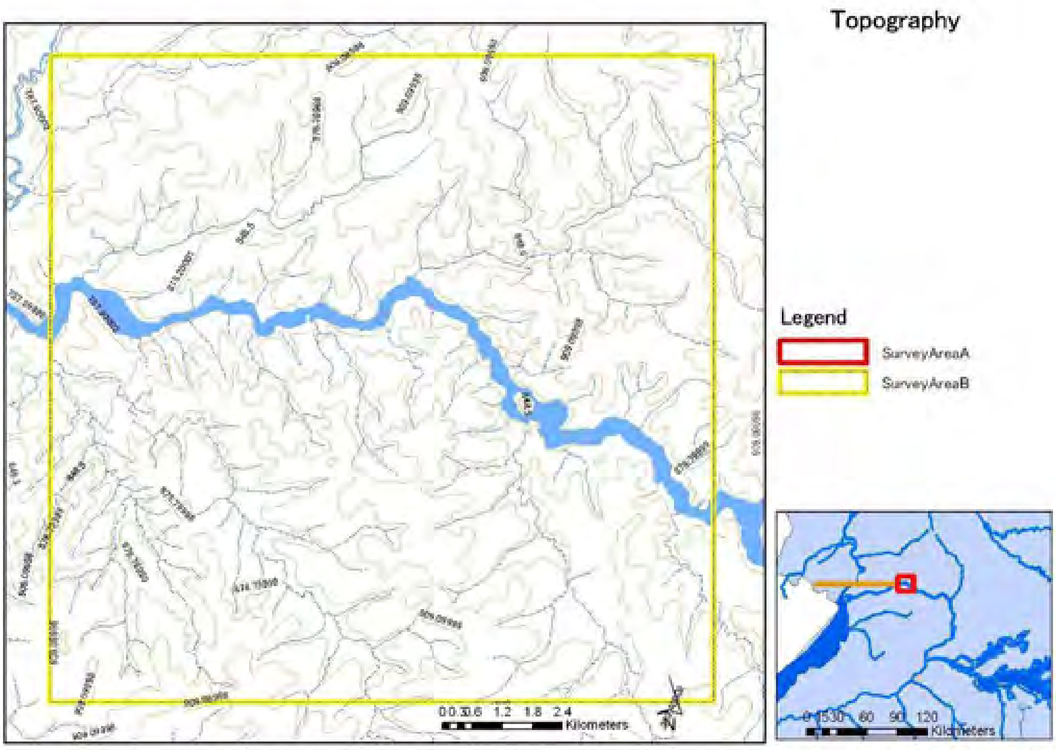
3.2 Ayago project area

3.2.1 Physical Environment

3.2.1.1 Topography

The elevation of the survey area is 757-909 m. Tributaries on the south bank flow from southeast to northwest and tributaries on the north bank flow from northeast to southwest.



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

Figure 3.2-1 Topography of the Project Site

3.2.1.2 Geology and Soils

Most of the project area is covered by Shallow brown sandy loams over rock or laterite. The area west of the survey area is covered by Shallow brown sandy loams over old alluvial. The area near the Karuma is covered by reddish brown sandy loams and loams on laterite. The following figure shows the soil map.

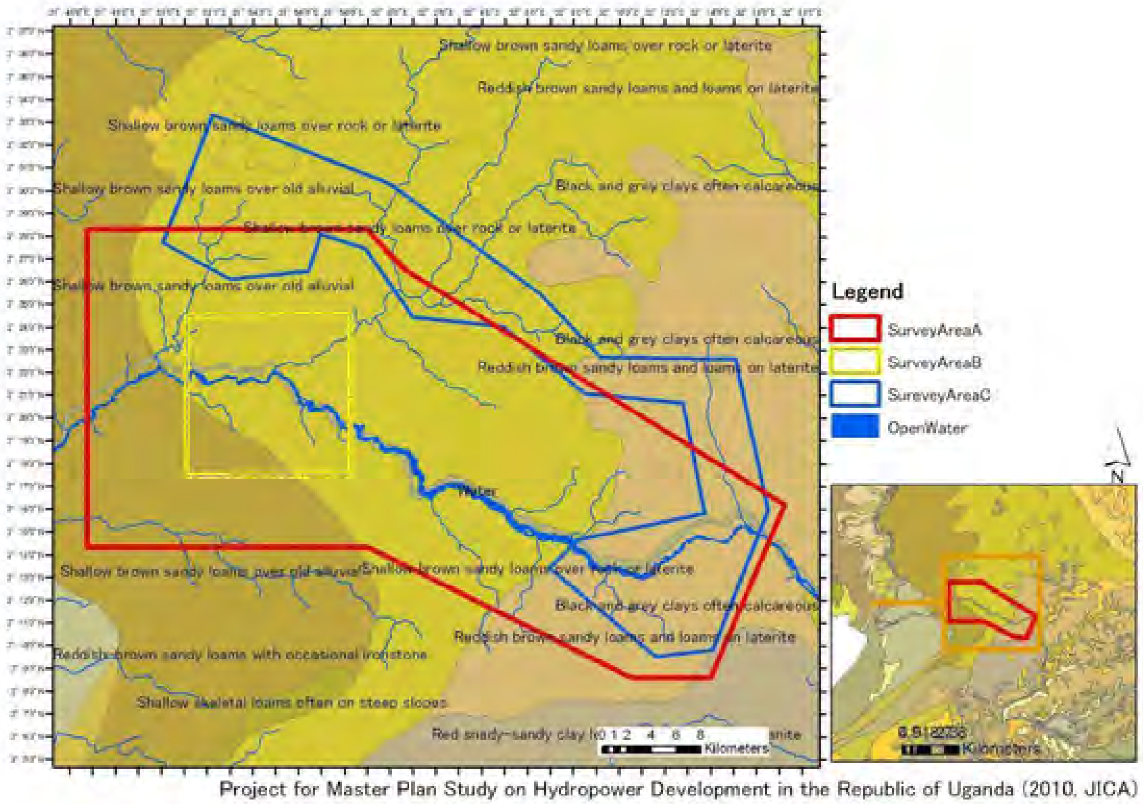


Figure 3.2-2 Soil Condition at the Survey Area

3.2.2 Natural Environment

3.2.2.1 Flora

A total of 244 vascular plant species belonging to 54 families and 168 genera were recorded. Among the species recorded to as IUCN redlisted include *Milicia excelsa* and *Khaya anthotheca* (VU) in the woodlands. According to Kalema (2005), other globally threatened species that occur in MFNP include *Afzelia Africana*, *Vitellaria paradoxa*, *Entandrophragma cylindricum*, *Hallea stipulosa*, *Khaya grandifolia*, *Pouteria altissima*, and *Dalbergia melanoxylon*.

Four types of vegetations, i.e., Riverine vegetation, Combretum-dominated grassland, Acacia-dominated wooded grassland, and Piliostigma-Acacia wooded grassland, are recorded near the project site. Riverine vegetation is identified as being of the highest conservation significance. Although the Riverine vegetation is not restricted in the MFNP, it should be protected because of vulnerability, inclusion of rare species, high biodiversity, and prevention of erosion. Detailed survey results are shown in the Annex 1.

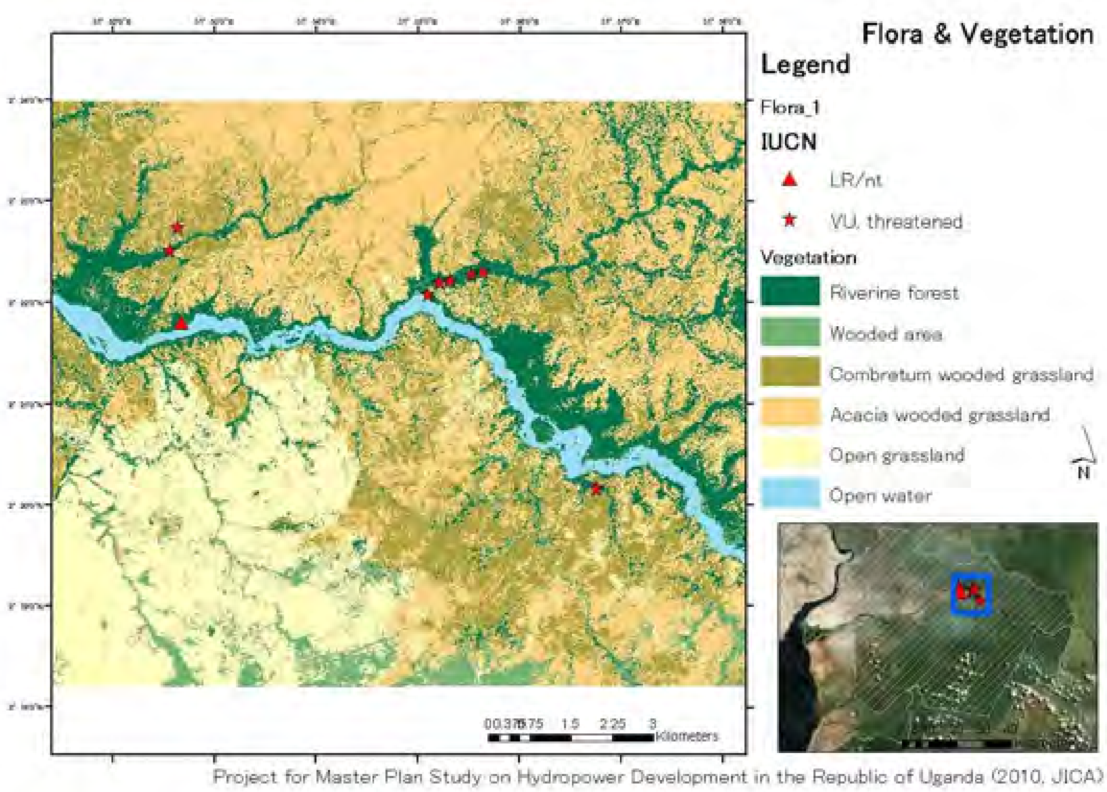


Figure 3.2-3 Location of the Red List Species and Vegetation

3.2.2.2 Mammals

Twenty-six mammals are recorded at the site survey. IUCN red list species are Hippopotamus (VU-Vulnerable), Leopard (NT-Near Threatened), Spotted Hyena (NT), and African Elephant (NT). Many Hippopotamus and African Elephant are recorded in the survey area. The recorded positions are shown in the Figure 3.2-4 and Figure 3.2-5. Detailed survey results are shown in Annex 2.

Table 3.2-1 IUCN listing status and population trends for important species of mammals in MFNP

Name			IUCN Red List status	Presence		Population in the MFNP							
Family	English name	Scientific name		area A	area B	pre-1973 a	1980b	1991c	April 1995d	Dec. 1995e	June 1999f	May 2002g	Jul-05
Cercopithecidae	Olive Baboon	*Papio Anubis*	LC	√	√								
	Black & White Colobus	*Colobus guereza*	LC	√	√								
	Red-tailed Monkey	*Cercopithecus ascanius*	LC										
Felidae	Leopard	*Panthera pardus*	NT		√								
	Lion	*Panthera leo*	VU										
Hyenidae	Spotted Hyena	*Crocuta crocuta*	NT	√	√								
Hippopotamidae	Hippopotamus	*Hippopotamus amphibius*	VU	√	√	12,000	7,565	-	1,498	1,238	1,792	-	2,104
Suidae	Bush Pig	*Potamochoerus porcus*	LC	√	√								
Suidae	Common Warthog	*Phacochoerus africanus*	LC	√	√	-	-	-	411	856	1,639	-	2,298
Bovidae	African Buffalo	*Syncerus caffer*	LC	√	√	30,000	15,250	1,610	1,087	2,477	3,889	8,200	11,004
	Bushbuck	*Tragelaphus scriptus*	LC	√	√								
	Sitatunga	*Tragelaphus spekii*	LC										
	Common (Bush) Duiker	*Sylvicapra grimmia*	LC	√	√								
	Hartebeest	*Alcelaphus buselaphus*	LC	√	√	-	14,000	-	3,068	2,431	2,903	-	4,101
	Uganda Kob	*Kobus kob*	LC	√	√	10,000	30,700	-	6,355	4,373	7,458	-	9,315
	Oribi	*Ourebia ourebia*	LC	√	√								
	(Defassa) Waterbuck	*Kobus ellipsiprymnus*	LC	√	√	-	5,500	-	539	566	792	-	1,441
Giraffidae	Giraffe	*Giraffa camelopardalis*	LC	√	√	150-200	-	78	100	153	347	229	245
Elephantidae	African Elephant	*Loxodonta africana*	NT	√	√	12,000	1,420	308	201	336	778	692	516

Note: Numbers in italics are from sample counts with standard errors omitted for clarity. Numbers in normal script are from aerial total counts. Sources: [a]UNP (1971), Laws et al (1976); [b]Malpas (1978), Douglas-Hamilton et al (1980); [c]Olivier (1991); [d]Sommerlatte & Williamson (1995); [e]Lamprey and Michelmore (1996); [f]Lamprey (2000); [g]Rwetsiba et al (2002).

VULNERABLE (VU): considered to be facing a high risk of extinction in the wild

NEAR THREATENED (NT): close to qualifying for or likely to qualify for a threatened category in the near future

LEAST CONCERN (LC): does not qualify for Critically Endangered, Endangered, Vulnerable, or Near Threatened

Table 3.2-2 Important mammals in the project area

Name	General Habitat	General Behaviour	Estimated Distribution in Ayago Area
Leopard (*Panthera pardus*- NT)	An extremely wide habitat tolerance: from coastal plains to high altitude mountains, from semi-desert areas to tropical rainforests.	Solitary with the exception of pairs coming together for mating, or when a female is accompanied by cubs. They are mainly active at night, but in areas where they are not disturbed they can be observed moving during the cooler daylight hours. Most activity takes place on the ground, but they are also capable climbers and swimmers. Adult males mark and defend a territory against other males, and a male's range may overlap those of several females. Territories are marked with urine scrapes, droppings, tree-scratching points, and the deep 'sawing', or grunting, call. Females also call, but this presumably serves no territorial function. Home ranges may be as small as $10km^2$ in optimal habitat, to several hundred square kilometres where prey densities are low. They stalk and then pounce on their prey and do not rely on running at high speed like the cheetah.	Population in the park is unknown. The population in the Ayago project area, their ranges, and their routes have not yet been clearly mapped.
Lion (*Panthera leo* – VU)	Very wide tolerance, from desert fringes to woodland and fairly open grasslands. Absent from true forest.	The most sociable large cat, living in prides of three to 30 individuals. Pride size is largely dictated by prey availability and varies from region to region. The social groupings are complex, with each composed of a relatively stable core of related females, their dependent offspring, and usually a 'coalition' of two or more adult males. Most hunting takes place at night and during the cooler daylight hours. A pride territory is defended against strange lions by both males and females, but some prides and solitary males may be nomadic. Territories are marked with urine, droppings, earth-scratching, and their distinctive roaring. These calls are audible over distances of several kilometres. Pride home ranges vary from 26 to 220 km^2 but in some cases may exceed 2000 km^2.	There is no record yet near the project site, but the possibility of occurrence exists given the presence of suitable hunting grounds such as the lekking grounds and wallow areas. The population in the park is unknown but could be under 500 individuals. Population in the Ayago site, home ranges, moving routes, and resting areas have not yet been mapped.
Spotted Hyena (*Crocuta crocuta* – NT)	Open and lightly wooded savanna, dense woodland types, rugged, broken country; also penetrates drier areas along vegetated water-courses.	Solitary animals may be encountered, but they usually live in family groups, or 'clans', led by an adult female. Clan size ranges from three to 15 or more individuals, with each clan defending a territory, which is marked with urine and anal gland secretions and the distinctive bright white droppings, usually deposited in latrine sites. They are both nocturnal and crepuscular, with more limited daytime activity. They frequently sunbask in the vicinity of their daytime shelters. Contrary to popular opinion, they are not skulking scavengers, although they are not above driving other predators such as lions from their kills.	Population in the park is unknown. Population in the Ayago site, home ranges, moving routes, and resting areas have not yet been mapped.
Hippopotamus (*Hippopotamus amphibious* – VU)	Sufficient water to allow for complete submergence is a requirement, and preference is shown for permanent waters with sandy substrates. Access to adequate grazing is also	Semi-aquatic, spending most of the daylight hours in water, but emerging frequently to bask on sandbanks and mudbanks and on occasion to feed, particularly on overcast, cool days and in areas where they are not disturbed. They emerge at night to move to the grazing grounds, which may be a few 100 meters to several kilometres away (distances of up to 30 km have been recorded), depending largely on the quantity and quality of grazing and the size of the population. They normally live in heads, or schools, of 10 to 15 individuals, although larger groups and solitary bulls are not uncommon. In areas of high density, heads of 30 or more	Around 2000 hippopotamus are living between Karuma and Murchison. Average population density is $14.3/km^2$. High populated area is unknown. They disperse for grazing at least 1 km away

Name	General Habitat	General Behaviour	Estimated Distribution in Ayago Area
	essential, but these animals will move several kilometres away from bodies of water to reach suitable feeding areas.	animals are common. Territories in the water are very narrow but broaden towards the grazing grounds. Territorial defence is generally in and close to the water but of little consequence in feeding areas. Herds disperse when feeding, retaining their integrity only when in the water. Fixed pathways to and from feeding grounds are used and these are characterized by a 'tram-line' trail, consisting of two parallel tracks separated by a slightly raised centre ridge. The hippopotamus is considered a dangerous mammal, as attacks almost invariably result in death for the unfortunate individual who provokes, wittingly or unwittingly, one of these animals.	from the River Nile. Preferred grazing areas have not been identified.
African Elephant (*Loxodonta Africana* – NT)	Extremely wide habitat tolerance, including coastal, montane, forest, different savanna association, semi-desert and swamp, with the only requirements being access to adequate food, water, and usually shade.	Home range size varies considerably and usually relates to the abundance of food and access to water, with matriarchal, or family, groups ranging over 15 to > 50 km^2, but range is frequently smaller. Ranges of the forest race are generally much smaller, primarily because of greater abundance of food. They are highly social, living in small family herds consisting of an older cow and her offspring, with larger groups including other related cows and their calves of different ages. At certain times, usually at water points or at abundant and localized food sources, several of these matriarchal groups may gather to form temporary 'herds,' sometimes up to several hundred, but each family unit retains its integrity.	Around 500 elephants are living in the MFNP. High populated area, home range, number of the herds, and migration routes have not been identified. Population on the northern bank seems higher than that on the southern bank.

