourism and Culture

The tourism industry in Uganda has expanded in the last two decades as a result of improved security and better facilities for tourists.

Uganda's major tourist attractions are its national parks and wildlife reserves. The table below provides the number of visitors to the ten main national parks within the country. These parks offer different tourism activities, such as gorilla tracking, nature guided walks, village walks, butterfly watching, bird watching, and rare fauna species.
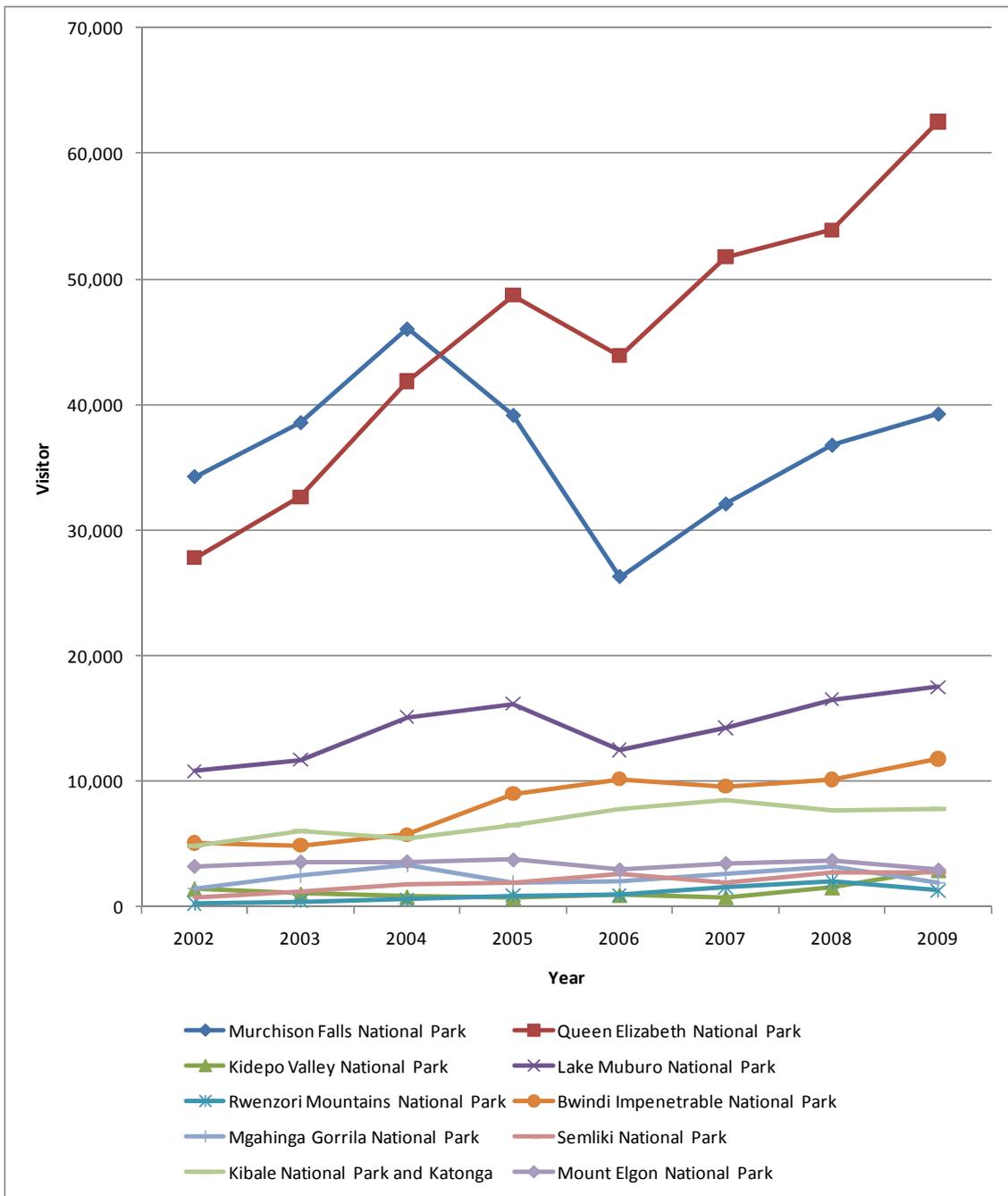
Source: Uganda Wildlife Authority