Source: Field guide to the larger Mammals of Africa (Chris & Tilde Stuart, 2006)

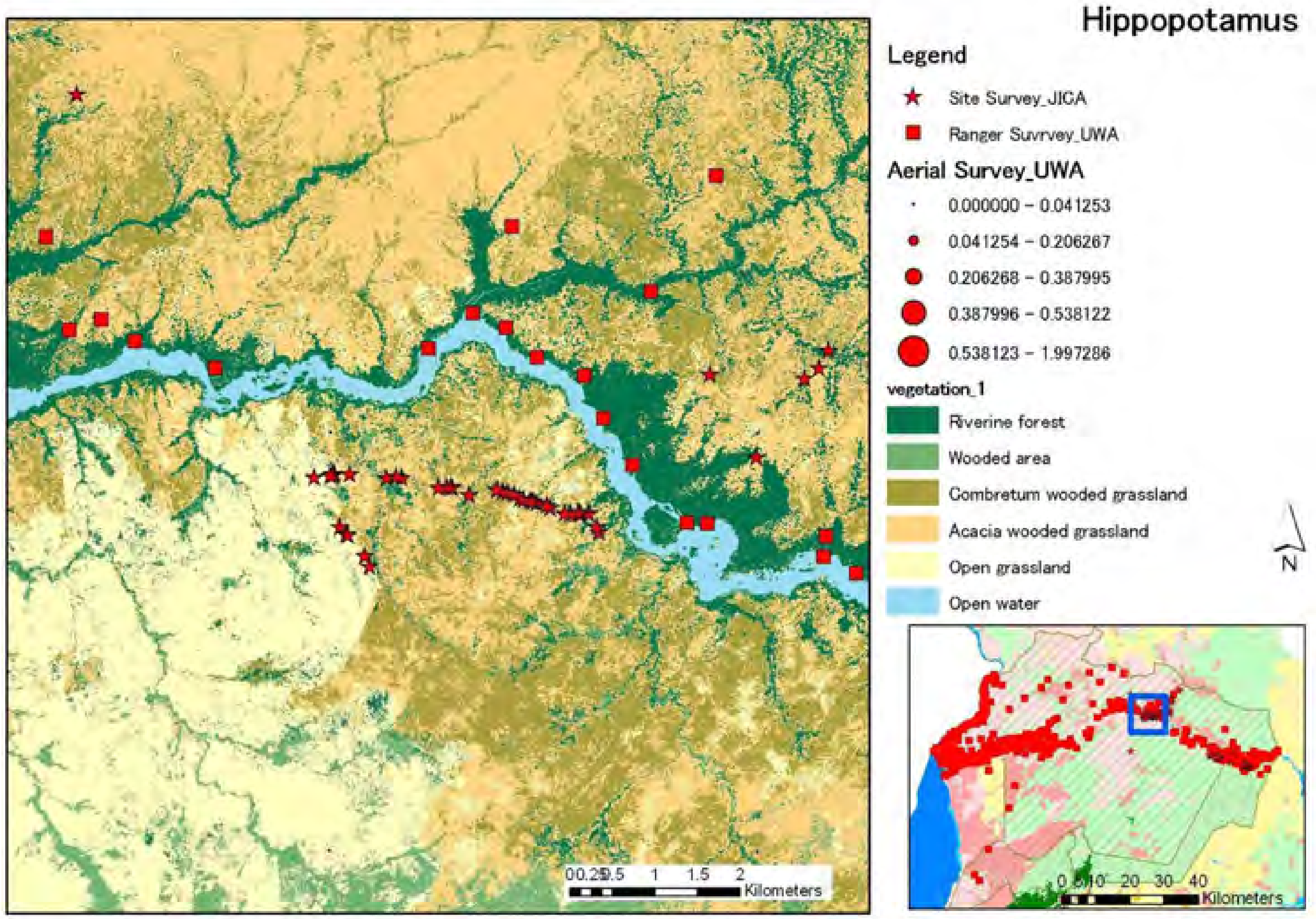


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Figure 3.2-4 Recorded locations of Hippopotamus

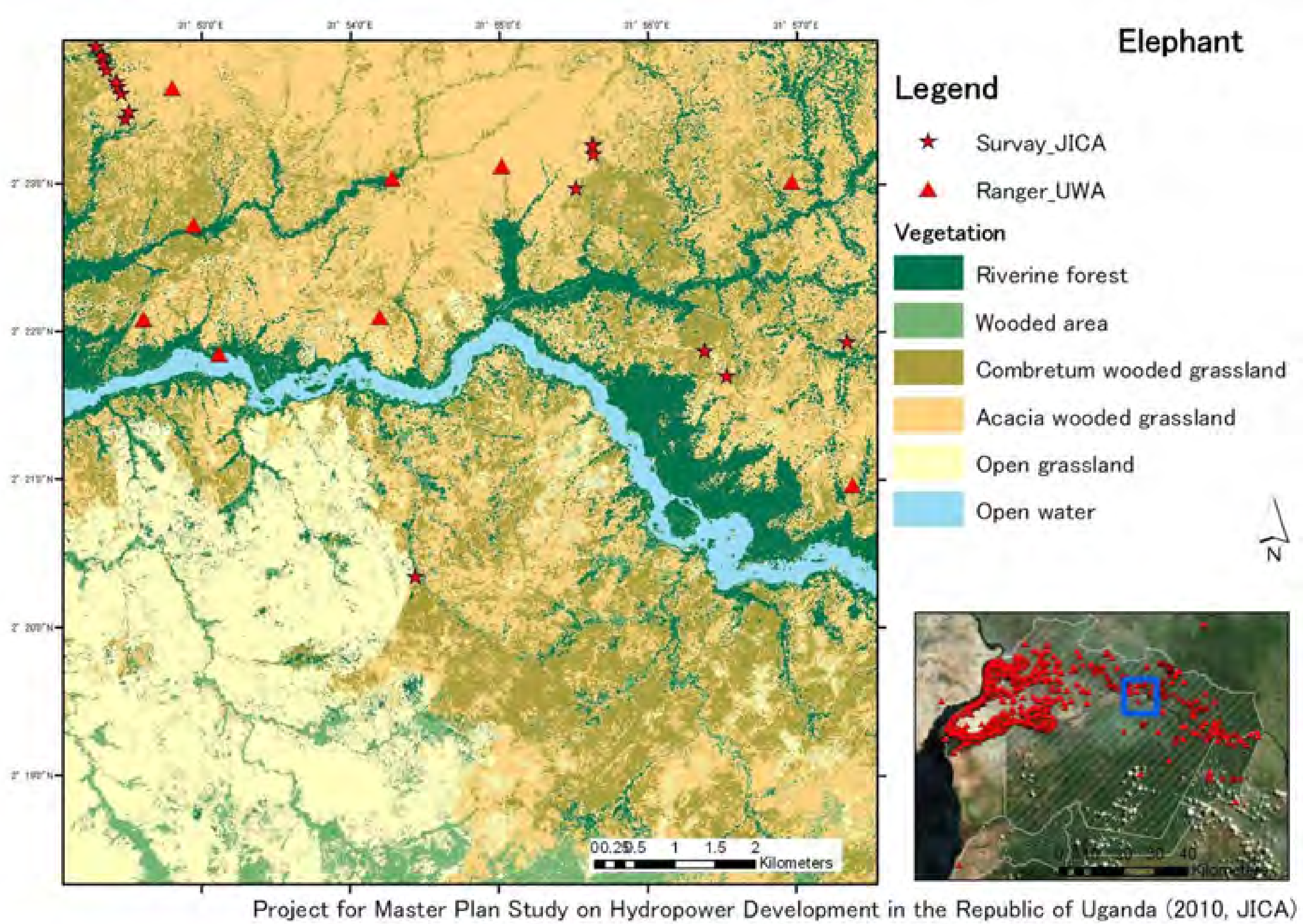


Figure 3.2-5 Recorded Locations of Elephant

3.2.2.3 Birds

A total of at least 491 species of birds are known to inhabit MFNP (Wilson 1995). Twelve of them are categorized in EN, VU, NT of IUCN red-list and 116 of them are migrant species, both intra African and intercontinental. A total of 119 species were recorded at the site survey, and 9 of them are of conservation concern (see Table 3.2-3).

Table 3.2-3 Species of birds of conservation concern recorded in the project area

Briton Number	Common name Scientific name	Threat	Habitat preference	Survey area A	Survey area B
B36	Purple Heron *Ardea purpurea*	R-NT	WW	√	√
B178	Brown Snake Eagle *Circaetus cinereus*	R-NT		√	√
B180	Western Banded Snake Eagle *Circaetus cinerascens*	R-VU	F	√	√
B324	Ring-necked Francolin *Francolinus streptophorus*	R-VU/RR		√	√
B468	Rock Pratincole *Glareola nuchalis*	R-VU	WW	√	
B876	Swallow-tailed Bee-eater *Merops hirundineus*	R-NT		√	
B984	Spot-flanked Barbet *Tricholaema lacrymosa*	R-RR		√	√
B1120	White-headed Saw-wing *Psalidoprocne albiceps*	R-RR	f	√	√
B1949	Sharpe's Starling *Cinnyricinclus sharpii*	R-NT	FF	√	

Over 53% of the known avifauna of MFNP have recognized habitat preferences (Wilson 1995). The preferred habitats are Forest (F) and Water (W and WW). The habitats seem to be conservation significant. Detail survey results are shown in Annex 2.

Table 3.2-4 Summary of habitat preferences for species recorded in the project area

Habitat preference	Number per category	
	Wilson (1995)	JICA study (2010)
Af/FF	1	
AW	1	
F	103	26
f/F	1	
FF	9	2
fW	9	2
FWW	6	1
W	41	8
WW	90	8
Grand Total	261	47

W - always resident in or near water (WW refers to a species strictly tied to a water habitat); w - often resident or observed in or near water; F -Forest resident (FF- refers to species of strictly forested habitats); f - resident in and near forests; Af - intra-African migrant,

3.2.2.4 Amphibians and Reptiles

A total of 12 amphibian species belonging to three families and 16 reptiles belonging to 12 families were documented during the study. Table 3.2-5 shows the results. 11 Amphibians are LC and one amphibian is DD of IUCN red list. One reptile, Crocodile, is LC of IUCN red list. The reptiles – apart from the Nile Crocodile, which is a resident of the rivers – were randomly distributed throughout the habitats sampled. However, tortoises were encountered only in the wooded grassland, while the Pelomedusids were recorded only in rain pools of water or wetlands/marshes. The most important habitats for amphibians and reptiles are along the Nile River banks. Detailed survey results are shown in Annex 2.

Table 3.2-5 Amphibians and Reptiles of Ayago

Name			IUCN Red List status	Survey area A			Survey area B	
	Family name	**Scientific name**		**I**	**II**	**III**	**IV**	**V**
Amphibians	Family Bufonidae	*Amietophrynus maculates*	*Least Concern (LC)*	1	0	0	1	0
		Amietophrynus regularis	*LC*	1	0	1	1	1
		Amietophrynus vittatus	*Data deficient (DD)*	1	0	0	0	0
	Family Hyperoliidae	*Afrixalus osorioi*	*LC*	1	1	0	0	0
		Hyperolius viridiflavus	*LC*	1	0	0	1	1
		Kassina senegalensis	*LC*	1	0	1	1	1
	Family Ranidae	*Amietia angolensis*	*LC*	1	0	1	1	0
		Phrynobatrachus acridoides	*LC*	1	0	1	1	1
		Phrynobatrachus natalensis	*LC*	1	0	1	1	1
		Ptychadena anchiateae	*LC*	0	1	1	0	1
		Ptychadena chrysogaster	*LC*	0	1	0	0	0
		Ptychadena mascareniensis	*LC*	1	1	1	1	1
Reptiles	Family Gecknoniidae	*Hemidactylus brookii*	*Not evaluated*	0	1	0	0	0
	Family Scincidae	*Mabuya maculilabris*	*Not evaluated*	0	1	1	1	1
		Mabuya megarula	*Not evaluated*	0	0	0	0	1
	Family Chamaelionidae	*Chamaeleo gracilis*	*Not evaluated*	0	1	1	0	0
		Chamaeleo laevigatus	*Not evaluated*	0	0	1	0	1
	Family Agamidae	*Agama agama*	*Not evaluated*	0	1	1	1	0
	Family Varanidae	*Varanus niloticus*	*Not evaluated*	1	1	1	1	0
	Family Crocodilydae	*Crocodylus niloticus*	*Least Concern*	1	0	0	0	0
	Family Typhlopidae	*Typhlops sp.*	*Not evaluated*	0	1	0	0	0
	Family Colubridae	*Dasypeltis scabra*	*Not evaluated*	0	0	0	0	1
		Philopthamnus sp	*Not evaluated*	0	1	0	1	1
	Family Elapidae	*Naja melanoleuca*	*Not evaluated*	1	1	0	1	1
	Family Viperidae	*Bitis arietans*	*Not evaluated*	0	0	0	0	1
	Family Pelomedusidae	*Pelomedusa subrufa*	*Not evaluated*	0	1	0	0	1
	Family Testudinidae	*Geochelone pardalis*	*Not evaluated*	0	1	1	1	1
		Kinixys belliana	*Not evaluated*	0	1	0	0	1

I. Habitats Adjacent to the Nile River Banks near the point of dam placement
II. Woodlands and Bushlands on the northern bank
III. Areas along the Karuma-Rabongo Forest
IV. Woodlands and Bushlands on the southern bank
V. Grassy Plains on the southern bank
Where 1= Presence and 0 = Absence

3.2.2.5 Insects (Butterflies)

A total of 66 species of butterflies are confirmed at the site survey. None of them are listed in the IUCN red list. None of the swamp/wetland species that have limited continental distribution were recorded by this study. Fourteen forest specialists (F and FL-ecotypes) butterfly species were recorded in the areas surveyed, along with one swamp species (S). Relatively higher biodiversity habitats, forest and wetland, would be important habitats. Detailed survey results are shown in Annex 3.

3.2.2.6 Fish

Literature survey suggests the possible existence of 8 fish species in the survey area, and 7 of the 8 are LC category of IUCN red list. During the site survey, 5 kinds of fish were confirmed. The area around the intake of the left bank and some relatively big tributaries, such as the Ayago River, are suggested to be the most important areas. Detailed survey results are shown in Annex 3.

Table 3.2-6 Evaluation of the survey sites

	Scientific names	IUCN Red List status	Habitat preferences	Population in the survey area*																
				Left Bank						North Bank										
				Intake				Outlet		Intake		Ayago River			Outlet				Kibaa	
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Survey result	*Lates niloticus*	**Least concern**	**open water; not very turbulent**	E	R		E	E	R	E	E			R		E	E	E	R	
	Barbus altianalis	**Least concern**	**open turbulent waters; upstream migrant**	R	E	R	E	E	E	E	E					E	E	E	E	E
	Mormyrus kannume	**Least concern**	**open turbulent/flowing water**	E	E	E	R	E	E	E	E			R		E	E	E	E	E
	Bagrus docmac	**Least concern**	**open flowing water**	E	E		R	E	E	E	E			R		E	E	E		
	Oreochromis niloticus	**Least concern**	**shallow non-turbulent open**	E	E	R			E	E	E	E	E	R				E		E
	Oreochromis variabilis	**Least concern**	**shallow, non-turbulent, open**			E						E	E						E	E
	Clarias gariepinus	**Least concern**	**near shore, aquatic vegetation**			E						E	E							
	Protopterus aethiopicus	**not determined**	**aquatic vegetation**			E						E	E							
	Synodontis afrofischeri	**not determined**	**upstream spawner, clean water**																	
	Synodontis victorie	**not determined**	**upstream spawner, clean water**																	
	Intermedius mystus	**not determined**	**upstream spawner, clean water**																	
	Tilapia zillii	**not determined**	**aquatic vegetation**																	
	Rastrineobola argentia	**Least concern**	**pelagic clean water**																	
	Labeo victorianus	**Threatened**	**upstream spawner, clean water**																	
	Number of species			5	5	6	4	4	5	5	5	4	4	4		4	4	5	4	4
				8				5		5		7			5				5	
Evaluation	Importance of the habitat	**Breeding, nursery, feeding, shelter/refugia**		A				B		B		A			B				B	

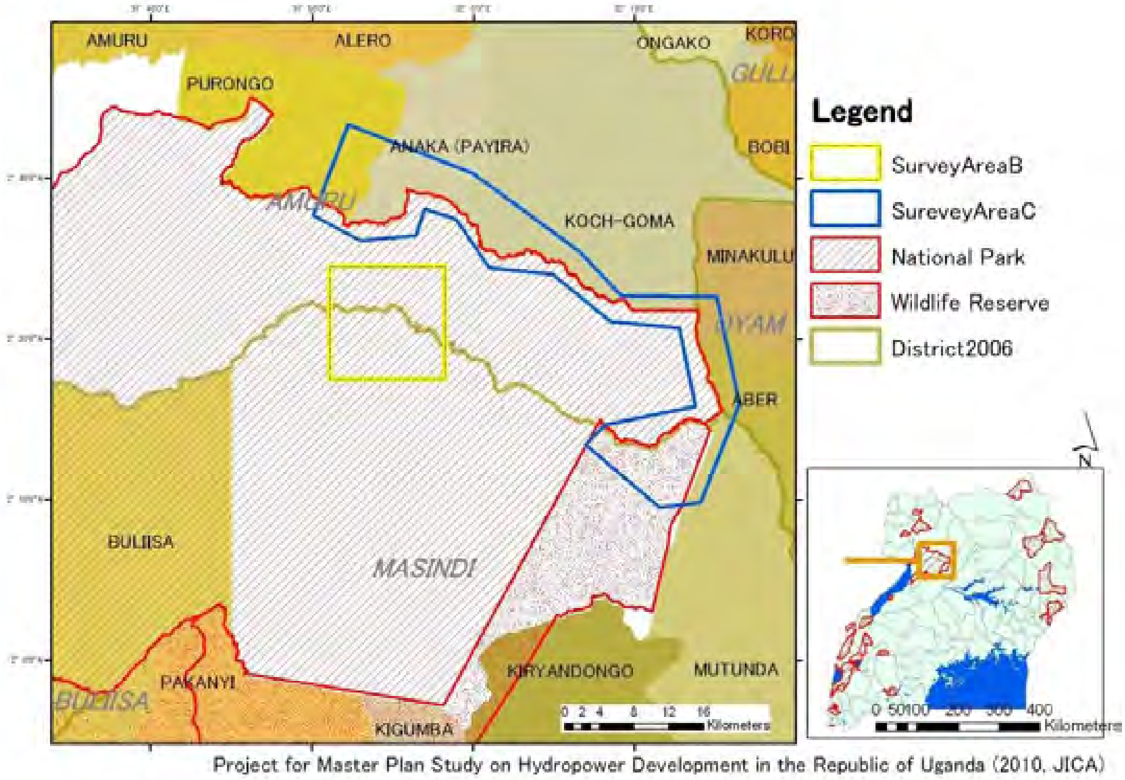
*** Detailed survey needed** R Record

E Expected

3.2.3 Social environment

3.2.3.1 Administrative Boundaries

Murchison Falls National Park is surrounded by the Districts of Amuru (Nwoya since July 2010) to the North, Masindi (Kiryandongo since July 2010) to the South, Oyam (Apace before July 2006) to the East, and Bulisa and Nebbi to the West. Survey Area C, which has a border with the Park, includes six Sub-counties: Purongo, Anaka, Koch Goma, Minakulu (Myene since July 2010), Aber, and Mutunda. The figure below shows administrative boundaries around the Ayago site (Survey Area B) in 2006.

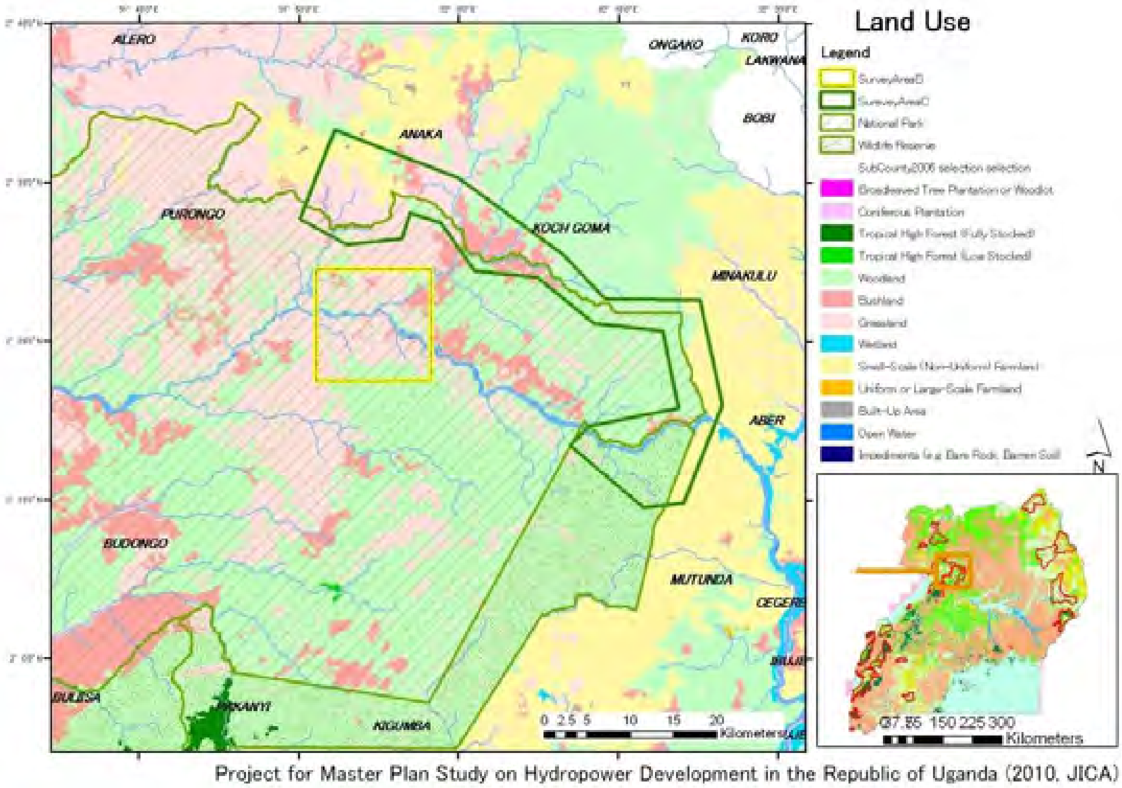


Source: Uganda Bureau of Statistics, 2006

Figure 3.2-6 Administrative Boundaries around Ayago Site, 2006

3.2.3.2 Land Use and Land Ownership

Land cover around the Ayago site is mainly grassland, bush land, and woodland. The northwest area near access roads (Anaka and Purongo Sub-counties) and most of the Eastern area (Myene/Minakulu, Aber, and Mutunda Sub-counties) is characterized by small-scale farmland. A part of the southern area (Mutunda Sub-county) and most of the northern area (Koch Goma Sub-county) are woodland and forest reserve. The characteristics of land use by sub-county in Survey Area C can be seen in Annex 4.



Source: National Forest Authority, 2005

Figure 3.2-7 Land Use Map around the Ayago Site, 2005

In Northern Uganda in general, the land is commonly owned under customary tenure, and land rights are vested in the clan elders or chiefs. Customary tenure actually means that the right to use land is regulated by local customs and linked to family inheritance and lineage. The clan heads have powers regarding access and use rights by the clan members.

However, Women have limited access and control over land and other household assets. Women do not usually own land, due to traditional culture in Uganda. A woman can purchase and own land only when her husband dies or she doesn't have one. More detailed information on land ownership can be seen in Annex 4.

3.2.3.3 Population

There are no residents of the Ayago site, since the area is inside the National Park. Population by sub-county in Survey Area C is shown in the table below. Population by parish can be found in Annex 5.

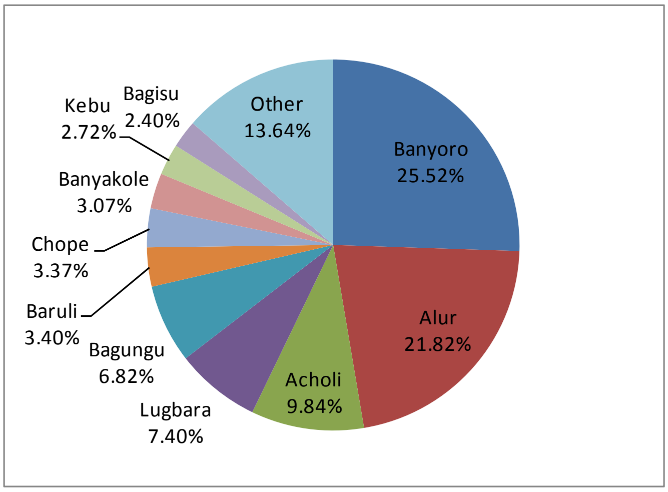
Table 3.2-7 Population Estimates of Survey Area C by Gender, 2010

Sub-county	Male	Female	Total
Aber	33,000	35,100	**68,100**
Anaka	7,600	8,100	**15,700**
Purongo	4,100	4,200	**8,300**
Mutunda	35,200	36,900	**72,100**
Myene/ Minakulu	26,700	26,900	**53,600**
Koch Goma	5,500	5,100	**10,600**

Source: Sub National Projections Report Northern, Western Region 2008-2012

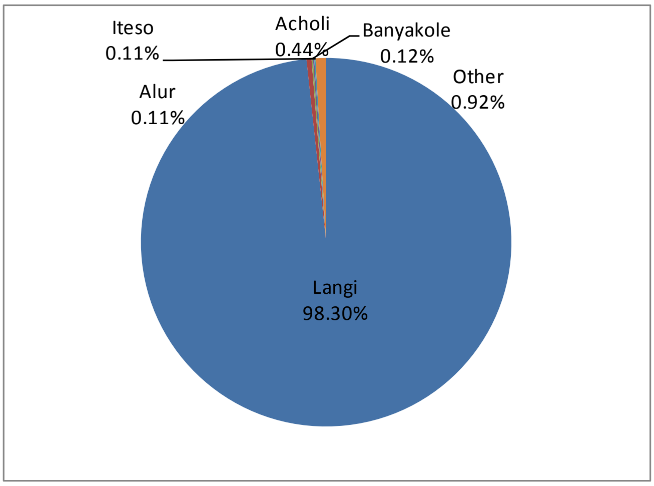
3.2.3.4 Ethnic Groups

Figures 3-26, 3-27, and 3-28 show the composition of ethnic groups in three districts in Survey Area C. In Masindi District, there are a variety of ethnic groups. Banyoro and Alur account for 25.53% and 21.82%, respectively. Chope accounts for only 3.07%, but they are dominant in Mutunda sub-county. In Minakulu/Myene and Aber sub-counties in Oyam District, the majority of people (98.30%) are Langi, while in Purongo, Anaka, and Koch Goma sub-counties in Amuru, people are mainly Acholi settlers (91.09%). Out of fifteen sub-counties surrounding the park and reserves, nine of them are occupied mainly by Luo-speaking tribes.



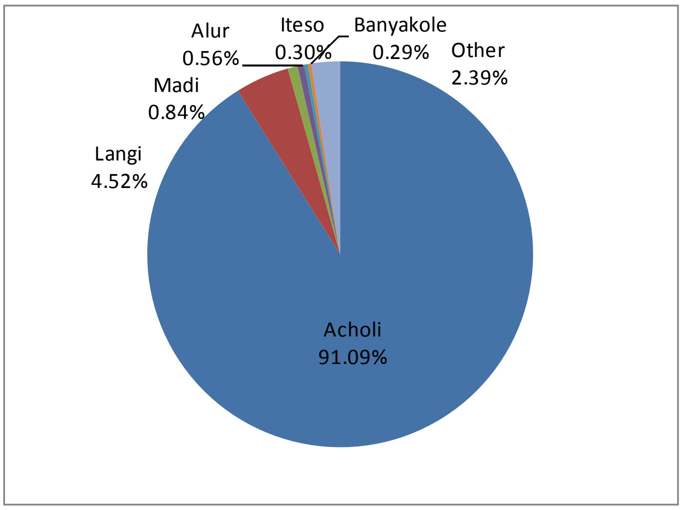
Source: 2002 Population and Housing Census

Figure 3.2-8 Distribution of Population by Ethnic Groups in Masindi District, 2002



Source: 2002 Population and Housing Census

Figure 3.2-9 Distribution of Population by Ethnic Groups in Oyam (Apac) District, 2002



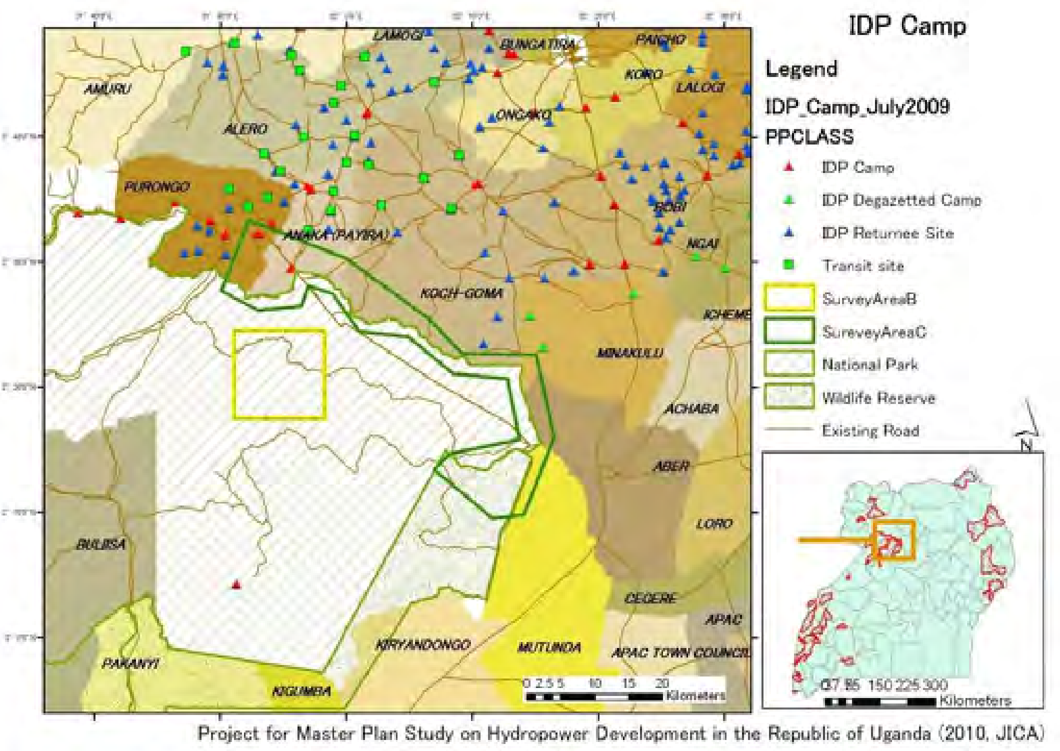
Source: 2002 Population and Housing Census

Figure 3.2-10 Distribution of Population by Ethnic Groups in Amuru (Gulu) District, 2002

3.2.3.5 Internally Displaced Persons

Due to activities of the Lord Resistance Army (LRA), Northern Uganda has experienced instability over the last two decades, resulting in the internal displacement of some 1.1 million people (UNOCHA, 2010). IDP camps were established along the main roads, trading centres, town centres, and suburbs. In Amuru District, there were 34 original camps with the population of 257,000 in 2005.

As the figure below shows, most camps were located in the northern part of Survey Area C, in Amuru and Oyam Districts.



Source: Northern Uganda Rural Road Project, 2009

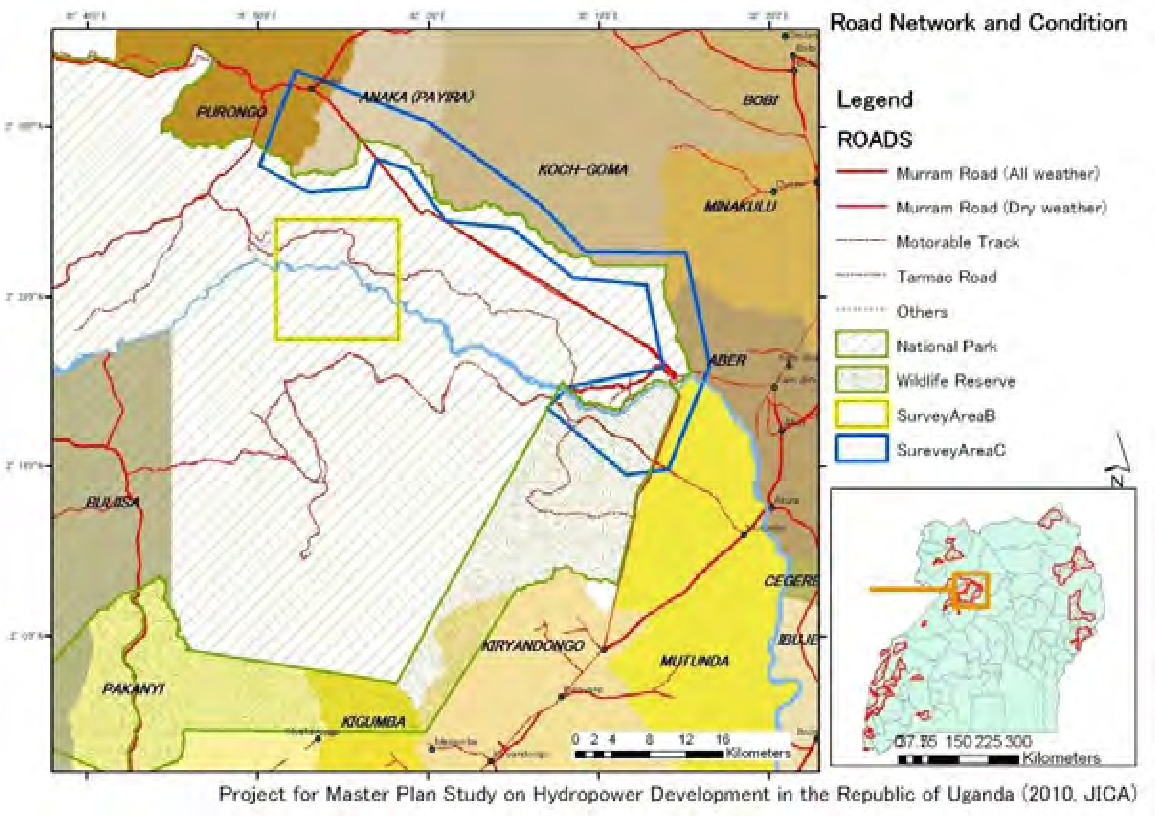
Figure 3.2-11 Locations of Internally Displaced Persons' Camps, 2009

Following the end of the insurgency in 2006, the IDPs have been returning and resettling on their ancestral lands under the auspices of the peace and recovery program initiated by the government of Uganda and other development partners, including JICA. According to UNHCR ("Camp phase out update as of 6th December, 2010"), all camps in Amuru District were officially closed by 30th July, 2010.

However, according to UNHCR camp mapping data from November 2010, 36,400 IDPs were estimated to still be residing in the former camps with 11,260 in transit sites in Amuru District. There are many extremely vulnerable individuals/persons with specific needs, including older persons, female/child-headed households, persons with disabilities, and the chronically ill.

3.2.3.6 Road Network

The roads that exist in Uganda fall under three major categories: national, district Sub-county, and community/feeder roads. The sub county of Myene, for instance, has a total of 18 roads belonging to district and community. The figure below shows the two categories of roads around the Ayago site; main and other roads, whereby the main roads include the national and district roads while other roads fall under community/feeder roads.



Source: JICA Study Team, 2010 and National Forest Authority, 1969

Figure 3.2-12 Road Network around the Ayago Site, 2010

3.2.3.7 Local Economy

The main source of household livelihoods in survey area C is subsistence farming. According to the Census in 2002, subsistence farming is the main source of livelihood for 67.4% of the household in Masindi, 77.4% in Amuru, and 94.0% in Apac.

Table 3.2-8 Main Source of Household Livelihood in Survey Area C

	Masindi	Amuru (Gulu)	Oyam (Apac)
Subsistence Farming	67.4%	77.4%	94.0%
Earned Income	20.1%	9.0%	3.8%
Property Income	1.7%	10.8%	2.1%
Other	10.7%	2.8%	0.1%

Source: 2002 Population and Housing Census 2002, District Reports of Masindi, Gulu, Apac

The main crops include maize, cassava, millet, sorghum beans, ground nuts, sweet potatoes, and sesame. Being largely peasant farmers, they consume domestically what they produce and sell the surplus in local markets for cash.

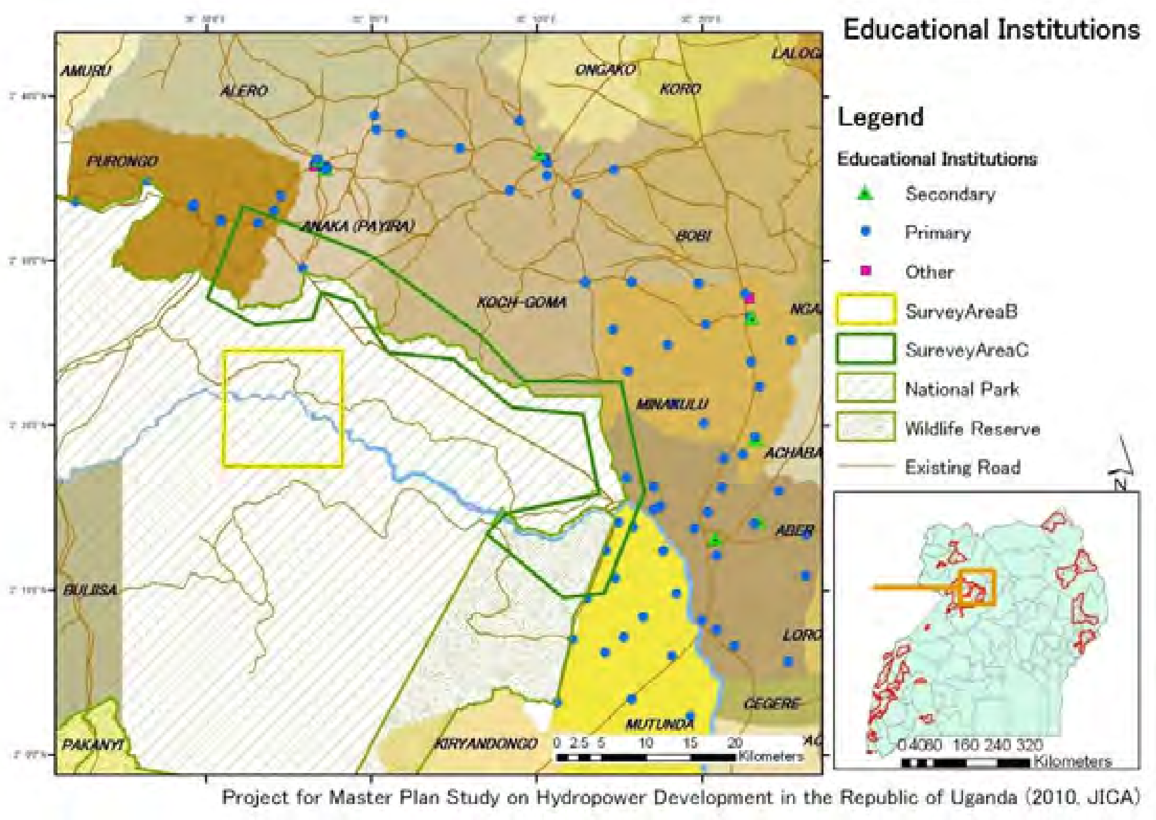
Animal rearing is also a key economic activity in survey area C, although small numbers of cattle goats, pigs, sheep, pigs, duck and turkey are kept. It was reported by the community that the LRA related war, which lasted twenty years in the areas, made large-scale animal rearing difficult.

The communities in Survey Area C carry out fishing activities on the River Nile outside the park area, and in the vast swamps and wetlands, small rivers, and streams which act as breeding places for the fish. Fishing is on a small scale and what is caught is locally consumed.

Other activities include petty businesses such as operating small kiosk grocery shops in the village and trading centres, brick making, charcoal burning and selling, and roadside sale of farm products. Annex 8 explains the characteristics of the local economy by Sub-county.

3.2.3.8 Education

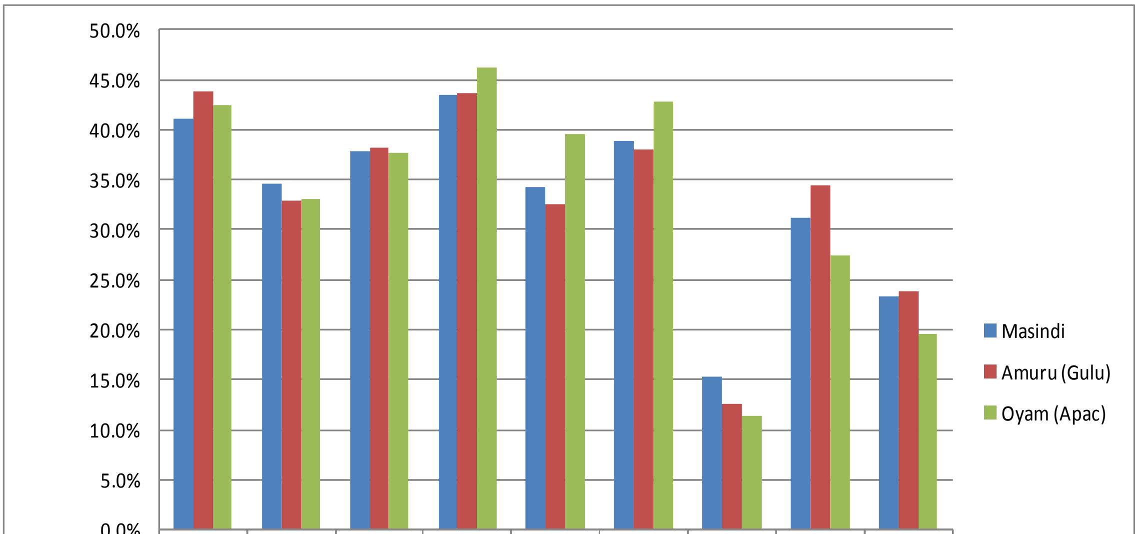
The figure below shows the location of Educational institutions such as primary, secondary, and tertiary schools around Ayago.