**Figure 3.1-20   Visitors to the National Parks (Citizen and Foreigners) 2002- 2009**

Tourists also like to visit natural features such as lakes, rivers, waterfalls, mountains, and hot springs and cultural sites such as forts, shrines, palaces, caves, rocks, and museums. Since Uganda has a long history of kingdoms, as indicated below, there are many cultural assets and archaeological properties.
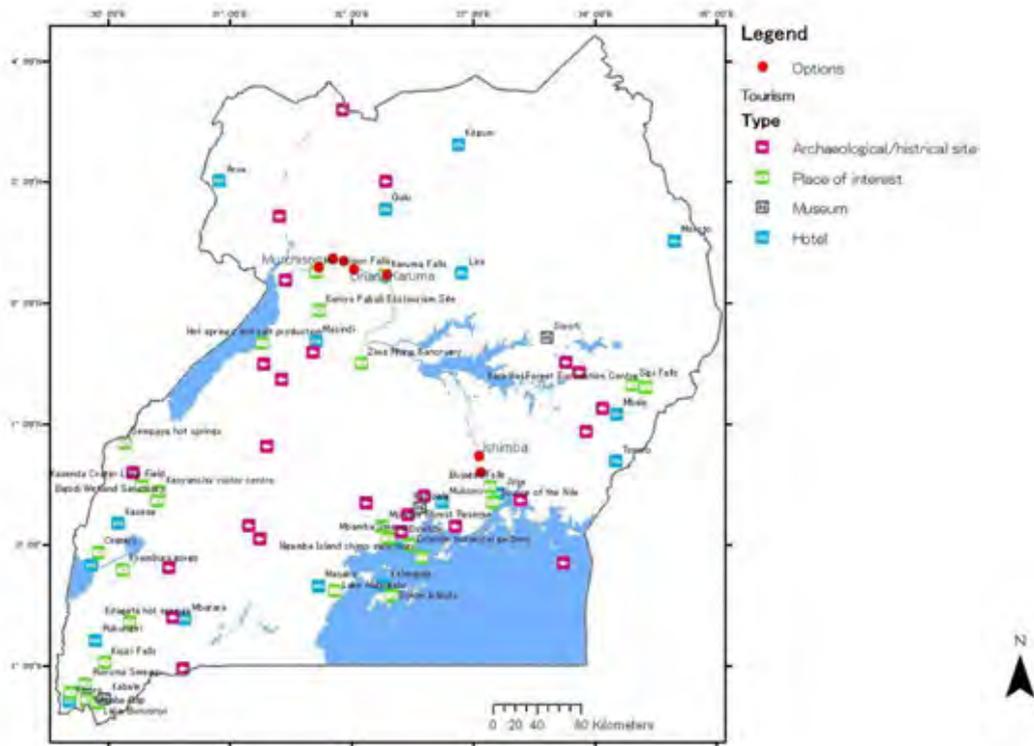
Source: Uganda Museum

Figure 3.1-21   Tourism Sites in Uganda

3.1.3.9   Transportation
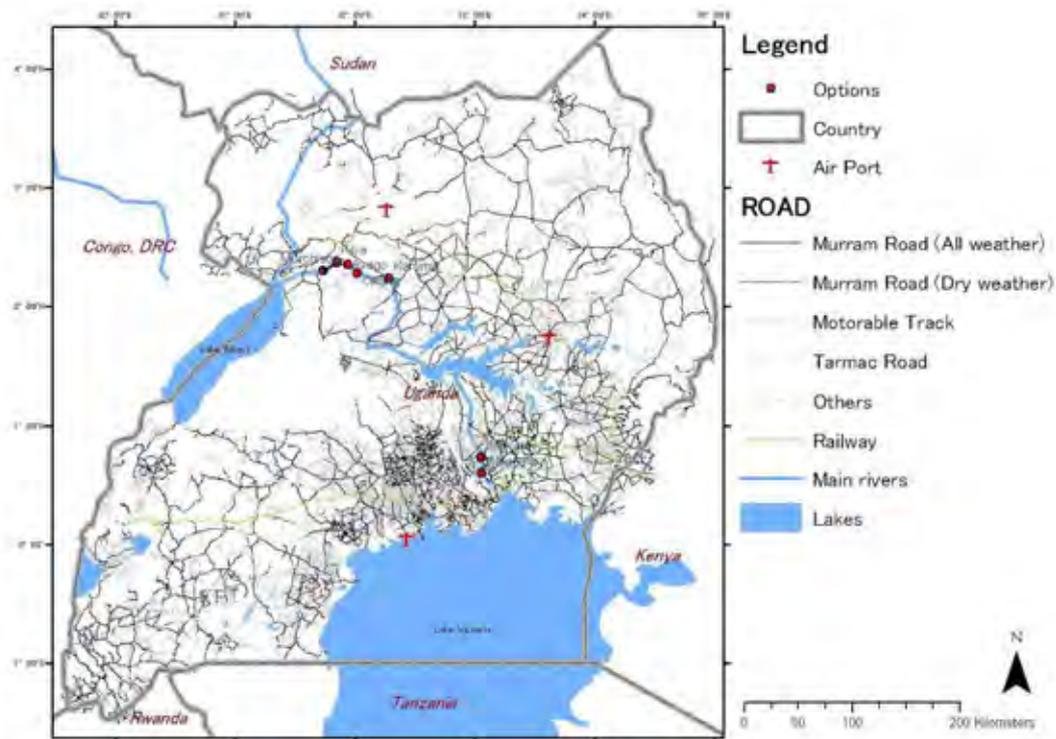
Figure 3.1-22   Transportation Network in Uganda