Source: JICA Study Team

Figure 3.2-13 Location of Educational Institutions around Ayago Site, 2010

School attendance by gender by three districts in Survey Area C is shown in the figure below. Compared to male, female attendance is low. More than 25% of females have never been to school, as compared with less than 15% of males.

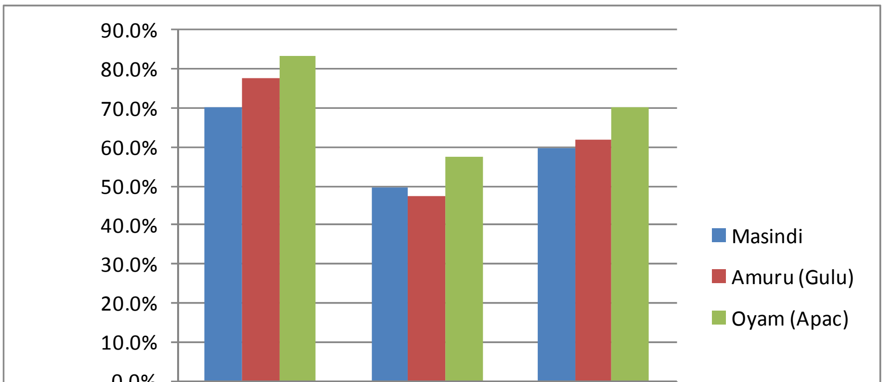


	Attended School in 2002			Left School			Never Attended School		
	Male	Female	Average	Male	Female	Average	Male	Female	Average
Masindi	41.1%	34.6%	37.8%	43.5%	34.2%	38.8%	15.4%	31.2%	23.3%
Amuru (Gulu)	43.9%	32.9%	38.3%	43.6%	32.6%	38.0%	12.6%	34.5%	23.8%
Oyam (Apac)	42.5%	33.1%	37.6%	46.1%	39.6%	42.8%	11.4%	27.4%	19.6%

Source: 2002 Population and Housing Census, District Reports of Masindi, Gulu, Apac

Figure 3.2-14 School Attendance by Gender in Survey Area C, 2002

Similarly, the literacy rate of women is lower than that of men in three districts, as the figure below indicates.



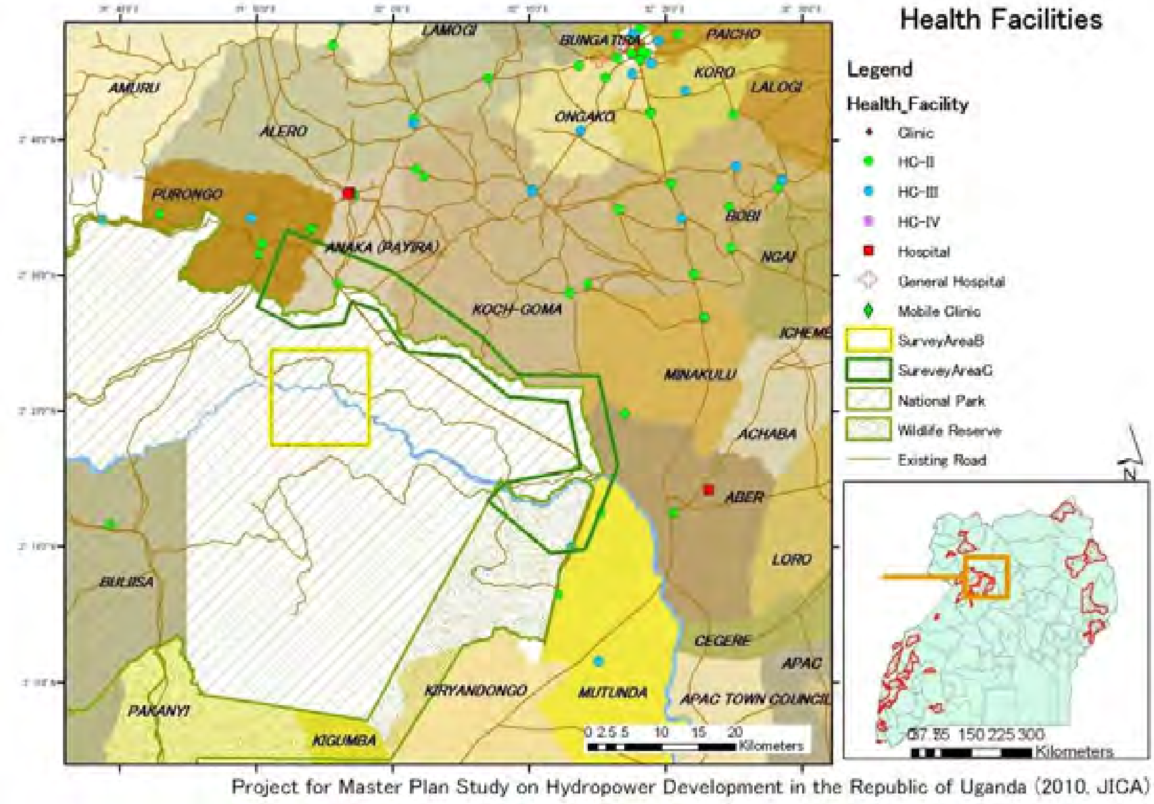
	Male	Female	Average
Masindi	70.1%	49.4%	59.7%
Amuru (Gulu)	77.7%	47.2%	62.0%
Oyam (Apac)	83.2%	57.7%	70.0%

Source: 2002 Population and Housing Census, District Reports of Masindi, Gulu, Apac

Figure 3.2-15 Literacy Rate by Gender in Survey Area C, 2002

3.2.3.9 Health

The figure below shows the locations of health facilities such as health centres and hospital around the Ayago site.



Source: UNOCHA, 2009

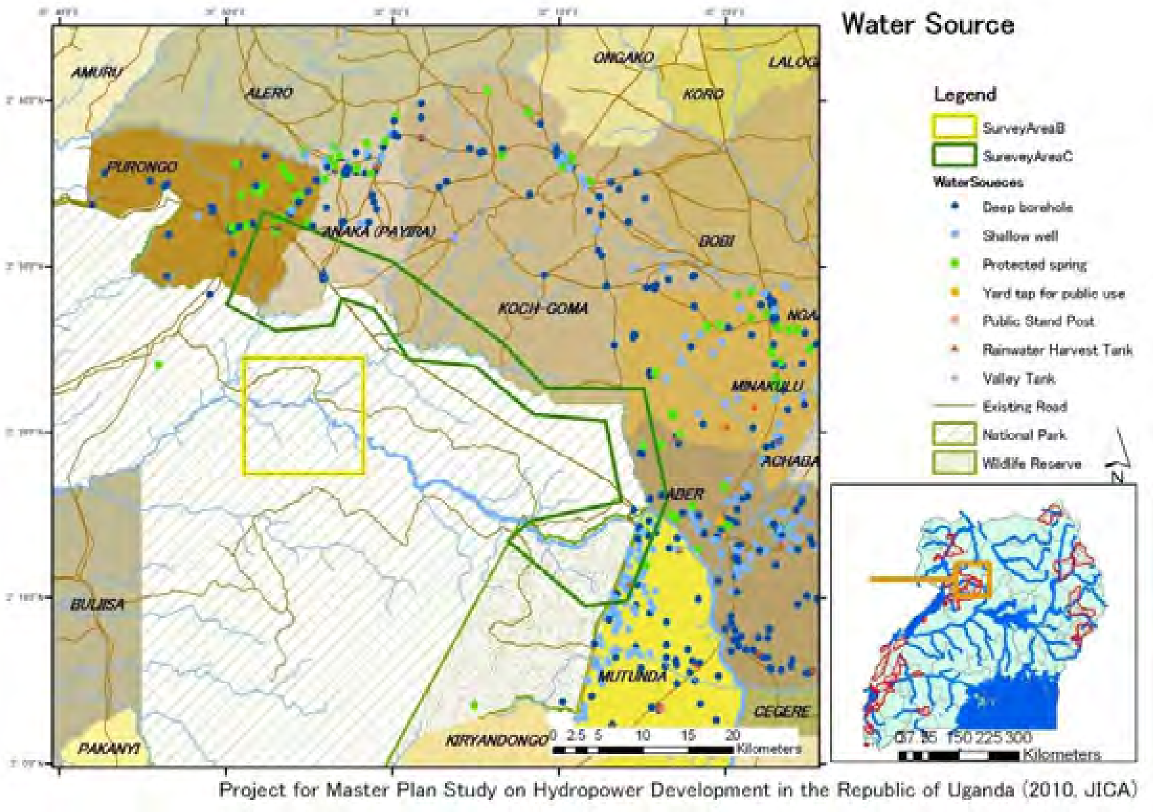
Figure 3.2-16 Locations of Health Facilities around Ayago Site, 2010

The Government policy provides that there should be HC II from the Parish level, HC III at sub-county, and so on up to the national referral hospital level. The public health facilities in the survey area are mostly HC II and HC III, except in Aber and Anaka Sub-counties, where there are hospitals.

The health centres, including hospitals, in the surveyed sub-counties are not only few but also fall short of the expected service standards. The most frequently raised complaints against the health facilities are inadequate drugs and supplies, unqualified health workers, and long waiting period before getting the services. The long waiting time at the health centre also means that there are limited health facilities in the sub-counties. As a result, some people obtain health care services from private health outlets such as clinics and drug shops.

3.2.3.10 Water Use

The major sources of water around Ayago site include rivers, boreholes, protected springs, shallow wells, rainwater, and streams. The locations are shown in the figure below.



Source: Department of Water and Drainage

Figure 3.2-17 Water Sources around Ayago Site, 2010

The Table below shows the accessibility of water by local people in Survey Area C. The majority of people do not have a water source on premises. The responsibility of fetching water lies mainly with women and children; hence it reduces their time for other productive activities.

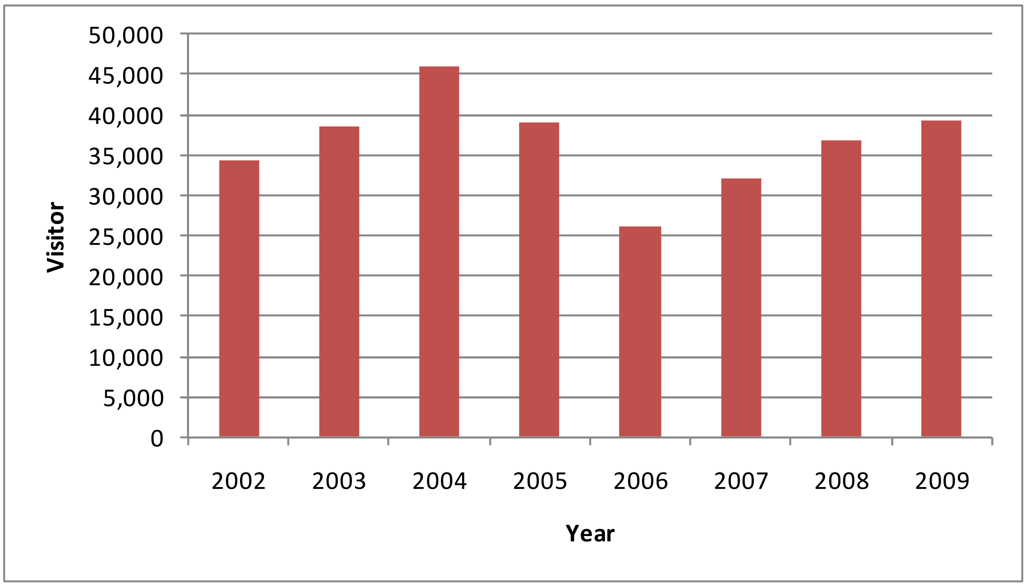
Table 3.2-9 Distance to Nearest Water Sources of Households by Sub County

Sub-county	Water Source		
	On premises	Up to 1 km	Over 1 km
Aber	163	6,287	3,532
Minakulu	312	7,100	1,056
Anaka	127	2,219	65
Purongo	104	1,419	75
Koch Goma	84	1,786	107
Mutunda	104	5,156	3,660

Source: 2002 Population and Housing Census, District Reports of Masindi, Gulu, Apac

3.2.3.11 Tourism

The tourism industry in Murchison Falls National Park has not been fully developed. The annual number of tourists has been less than 50,000, as indicated in the figure below. Contributing factors towards the small number of visitors include rebel activities in Northern Uganda that posed a security threat, and failure to adapt to tourism needs and expectations. According to interviews with UWA officials, the current number of visitors accounts for only 30 to 40% of the carrying capacity of the Park.



Source: Uganda Wildlife Authority

Figure 3.2-18 Number of Visitors to Murchison Falls National Park

Tourism activities in Murchison Falls National Park are generally limited to boat/launch trips to view wild animals and the falls, visits to the falls, and game drive. The list of tourism activities and their fees are shown in Annex 9.

The table below shows the tourism revenue of Murchison Falls National Park in 2009. It indicates that most revenue (70%) was collected through the entrance fees. Tourism activities such as boat rides, nature walk game drives, and fishing are not major sources of revenue. This means that currently, many of the visitors are on self-drive and they do not pay anything except entrance fee to see all the beautiful wildlife in the Park (Performance Evaluation of the Murchison Falls Protected Area General Management Plan Report, 2007).

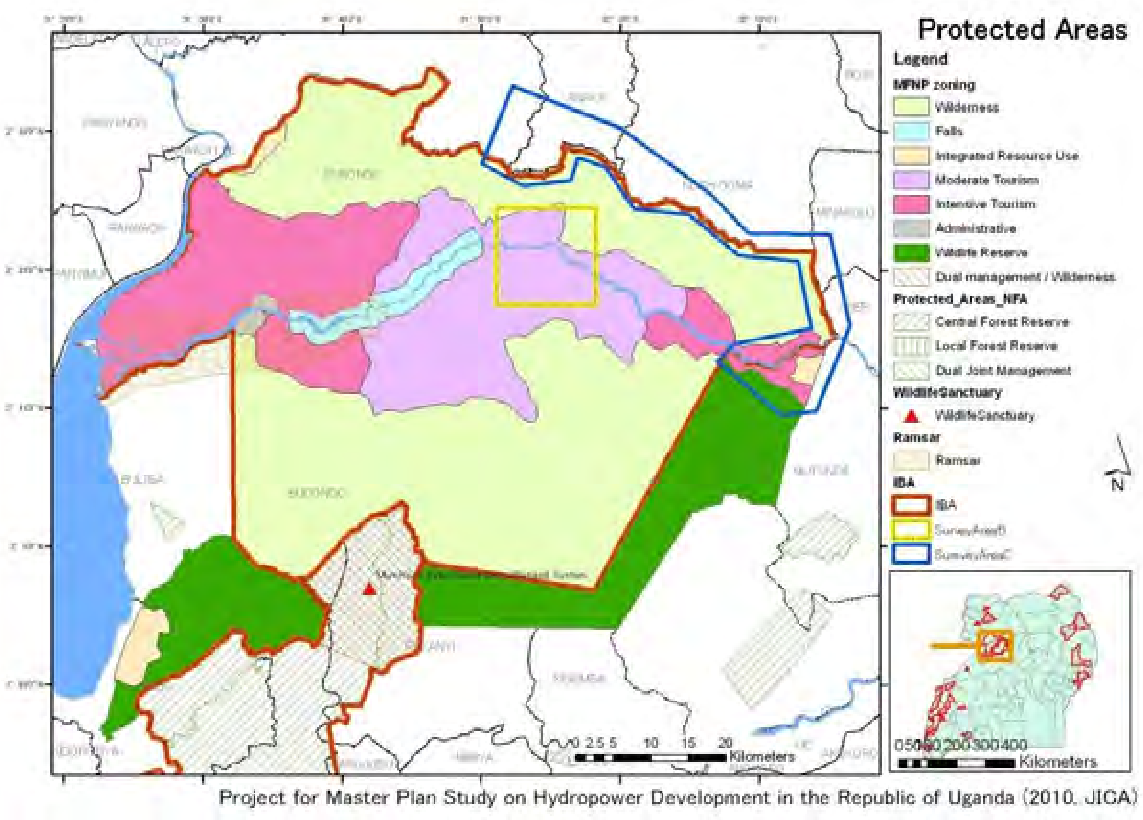
Table 3.2-10 Murchison Falls National Park Tourism Revenue in 2009

Tourism Activity	Annual Revenue in Ush.	%
Entrance fees (visitors)	1,649,033,319	63.7
Entrance fees (vehicles)	192,906,513	7.4
Canping fees	40,526,570	1.6
Landing fees	10,775,951	0.4
Photographic fees	29,938,677	1.2
Ranger Guide Fees	51,735,529	2.0
Ferry Crossing	301,849,052	11.7
Fishing Permits	39,960,836	1.5
Nature Walk fees	71,325,277	2.8
Lauch Hire	71,768,241	2.8
Vehicle Hire	3,941,737	0.2
Accomodation Bandas	16,452,950	0.6
Accomodation Ugandan Students	31,449,980	1.2
Boat rides	78,722,312	3.0
Total	**2,590,386,944**	**100.0**

Source: Uganda Wildlife Authority

To diversify tourism activity in the Park, UWA has considered the potentials for sport fishing, walking safari, and white water rafting (Murchison Falls Protected Area General Management Plan for 2001-2011). More detailed information is provided in Annex 9.

The Murchison Falls Protected Area (MFPA) includes Murchison Falls National Park, Bugungu Wildlife Reserve, and Karuma Wildlife Reserve. It is one of the most important tourism resources in Uganda. The area has been divided into several zones to clarify tourism development and to protect important and sensitive resources. The figure below shows the location of the zones.



Source: UWA 2010, NFA 2010, Nature Uganda 2010, Ministry of Water and Environment 2008, World Database on Protected Area2009

Figure 3.2-19 Management Zones of Murchison Falls Protected Area, 2010

The areas that have a potential for tourism development include an Intensive Tourism Zone, a Moderate (Low) Tourism Zone, and the Falls Zone. Ayago is located in the Moderate (Low) Tourism Zone.

The table below shows the classification of the zones from the viewpoint of tourism development, natural resource management, and community collaboration.

Table 3.2-11 Classification of Management Zones of Murchison Falls Protected Area

Management Zones	Tourism Development	Natural Resource Management	Community Collaboration
The Falls Zone	• Proposed for nomination for the World heritage Site list. • All developments are carefully designed to give the visitor the fullest exposure to the spectacular landscape of the Falls.	• It is the main breeding area for Nile Crocodiles. • There is the unique spray forest around the Falls.	• None

Management Zones	Tourism Development	Natural Resource Management	Community Collaboration
The Intensive Tourism Zone	• Activities comprise the launch trip to the Falls, the drive to the Falls, game drive, walking safari, bird watching, and sport fishing. Activities will continue to be promoted with diversification of visitor experience.	• None	• None
The Moderate (Low) Tourism Zone	• It is confined to game drive, walking safari, and sport fishing by concession. Development is conducted in a particularly sensitive way.	• The central part of this area is a unique habitat to almost half of the large mammals of the entire conservation area.	• None
The Wilderness Zone	• Although tourism activities suggested by operators may be allowed, the area does not appeal to tourists.	• It comprises dense bushland and thicket with low numbers of wildlife. Tsetse flies are abundant. Wildlife and habitats will remain undisturbed.	• None
The Integrated Resource Use Zone	• None	• None	• Local community may use resources such as firewood and thatching materials in a sustainable manner under MoUs.
Administrative Zones	• It contains the developed areas where resources are allocated for operations and visitor accommodation.	• The environment in this zone is kept as natural as possible.	• None
Wildlife Reserve (Alternative Management Area)	• It will be offered for long-term management by concessionaries. Sport hunting may be permitted.	• Wildlife populations are low. The vegetation is thick, infested with tsetse flies.	• None

Source: Murchison Falls Protected Area General Management Plan for 2001-2011

3.2.3.12 MFNP and the Community

According to the Murchison Falls Protected Area General Management Plan 2001-2011, UWA has promoted better relationships with local communities for collaborative management of the area. The objectives of community collaboration include the following.

- To conserve and protect natural resources in MFPA, in collaboration with adjacent communities
- To minimize the impact of problem animals and vermin on local communities
- To support local communities in implementing benefit-sharing programs
- To develop programs to enable local communities to use MFPA resources in a sustainable manner

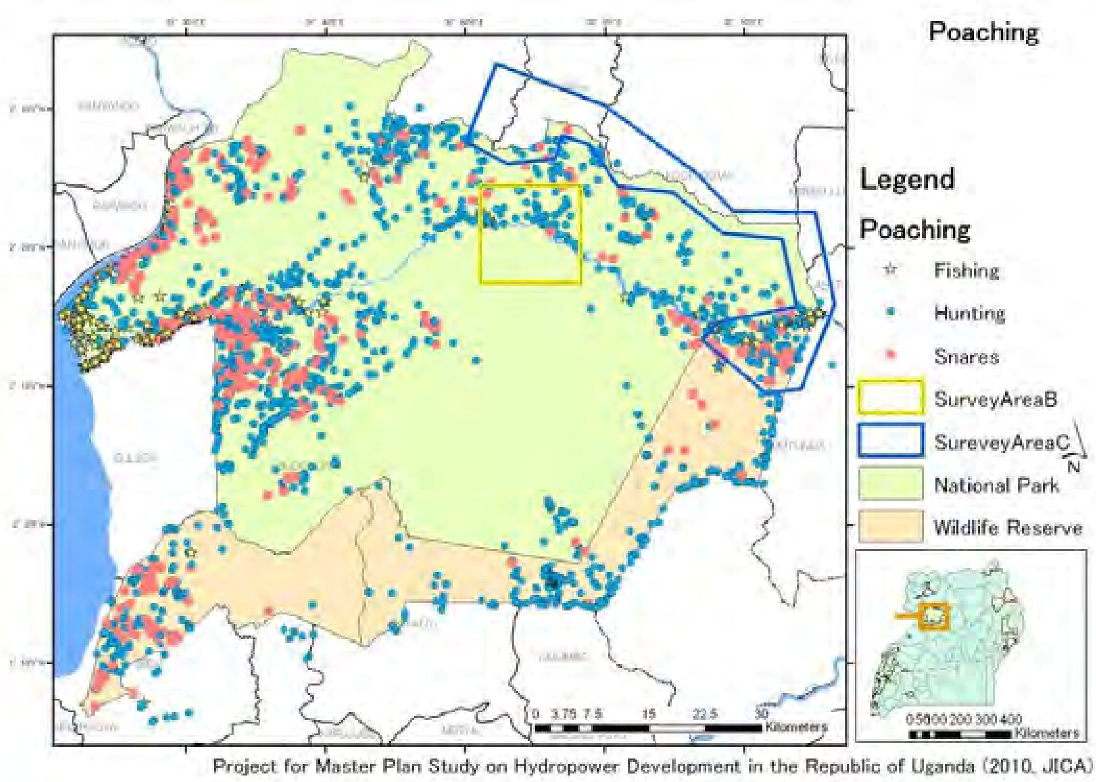
In order to meet the above challenges, UWA established the Community Protected Areas Institutions (CPIs). CPIs are integrated within Local Environment Committees, and report to local councils. They are expected to address community issues in PA management, to act as intermediaries facilitating communication, and to plan and implement revenue sharing projects. According to UWA officials, the institutions have been functioning well to link with the communities.

In communities adjacent to MFPA, the rapidly growing human population and changes in land use have led to increased conflicts between people and wildlife. Problem animals such as elephant, hippopotamus, baboon, and buffalo sometimes damage crops and livestock. There are strong complaints by local people that the MFPA management is not sufficiently staffed or equipped to respond when communities need help in controlling problem animals (Murchison Falls Protected Area General Management Plan 2001-2011).

The Wildlife Statute 1996 provides that 20% of gate entrance fees are given to local communities to be used in funding development projects. The park disbursed USh.896,396,296 (nearly equal to US$487,453) from July 2002 to June 2009. The communities have utilized this revenue mainly for the constructions of primary schools, health centres, pit latrines, community roads, and livestock production.

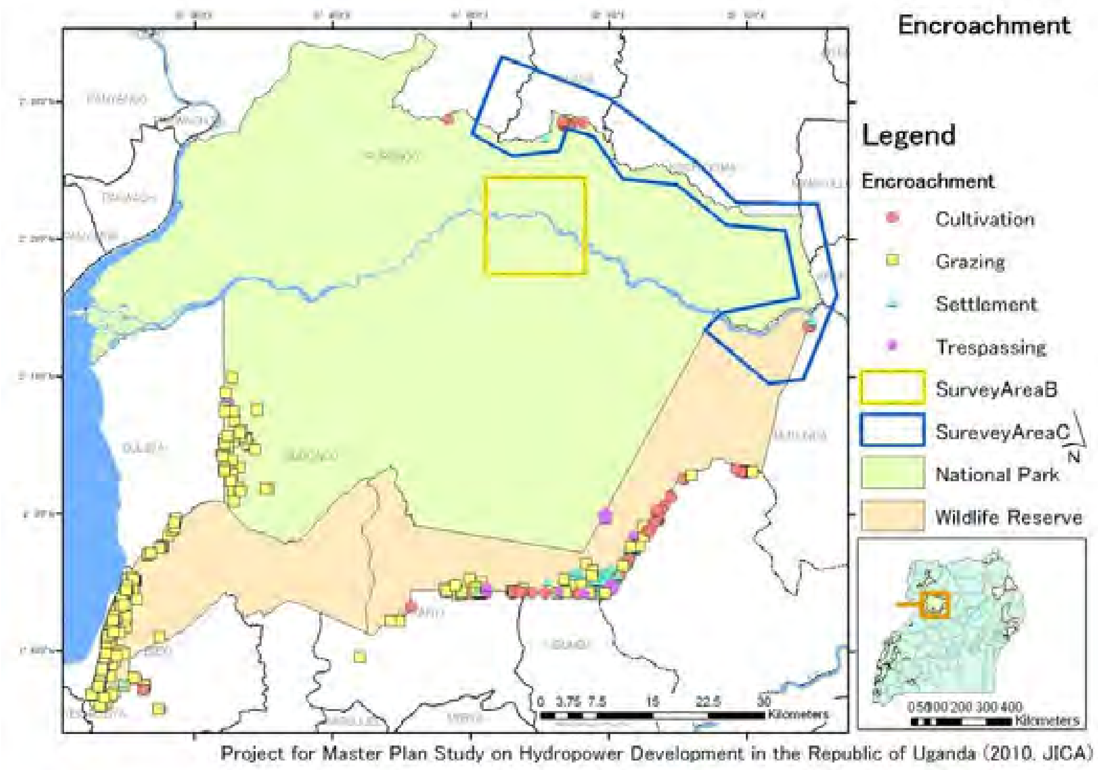
The Wildlife Statute 1996 clearly indicates that no resources should be taken from a protected area without the permission of the UWA Executive Director. At the same time, UWA considers local community incentives powerful tools for encouraging and promoting wildlife conservation. One of such incentives is the access to resources within PAs. Under the collaborative management strategy, PA managers prepare Memoranda of Understanding (MoUs) with community groups specifying which resources may be used in what quantities, control mechanisms for resource use, and penalties for violation of the agreement. The MoU allows them to carry out sport fishing, and to collect firewood, grass, and local herbs in designated areas and on designated days. As a result of implementing the collaborative park management policy, the communities have played an instrumental role in protecting and conserving the environment within the park.

However, illegal activities such as hunting wildlife, collecting firewood, and encroachment have been continued by local people. Two figures below show examples of poaching and encroachment. More detailed information is provided in Annex 10.



Source: UWA

Figure 3.2-20 Location of Poaching in Murchison Falls Protected Area, 1989-2009

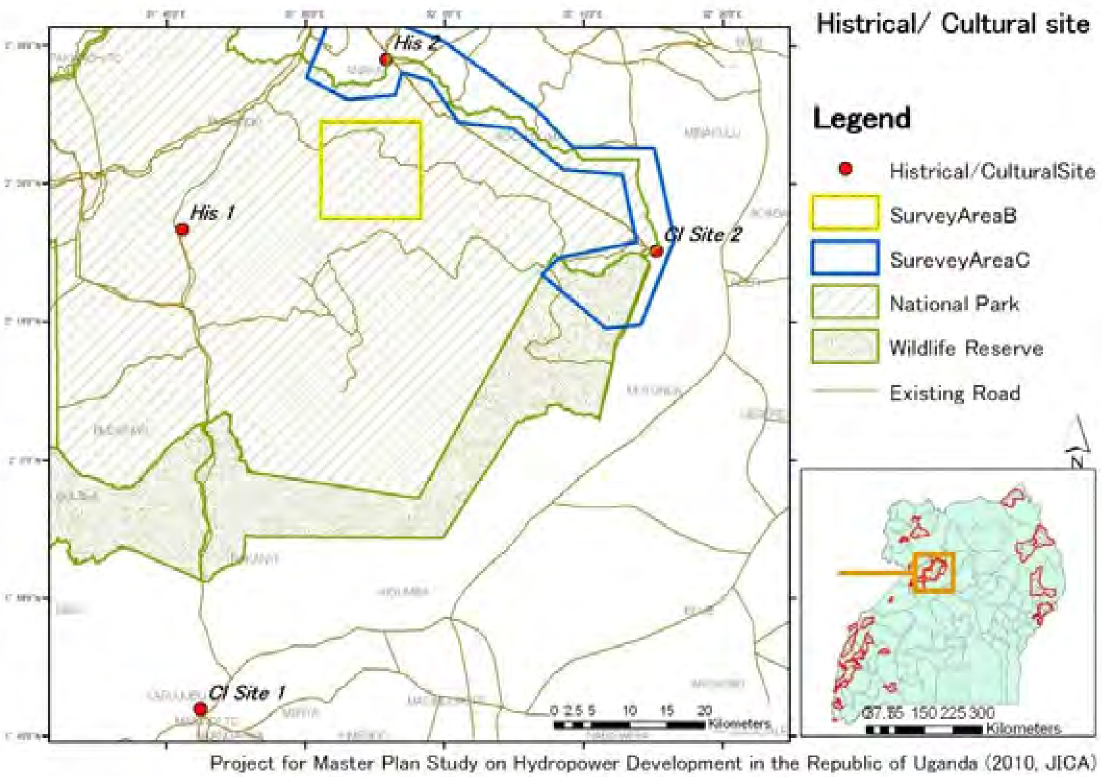


Source: UWA

Figure 3.2-21 Location of Encroachment in Murchison Falls Protected Area, 1989-2009

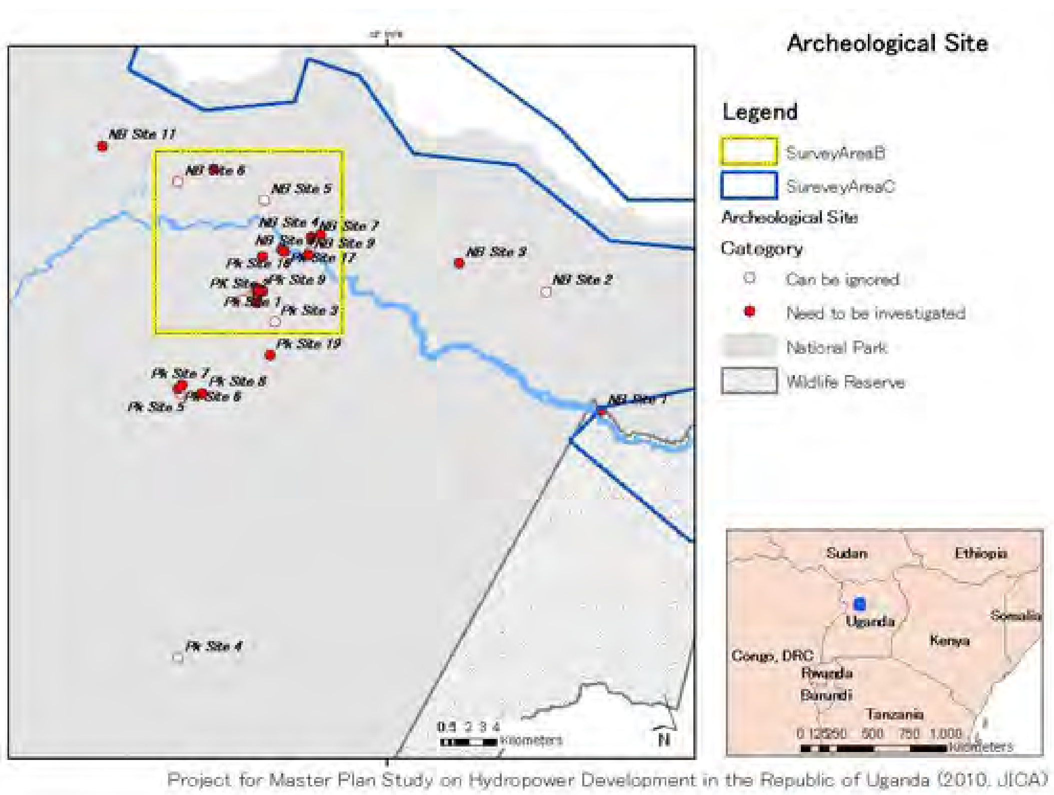
3.2.3.13 Culture and Archaeology

The locations of historical/cultural and archaeological sites around the Ayago site are shown in the figures below. The historical/cultural sites in the figure were recognized by the Government of Uganda. Although many archaeological sites were found in the project area (Survey Area B), some of them can be ignored since they are common in the region. Others need to be investigated further through deep archaeological work and analysis to assess the importance of the sites. More detailed information, including field survey sheets, can be seen in Annexes 11 and 12.



Source: JICA Study Team, 2010

Figure 3.2-22 Location of Cultural and Historical Sites around Ayago Site, 2010



Source: JICA Study Team, 2010

Figure 3.2-23 Location of Archaeological Sites around Ayago Site, 2010

3.3 Examined Alternatives

3.3.1 Stage 1

Examined power sources are Hydropower, Geothermal, Wind power, Biomass Cogeneration, Nuclear, and Energy import.

Table 3.3-1 Examined power sources

Power Source	Energy Production Method
Hydropower (Large Scale Hydro)*1)	Hydropower is power that is derived from the force of moving water, which may be harnessed for useful purposes.
Geothermal	Geothermal is the power extracted from heat stored in the earth.
Diesel Engine (Heavy Oil) *2)	The diesel engine is the most popular type of reciprocating engine for driving an electrical generator.
Solar thermal*3)	Solar power is the generation of electricity from sunlight.
Wind Power	Wind power is the conversion of wind energy into a useful form of energy, such as using wind turbines to generate electricity.
Biomass Cogeneration*4)	Biomass Cogeneration produces thermal energy by burning biomass material with a heat recycling system. A steam turbine or gas turbine type can be selected.
Nuclear	Nuclear power is derived from atomic energy. Steam heated by a water reactor spins a steam turbine, which drives an electric generator.
Energy Import	Energy will be imported from neighbouring countries.

*1) Note: The JICA Study team aims to develop a hydropower energy source in order to meet the energy demand on the national grid until the year 2023. Target power demand is over 500MW, and a scale of more than 50MW may be suitable for development scale of a power plant. Hence, mini or micro hydropower is excluded from the study.

*2) Note: UoE surveyed oil potential in Uganda and planned to extend diesel engines with domestically produced heavy oil fuel power plants. The plan is the most feasible development plan for fossil thermal development.

*3) Note: As described in *1), our target development is more than 50MW/Plant, and at present, among solar energy technologies, only solar thermal can be adopted to large-scale power generation. Hence, we selected solar thermal as a competitive energy source of large-scale energy development.

*4) Note: Biomass cogeneration is most feasible type to develop on a scale over 50MW. There are two kinds of biomass material, 1) wood chip, waste crop and/or garbage, peat, bagas, and 2) bio fuel such as bio diesel ethanol. A biomass cogeneration plant can be planned to use both of the above materials; however, the production amount of bio fuel in Uganda’s market is too small. Hence, we assume that a biomass cogeneration plant would use wood, waste crop, and/or garbage.

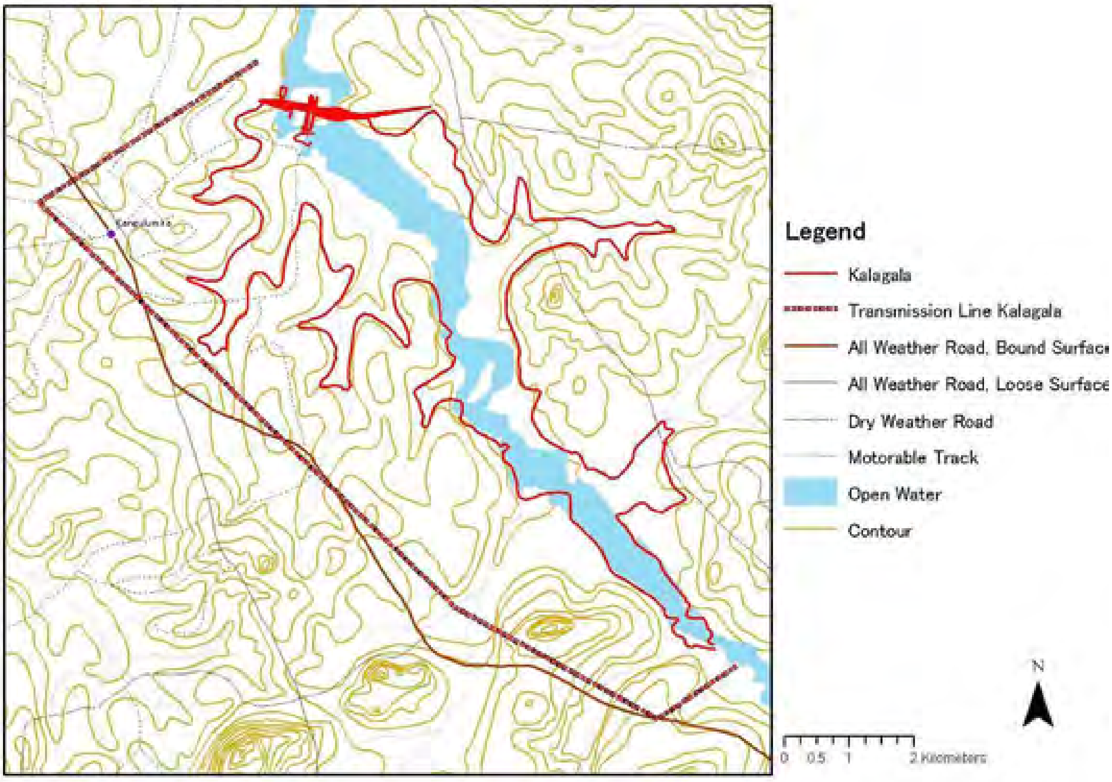
3.3.2 Stage 2

Examined candidate projects are Kalagara, Isimba, Karuma, Oriang, Ayago, Kiba, and Murchison.

Table 3.3-2 Examined candidate projects

Items	Unit	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Development Type		Dam	Dam	Run of River	Run of River	Run of River	Run of River	Dam
Dam								
Type		Concrete	Concrete	Concrete	Concrete	Concrete	Concrete	Concrete
Height	m	45	30	20	20	20	20	45
Crest Length	m	235	320	620	610	480	550	650
Width of River Bed	m	175	70					
Design Flood Discharge	m^3/s	4,500	4,500	4,000	4,000	4,000	4,000	4,000
Catchment Area	km^2	264,450	264,620	346,000	346,710	346,850	348120	348,600
High Water Level	m	1,088.00	1,059.00	1,029.50	910.00	852.00	765.00	718.00
Rated Water Level	m	1,087.00	1,058.00	1,029.50	910.00	852.00	765.00	715.00
Low Water Level	m	1,086.00	1,057.00					712.00
Storage Capacity at High Water Level	10^6m^3	82	88					42
Storage Capacity at Low Water Level	10^6m^3	63	66					23
Effective Storage Capacity	10^6m^3	19	22					19
Surface Area at High Water Level	10^6m^2	9.4	11.8					3.3
Tail Water level	m	1,059.00	1,045.00	945.00	852.00	765.00	718.00	625.00
Average Discharge	m^3/s	865	865	866	866	866	866	866
Firm Discharge (90%)	m^3/s	535	535	467	467	467	467	467
Amenity Flow	m^3/s	0	0	50	50	50	50	50
Waterway								
Headrace								
Number of Tunnel				6	4	6	6	6
Inner Diameter	m			8.40	9.80	8.40	8.40	8.40
Length	m			555	740	96	390	290
Penstock								
Number of Tunnel				12	8	12	6	12
Inner Diameter	m			3.80	4.90	3.80	5.40	4.80
Length	m			70	90	50	55	46
Tailrace								
Number of Tunnel				6	4	6	6	6
Inner Diameter	m			8.40	9.80	8.40	8.40	8.40
Length	m			11,000	11,000	7,600	14,000	1,800
Powerhouse								
Type		Surface	Surface	Undergra	Undergra	Undergra	Undergra	Undergra
Number of Unit		10	6	12	8	12	6	12
Type of Turbine		Kaplan	Kaplan	Francis	Francis	Francis	Francis	Francis
Trancemission Line								
Length	m	28	47	1	34	46	56	122
Voltage	m	220	220	400	400	400	400	400
Development Plan								
Gross Head	m	28.0	13.0	84.5	58.0	87.0	47.0	90.0
Effective Head	m	27.5	12.5	78.9	52.8	83.0	40.5	88.0
Maximum Power Discharge	m^3/s	1,375	1,375	840	840	840	840	840
Maximum Power Discharge per Unit	$m^{3/}s$	137.5	229.2	70.0	105.0	70.0	140.0	70.0
Turbine Efficiency	%	91.3	84.3	92.5	92.4	92.5	89.9	92.5
Generator Efficiency	%	97.5	97.0	97.6	97.6	97.5	97.6	97.7
Combined Efficiency	%	89.0	81.8	90.3	90.2	90.2	87.7	90.4
Installed Capacity	MW	320	132	576	392	612	288	648
Unit Capacity	MW	32	22	48	49	51	48	54
Firm Power	MW	320.0	132.0	291.2	194.6	305.9	145.1	648.0
Annual Total Energy Production	GWh	1,801	752	4,145	2,768	4,357	2,066	2,314
Annual Firm Energy Production	GWh	1,114	465	2,514	1,679	2,641	1,253	1,403
Annual Secondary Energy Production	GWh	687	287	1,631	1,089	1,716	813	911

(Source: Hydropower Master Plan, November 1997 / MEMD)



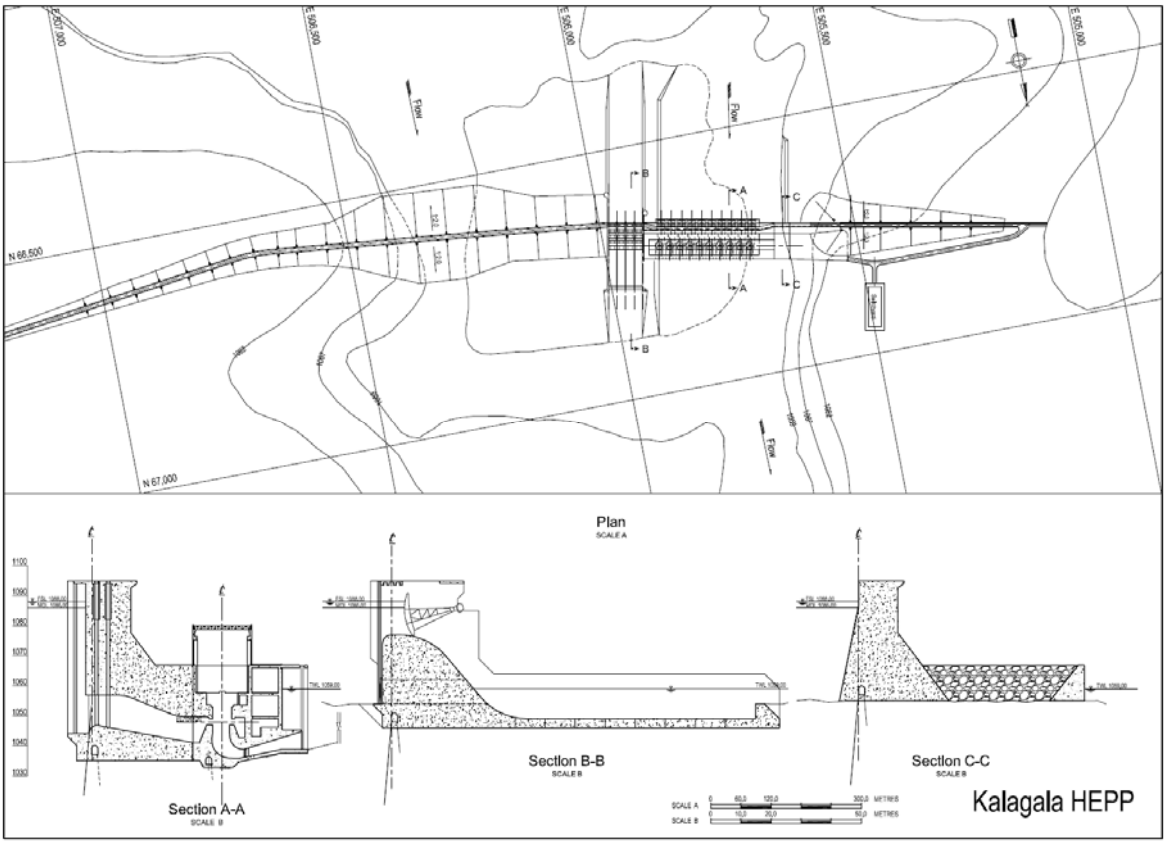
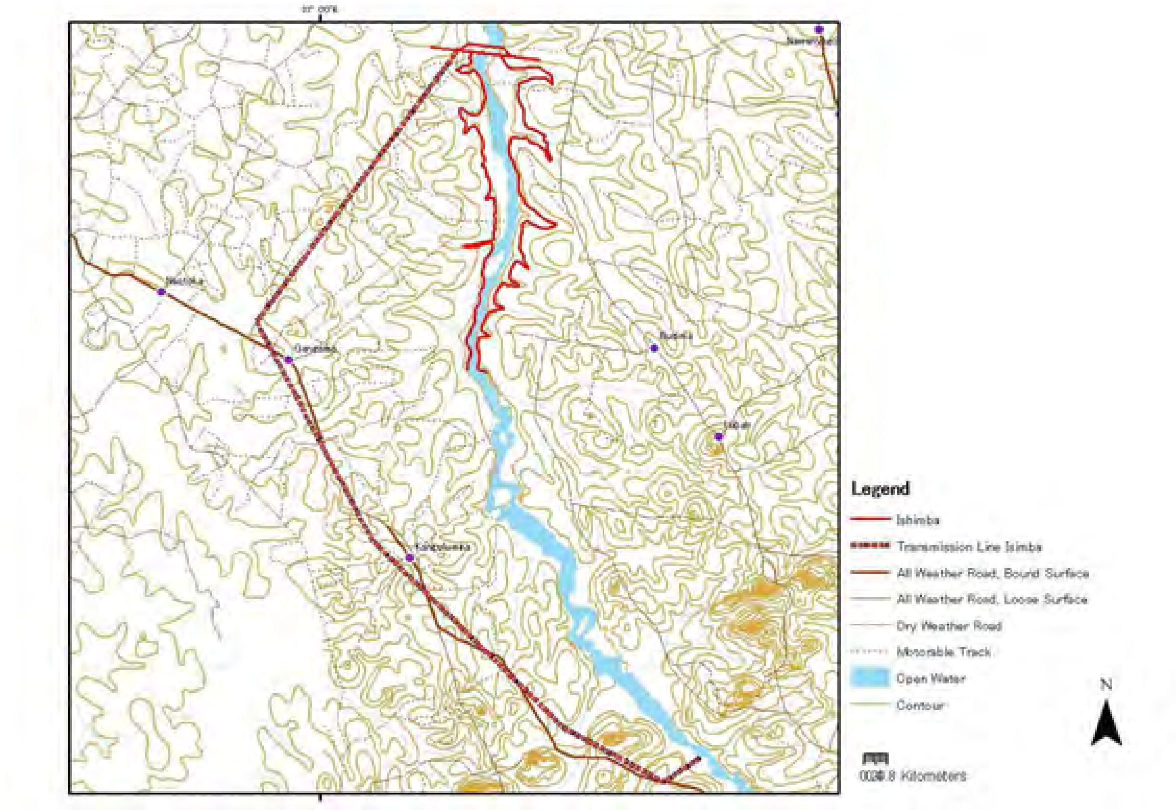


Figure 3.3-1 Kalagala



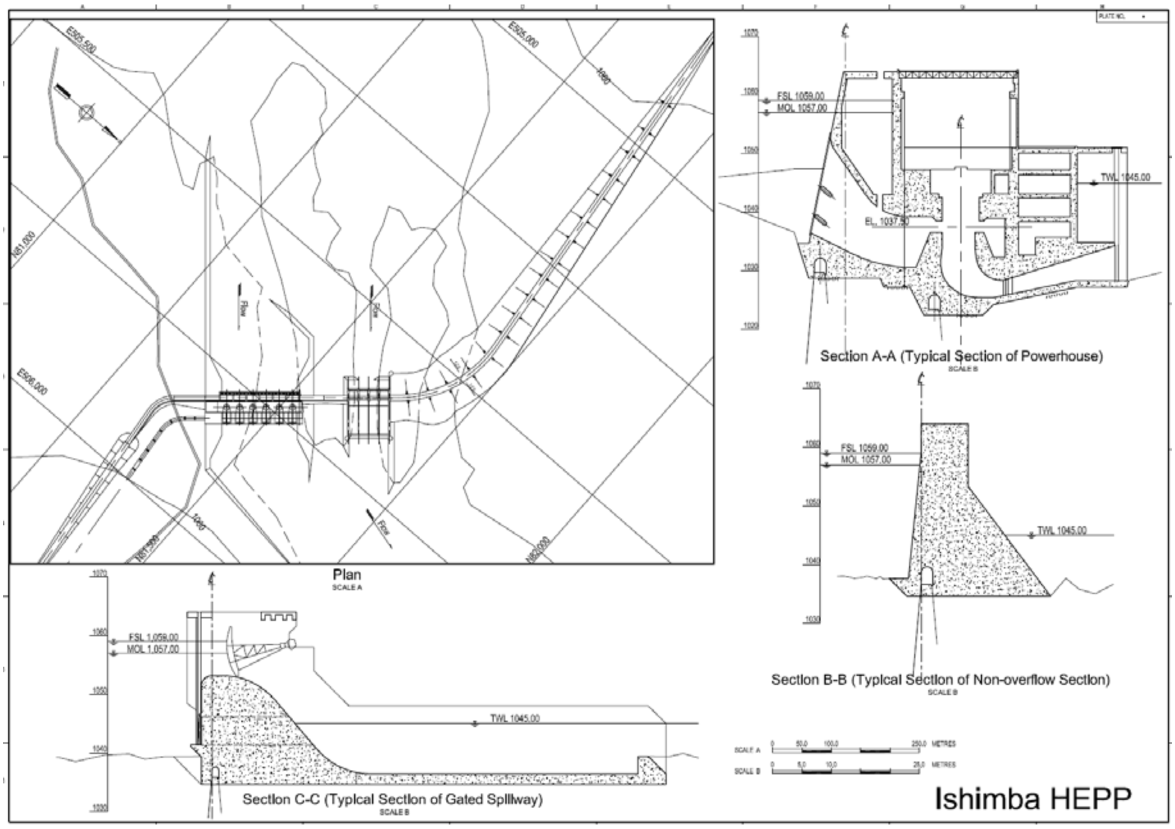
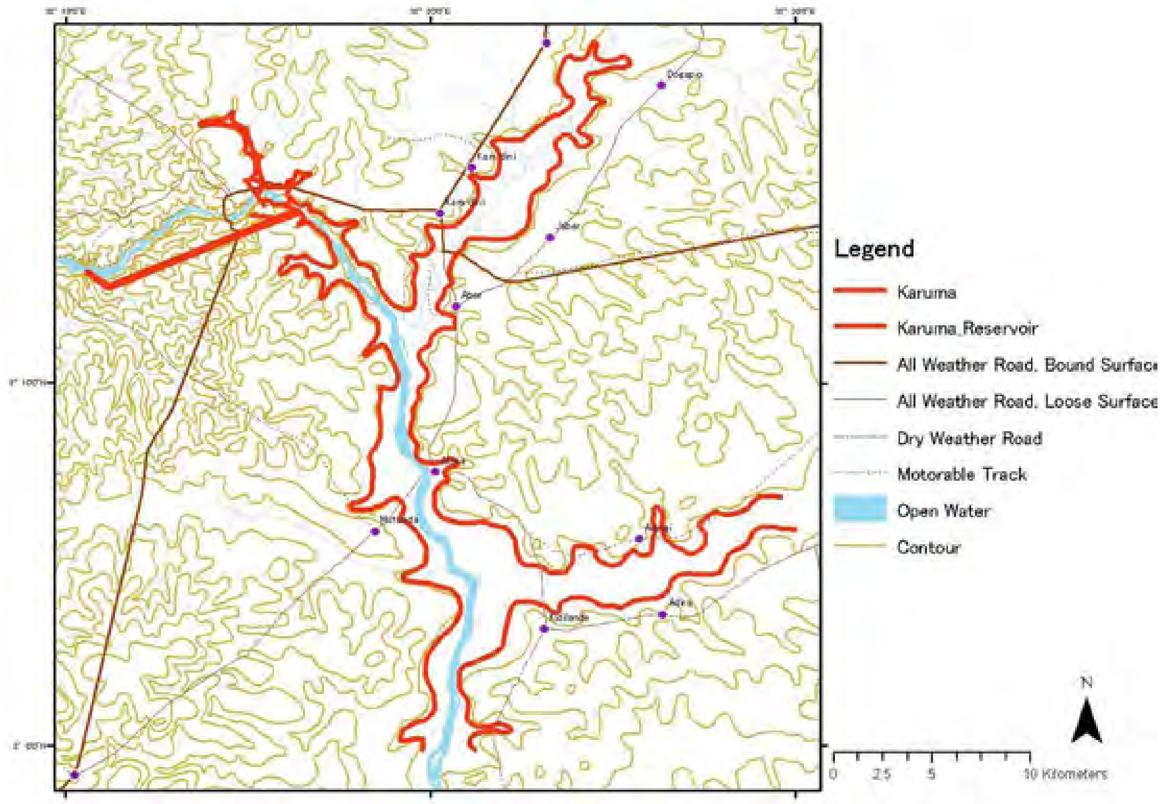


Figure 3.3-2 Isimba



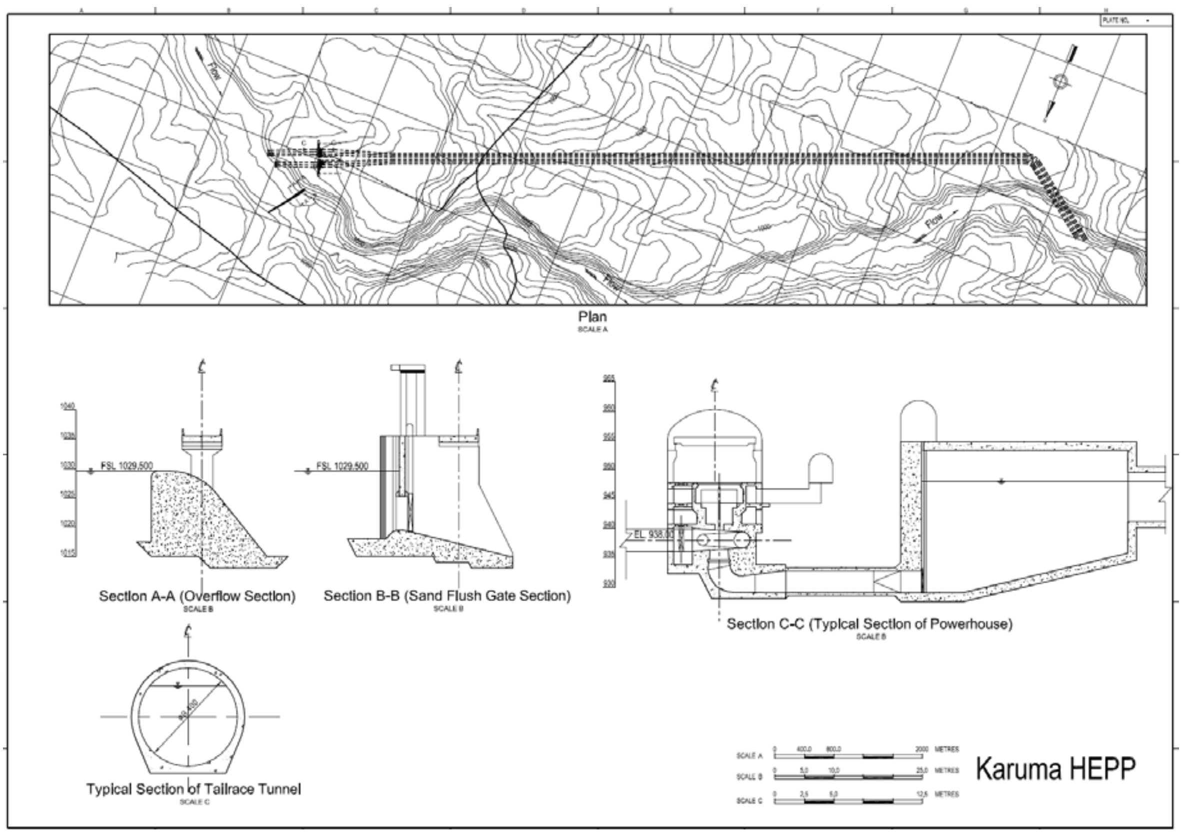


Figure 3.3-3 Karuma

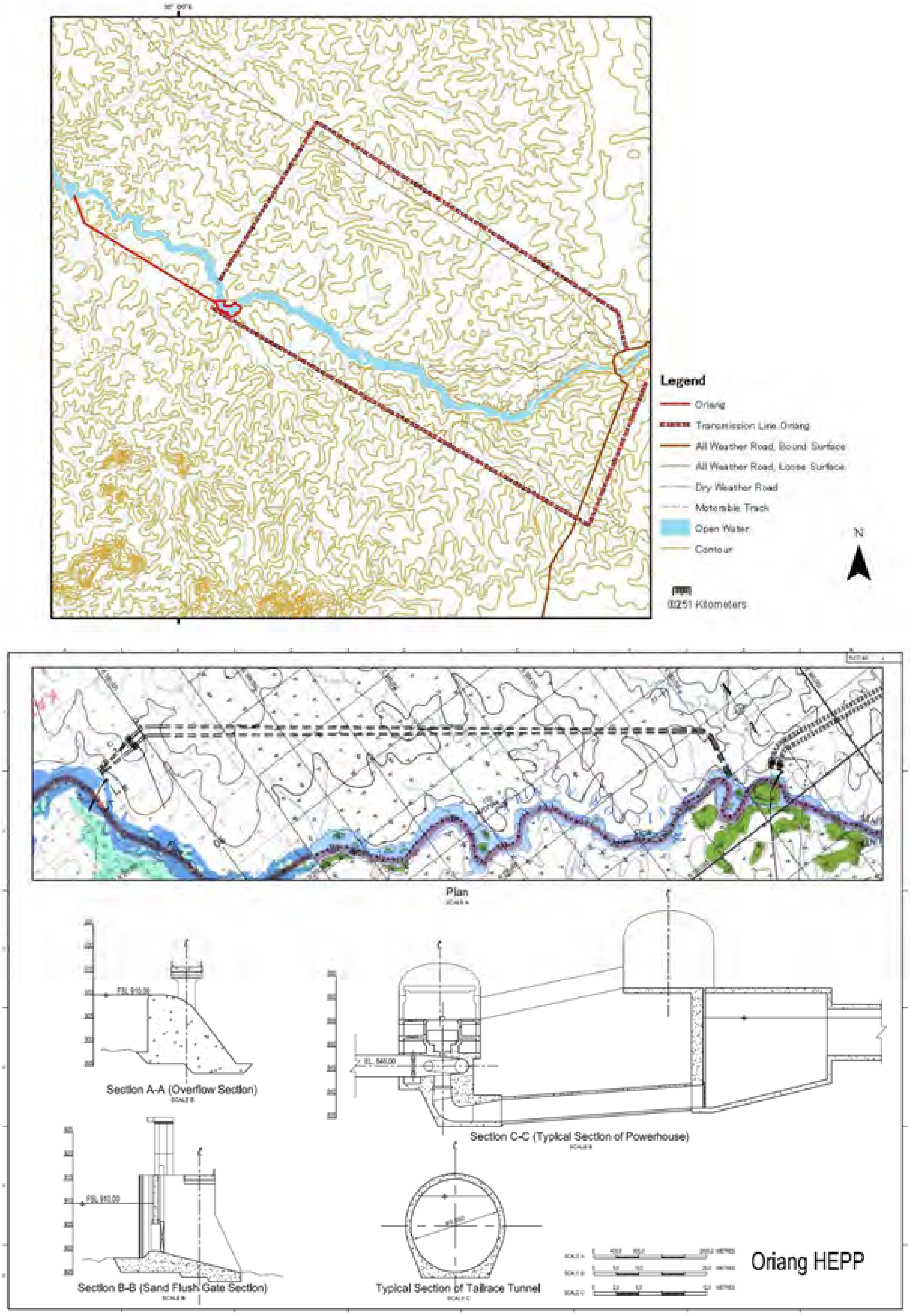
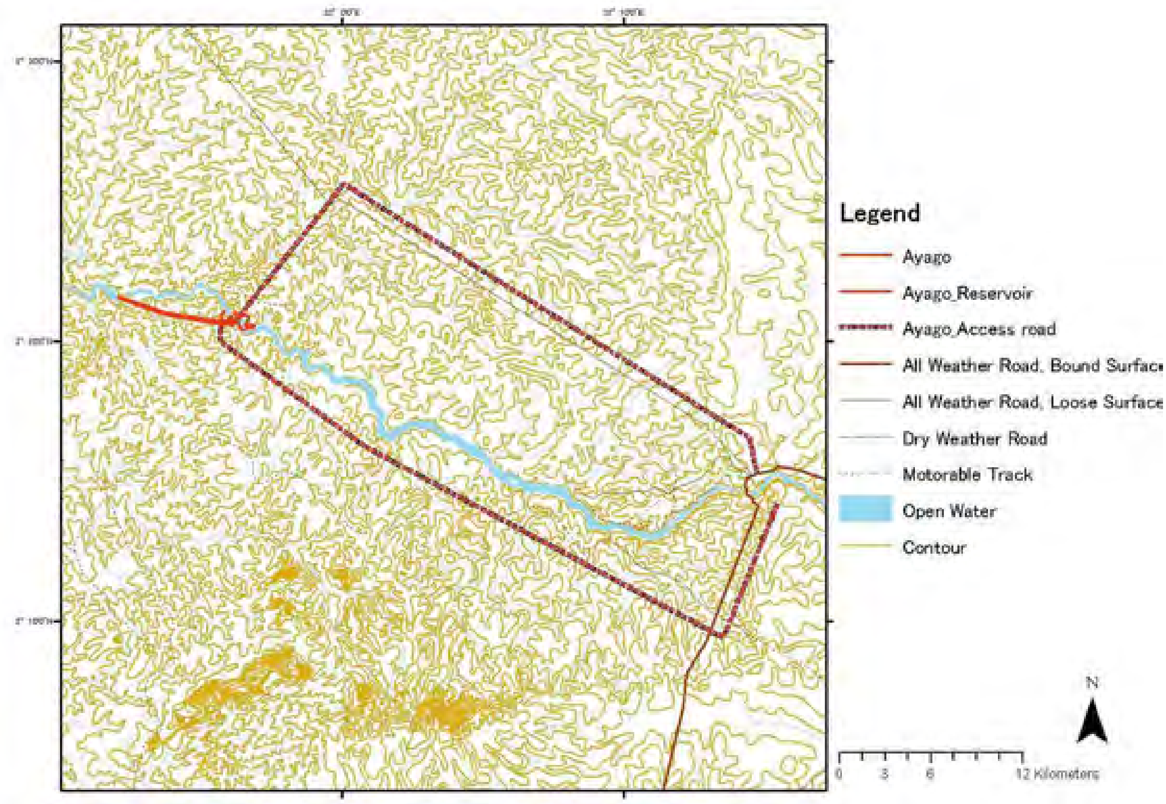


Figure 3.3-4 Oriang



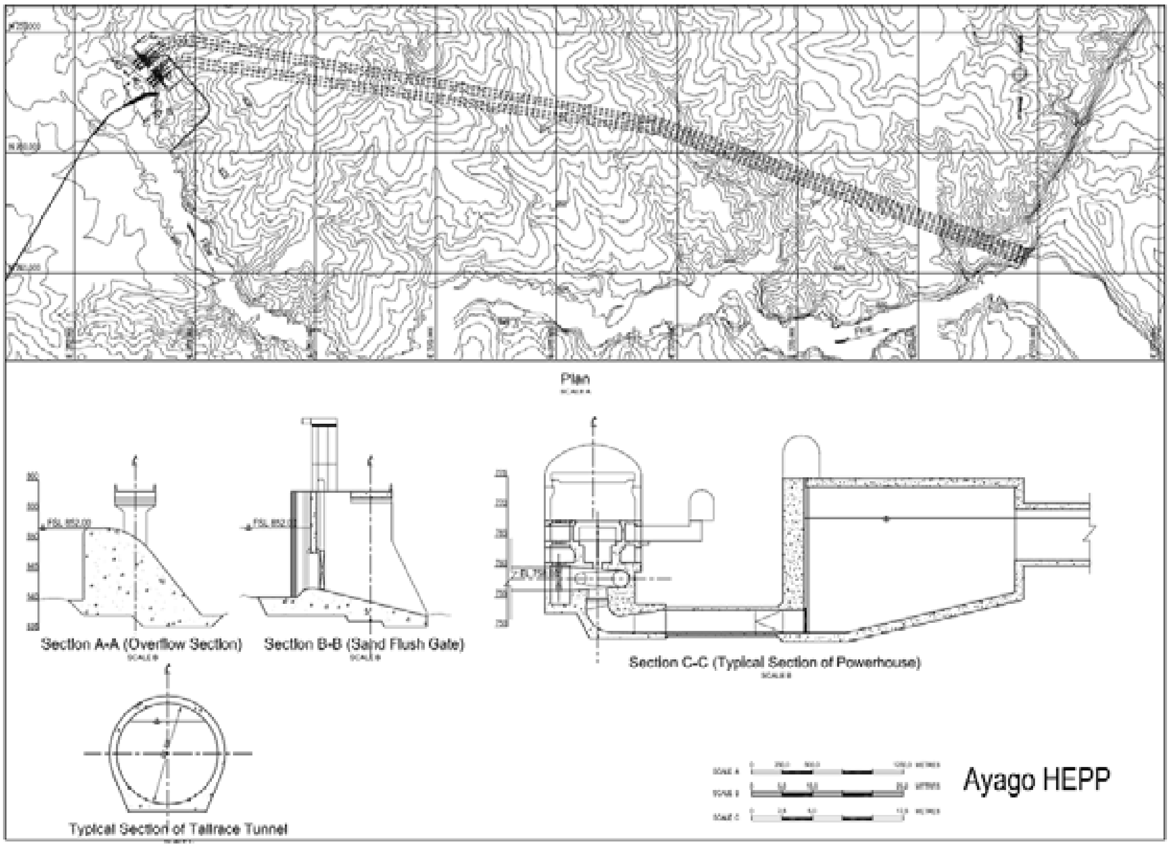


Figure 3.3-5 Ayago

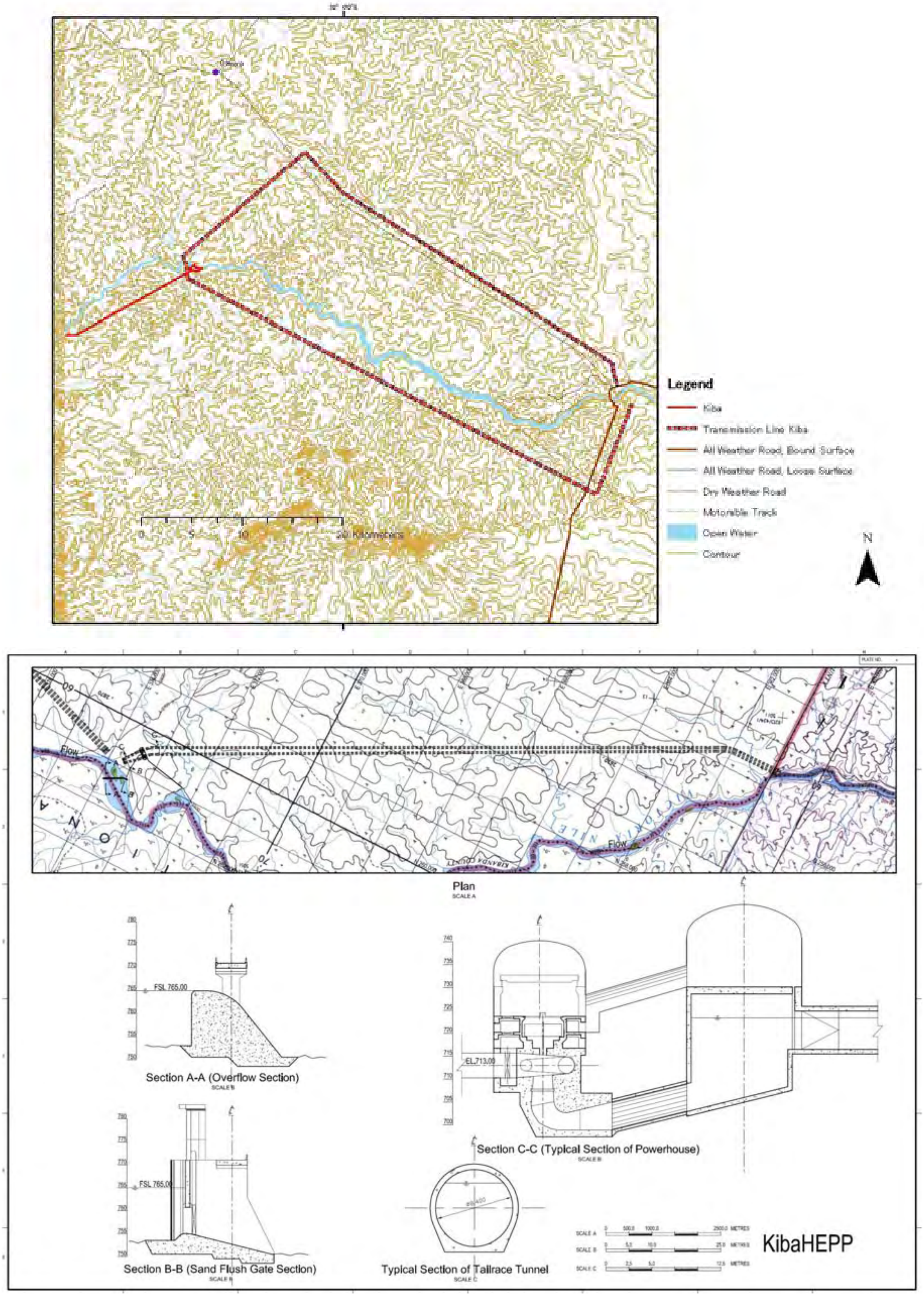


Figure 3.3-6 Kiba

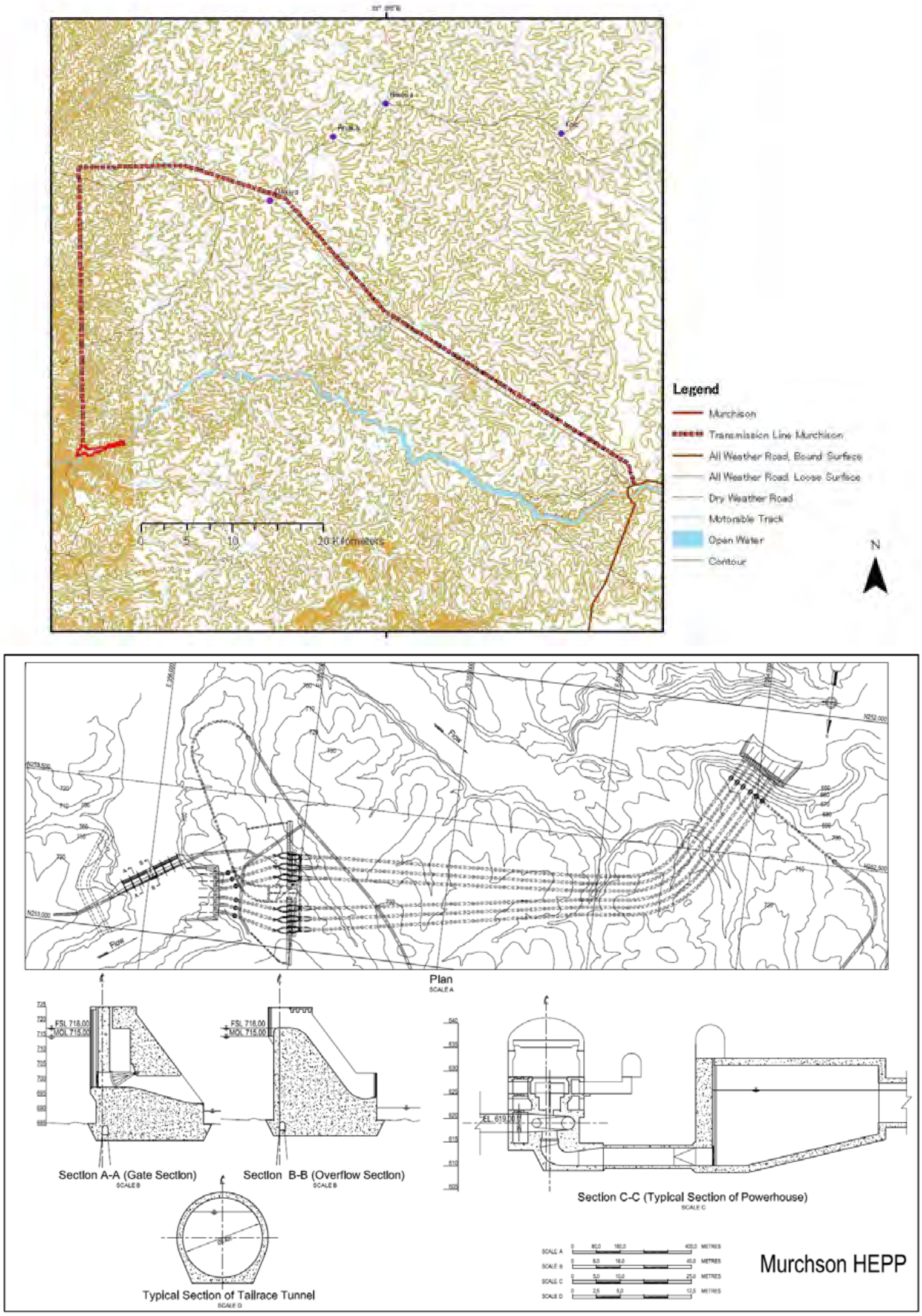


Figure 3.3-7 Murchison

3.3.3 Stage 3

Three types of design are compared. First is Dam and waterway type, second is right bank layout of run-off river type, and third is left bank layout of run-off river type. Brief explanations of the three layouts are as follows.

(1) Dam and waterway layout (Alternative-1, See Figure 3.3-8)

There is only one suitable location for the dam site just downstream of the confluence between the Ayago River and the Nile River. Right bank side waterway route is selected, since the route is shorter than the left bank route and obviously economical.

Principal structures of the dam & waterway type hydropower plant consist of the intake dam, the headrace tunnel, the penstock (tunnel embedded type), the underground powerhouse, and the tailrace tunnel. The Ayago Project is planned to be constructed in the National Park area and the land alteration should be minimized. Hence the concrete gravity dam is deselected, since the concrete dam can minimize the land alteration comparing with the other dam type. The concrete gravity dam consists of 1) gated section, which has function of normal food spillway and amenity flow gate, 2) overflow section, which has function of excess flood spillway, and 3) non-overflow section.

(2) Runoff-type layout

1) Left bank option(Alternative-2, refer to Figure 3.3-9）

Head type and tail type, which are layout types of vertical alignment of the waterway, can be applied to the left bank route. Head type layout was applied as a type of the vertical alignment for the left bank route with following reasons;

Selection of the layouts should be determined considering not only topographic conditions but also geological conditions along the waterway.

Geological condition along the water way is unclear, except geology at intake and tailrace outlet sites (means; geology at origin and end points of the waterway), in this Pre-feasibility Study level.

It seems that the head type layout can be taken thicker ground cover than the tail type layout. Therefore, it is highly likely that geological condition along the waterway is relatively-good by means of applying the head type layout.

Principal structures of the left bank route (waterway type) consist of the intake weir, the headrace tunnel, the penstock (tunnel embedded type), underground powerhouse and the tailrace tunnel. Overflow type concrete weir for typical section is selected due to economical advantage and gated weir section for sand flushing also required at the left bank side of the weir in order to flush out sediment material. Underground powerhouse was selected as a structural type of the powerhouse due to vertical alignment of the waterway and topographic conditions. Pressure flow type of concrete linered tunnel was selected as a structural type of the headrace tunnel and tunnel embedded type of steel penstock was selected.　Pressure flow type and free flow type tunnel structure can be applied to the tailrace tunnel. Since water level fluctuation of the Kyoga Nile River is not so high and it is low provability to fill water in the tailrace tunnel with pressure due to usual food water rising, the non-pressure type tunnel is economical under such river conditions. Hence, the non-pressure type concrete lining tunnel is selected for the type of the tailrace tunnel.

2)　Right Bank Option（Alternative-3, Figure 3.3-10）

The right bank route requires considerably longer waterway than the left bank route and the right bank route seems to be uneconomical.　However, if the left bank rout has fatal problem in geological and/or environmental aspects, the right bank rout may be selected as the optimal layout of the Ayago Project. Hence, the right bank route also is nominated as one of alternative layout of the Project.

Composition of the main structures and their structural types are as same as the left bank route.

Principal feature of the alternative layouts is shown in Table 3.3-3, typical layout drawings for the alternatives are shown in Figures 3.3-8 to 3.3-10 respectively.

Table 3.3-3 Principal Features of Alternative Layouts at Ayago Site

Item		Unit	Dam and Waterway Type	Run of River Type	
				Left Bank Route	Right Bank Route
General					
	Catrchment Area	km^2	348,120	346,850	346,850
	Reservoir Area	km^2	4.2	0.03	0.03
	Full Supply Level	m	852	852	852
	Rated Water Lvel	m	850	852	852
	Minimum Operation Level	m	848	-	-
	Gross Storage Capacity	mil.m3	100	-	-
	Effective Storage Capacity	mil.m3	20	-	-
	Tail Water Level	m	765	765	765
	Gross Head	m	87	87	87
	Effective Head	m	80	80	80
	Plant Discharge	m3/s	840	840	840
	Installed Capacity	MW	610	610	610
Dam / Weir					
	Type		Concrete Gravity Dam	Concrete Weir	Concrete Weir
	Height	m	45	15	15
	Crest Length	m	1,400	245	245
Headrace / Pressure Shaft					
	Type		Pressure Flow Tunnel	Pressure flow Tunnel	Pressure flow Tunnel
	Number of Tunnel	Nos.	6	6	6
	Inner Diameter	m	8.4	8.4	8.4
	Length	m	940	113	113
Steel Penstock					
	Number of Tunnel	Nos.	6	6	6
	Inner Diameter	m	8.4 to 5.4	8.4 to 5.4	8.4 to 5.4
	Length	m	6.9	6.9	6.9
	Number of Tunnel	Nos.	6	6	6
	Inner Diameter	m	5.4	5.4	5.4
	Length	m	44	44	44
	Number of Tunnel	Nos.	12	12	12
	Inner Diameter	m	3.8	3.8	3.8
	Length	m	37	37	37
	Total Length	m	87.9	87.9	87.9
Tailrace					
	Type		Free Flow Tunnel	Free Flow Tunnel	Free Flow Tunnel
	Number of Tunnel	Nos.	6	6	6
	Inner Diameter	m	8.4	8.4	8.4
	Length	m	5050	7450 (#1 to #3) / 7890 (#4 to #6)	9350 (#1 to #3) / 9900 (#4 to #6)
Powerhouse					
a) Machine Bay and Erection Bay Cavern					
	a) Inner Height	m	40	40	40
	b) Innter Width	m	23	23	23
	c) Number	Nos.	2	2	2
	d) Length	m	150	150	150
b) Transformer and GIS Room Cavern					
	a) Inner Height	m	20.5	20.5	20.5
	b) Innter Width	m	18	18	18
	c) Number	Nos.	2	2	2
	d) Length	m	67	67	67
c) Main Acces Tunnel		m	1330	1740	1490
Access Road					
	Improved	km	103	122	103
	New	km	27	6	32
	Total	km	130	130	130
Transmission Line		km	56	58	51
Volume of Disposal Material		mil. m^3	5.2	6.1	7.6
Area of spoil bank		ha	43.2	57.1	66.7
Volume of Rock Material from Quarry		mil. m^3	0.17	negligible	negligible

(Source: Study Team)

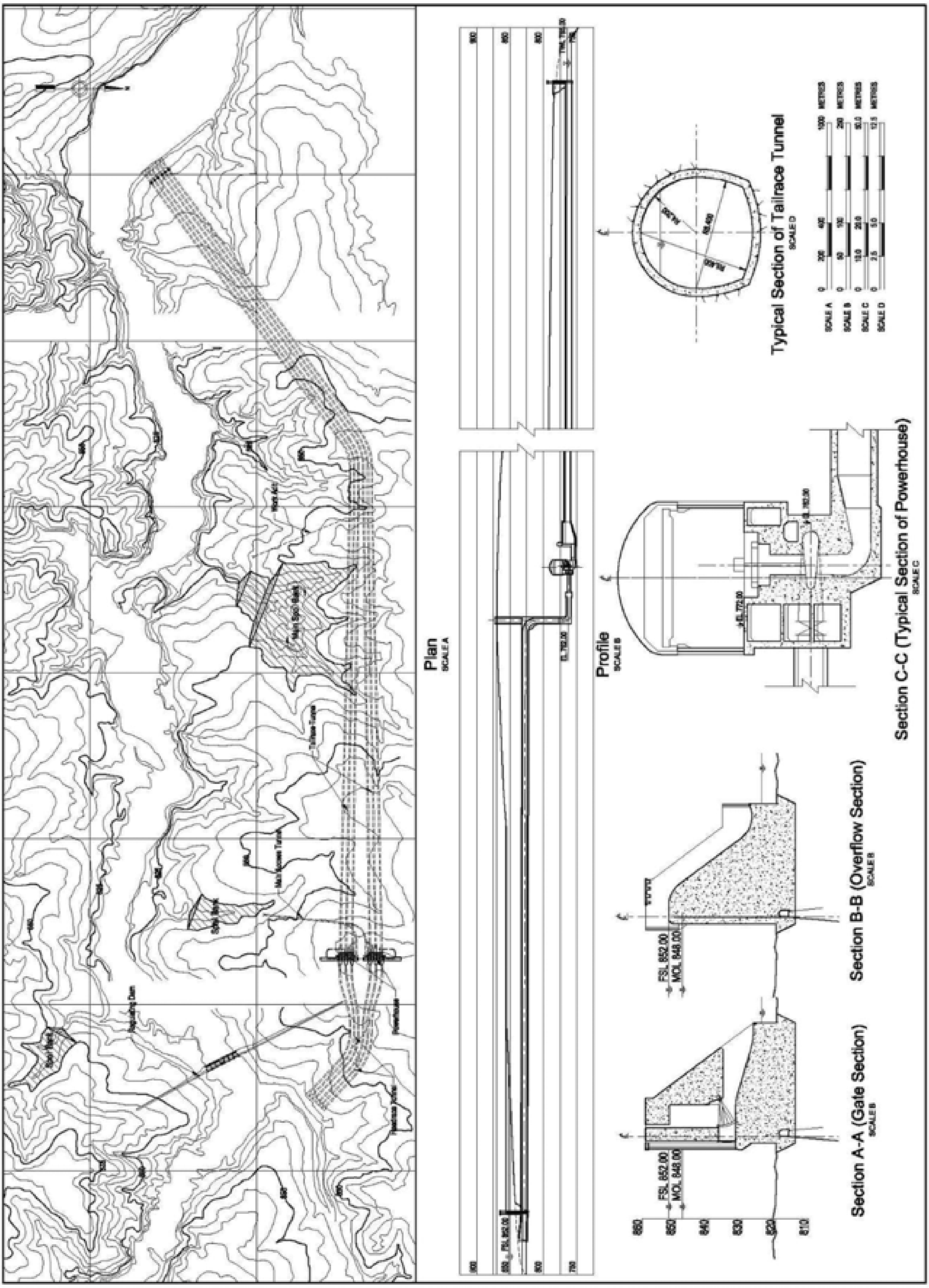


Figure 3.3-8 Layout Altenative-1 at Ayago Site (Dam and Waterway Type)

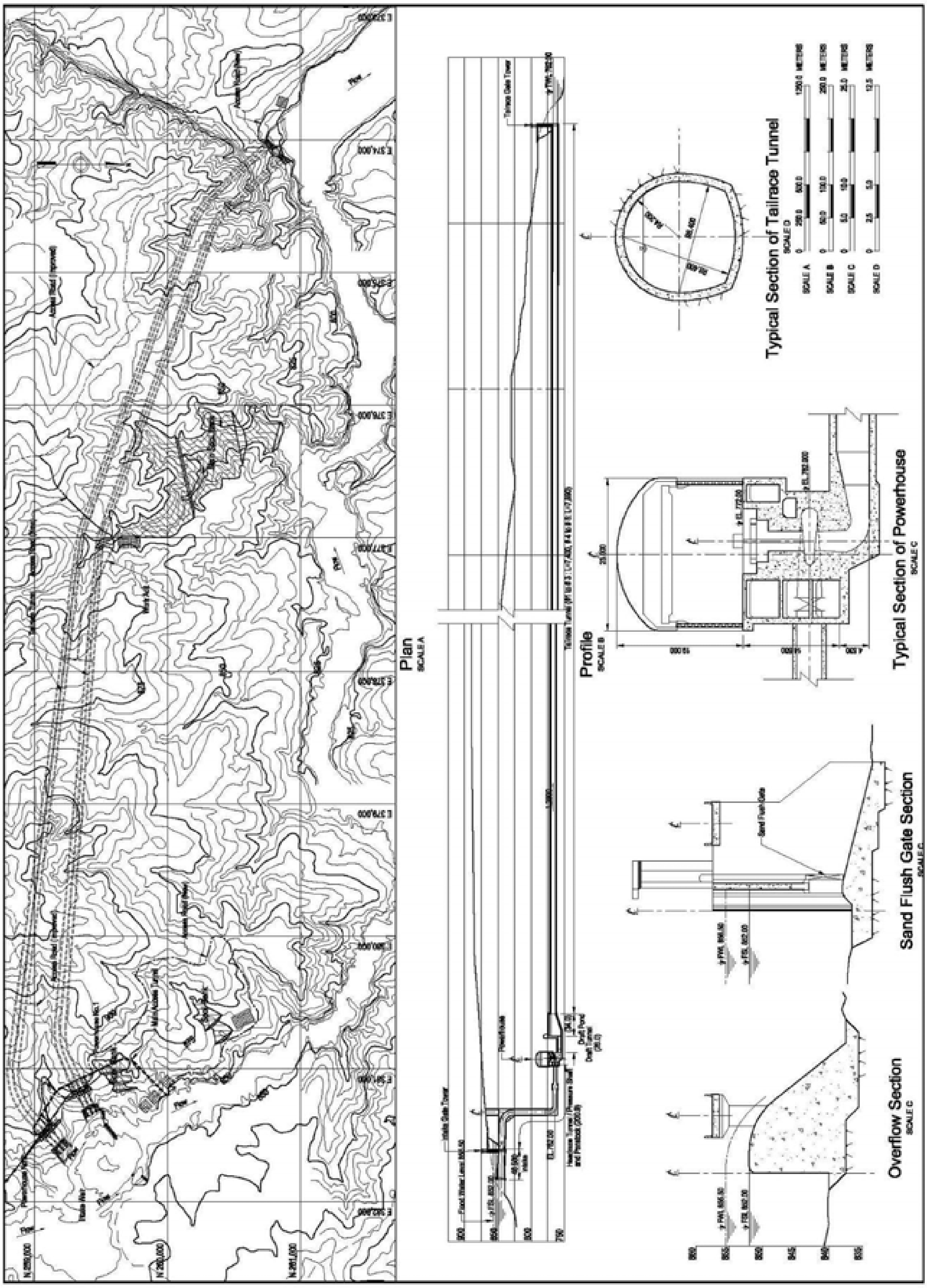


Figure 3.3-9 Layout Altenative-2 at Ayago Site (Waterway Type, Leftbank Route)

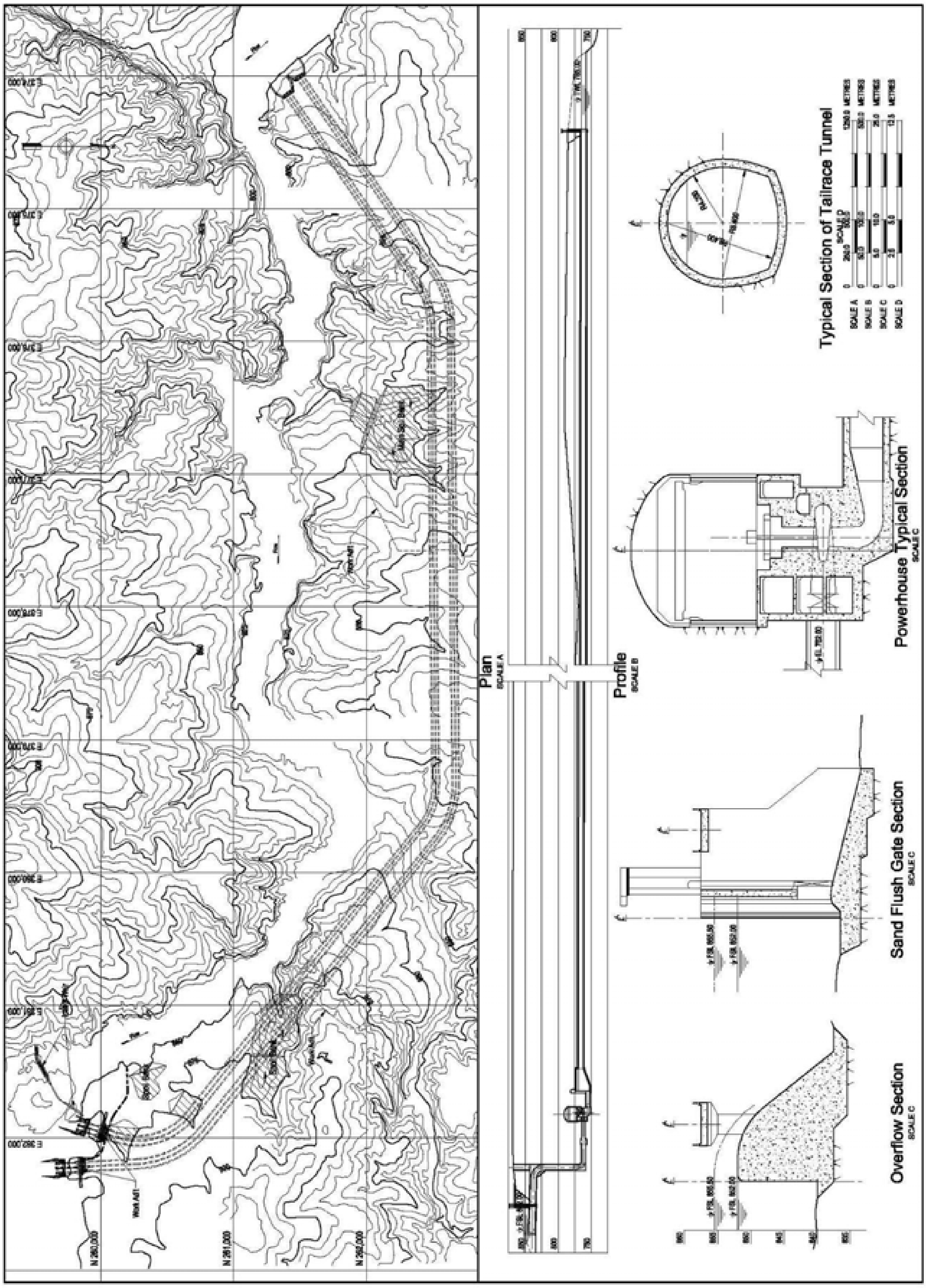


Figure 3.3-10 Layout Altenative-3 at Ayago Site (Waterway Type, Rightbank Route)

4 Public Consultation and Disclosure

4.1 1st Stakeholder meeting

- Date: 11th December 2009, 9:30-13:30
- Venue: Statistics House, Kampala, Uganda
- Participants: 47（Project Implementers: 12, Implementing Ministry: 1, Relevant Ministries: 3, University: 0, NGOs: 4, Representatives from local resource users: 0, Cultural leaders: 0, Institutions: 9, Media: 8, Donors: 5, Participants from private sector: 5）
- Contents
  - Overview of the Master Plan Study
  - Explanation on Strategic Environmental Assessment (SEA)
  - Discussion on the evaluation criteria used in stage 1 and stage 2 of SEA
- Major comments:
  - Nuclear power should be included in the comparative analyses, as it produces clean and sustainable energy and produces much energy from little fuel. – The Study Team has included it.
  - Evaluation Criteria in stage 2 should be expanded to include risk on human health. - the Study Team expanded the criteria to include it.
  - The environmental sensitivity of the project sites should be closely studied. Let's make an effort to make sure that the outline of the methodology is going to be fully put into practice. – The Study Team planned a field survey during the third period of study in Uganda.
  - The Study Team should include as many stakeholders as possible, such as private sector participants, NGO representatives, National Planning Authority, and National Investment Authority. – The Study Team invited the proposed stakeholders to the next meeting.
  - It is better to review District Development Plans of local governments along the River Nile. – The Study Team agreed to review them.
  - The Study Team should look at the Power Sector Investment Plan and see how best to synchronize the Hydropower Master Plan Study. – The Study Team will consider the Power Sector Investment Plan through discussions with MEMD.
  - The oil company is going to conduct field surveys at Murchison Falls National Park, since there is a possibility of oil production near Lake Albert. The company would like to exchange ideas with the Study Team. – The Study Team agreed on that.

4.2 2nd Stakeholder meeting

- Date: 19th February 2010, 9:30-13:30
- Venue: Hotel Africana, Kampala, Uganda
- Participants: 67（Project Implementers: 12, Implementing Ministry: 1, Relevant Ministries: 4, University: 1, NGOs: 2, Representatives from local resource users: 5, Cultural leaders: 2,

Institutions: 3, Media: 3, Donors: 5, Participants from private sector: 14, JICA or Study team: 15)

- Contents:
  - Overview of the Master Plan Study
  - Discussion on the results of stage 1 and stage 2 of SEA
  - Explanation of TOR for Stage 3
- Comments:
  - Although the Government of Uganda has given the priority to the energy sector, this should not be at the expense of or threaten to choke other sectors of the national economy such as tourism, which is a major revenue earner. UWA is very concerned that Murchison Falls is being considered for hydropower development in the Master Plan. There is a need for the Ministry of Energy and Mineral Development (MEMD) and the Ministry of Tourism and Industry (MTTI) to discuss and come up with the best strategy for all the economic activities without putting wildlife at stake. – MEMD will discuss with UWA.
  - Although it is concluded that hydro is the best energy source to meet the country's energy demands, did the study consider possible impacts of climate change on flows and that the possible reduction of flows might change the ranking of hydro? – The study team considered these factors based on the data of 100 years hydrology to come up with appropriate design discharges. Also, the Government of Uganda has come up with an energy mix strategy.
  - The current projections on oil development are that heavy oil will be available for power generation by June 2010. Wouldn't this make heavy diesel oil power generation a cheaper option than Hydro sooner rather than later as projected in the Master Plan Studies? - The estimated quantities of production of heavy diesel oil for power production do not provide the large capacities required by the load forecast. Hydro still remains on top.
  - Kalagala offset is a government obligation in return for World Bank funding of the Bujagali Project. Does the inclusion of Kalagala in the Hydro Master Plan mean that the government is reneging on its obligation for the implementation of projects under the Kalagala Offset? – The government is still committed to implementing programs under the "Kalagala Offset." This is why although Kalagala is ranked top; it is not being advanced to the Feasibility stage. However, when conditions change in the future, it will be reviewed in light of then-changed conditions.
  - I am not satisfied with the explanation given that small hydro and wind energy were not considered in this study. Micro hydro and wind power have big impacts on rural villages/communities. - Small hydro and wind power can indeed have impact on rural communities. However, looking at the national demand forecast, several small hydro projects will be required to have a significant impact on the energy demand, while one large hydro project provides exactly that big impact required by the demand forecast.

- We must consider that existing /completed dams are not performing to expectations. - Poor performance of existing dams cannot be used as standard for all dams, as several issues, including design criteria, vary.
- There is a concern that the construction of a dam may cause deforestation. - The projects are all runoff river type and have small daily poundage reservoirs, if any, which will not cause any inundation. On the other hand, it could be hoped that availability of electric power to a larger population will reduce charcoal burning and relieve pressure on the forests.
- It appears that the weighting was done from an environmental perspective. Did the weighting also consider monetary factors in terms of revenue lost from tourism? – Yes.
- It was mentioned by the PS in his remarks that the study needs to be undertaken through the Feasibility level up to design and Tendering. Who makes that decision? - MEMD
- The Nile goes through many countries. Will there be a conflict of interest with countries such as Egypt? - This will be solved through political negotiations.
- While looking at power import, the study should critically examine the potentials of respective countries before recommending imports. - This will be considered.
- Increase in population will increase pressure on water usage and consequently reduce yield of flows and power generation. Did the study consider such a scenario and the impact on downstream water uses? - The study under "hydrological studies" considers that minimum flows taken into consideration in determining design discharges will take care of such variations.
- The zoning of the Park as availed to the study team by UWA was done several years ago when there were no human activities in the park. This might have to be reconsidered in light of oil drilling activities taking place in the western part of the conservation area. UWA would want to rezone the park area to enable animals to move to less activity areas. Therefore, what was demarcated as moderate tourist activity would become a zone of intense tourism. - This will need to be discussed with all stakeholders
- The opinion of a participant was that Slide 13 of the presentation of the third session with pictures that were taken by the study team after bush fires gave a wrong impression that the conservation area was clear and easy to access. He suggested that the area was an impenetrable forest during most of the year. - The picture was indeed taken after a bush fire; however, the trees were not destroyed and the picture well shows the distribution of trees, which is well confirmed by the satellite image.

4.3 Information Disclosure

Information of the project and stakeholder meeting is provided on the website of MEMD. The address of the website is http://www.energyandminerals.go.ug/jica.php.

Around Lake Victoria, which is the source of Victoria Nile, there are several countries such as

Kenya, Tanzania, Rwanda and Burundi. In addition, Sudan and Egypt are located in downstream of River Nile. In order to avoid international affairs on the Nile, it is important to disclose information on hydropower development in Uganda to such countries as much as possible.

In particular, Sudan and Egypt are conscious on water use for irrigation by Uganda, since it is an upstream country. Therefore, it is necessary to take possible measures with appropriate timing such as inviting both countries for stakeholder meetings in Uganda, disclosing information on the webpage, and informing the progress by formal letters.

For example, during the EIA stage, the hydropower development project at Bujagali sent a letter from Ministry of Foreign Affairs of Uganda to the governments of downstream and neighboring countries to inform the project summary (project area map, design and TOR). Then, the Ministry received a reply of "No objection letter" by Egypt. Similar procedure may be expected for the future hydropower project in Uganda.

5 Impact Assessment

5.1 Stage 1

5.1.1 Technical and Economic aspects

5.1.1.1 Cost

Cost data of each power source are based on the existing and planned power plants that belong to OECD countries, because there are not enough precedents in the Republic of Uganda. The data pertain to 130 power plants, and were compiled by the International Energy Agency (IEA). The costs shall be evaluated with some price range, because of the variety of unit sizes, fuels, materials, labour costs, and so on.

Hydro power plants vary enormously in size, from several megawatts for micro-hydro facilities to thousands of megawatts. Specific construction costs vary widely between 500USD/kW and 2,000USD/kW, because hydro power plants depend mainly on site-specific characteristics. Annual O&M costs also vary widely between 4USD/kW/year and 90USD/kW/year. Thus, normal generation costs range between 40USD/MWh and 80USD/MWh.

Geothermal technology depends on the type and location of the natural resource. Geothermal power plants tend to be in 20MW to 60MW range, and the capacity of a single geothermal well usually ranges from 4MW to 10MW. The specific construction and O&M costs are unknown, because there is little significant data for cost estimation. However, the generation cost is estimated at 27USD/MWh as a reference, according to one plant in the United States.

Gas thermal power plants tend to have enormous capacities of more than 300MW, in order to pursue scale merits, because they require much cost for incidental facilities such as pipelines. The specific construction costs range between 400USD/kW and 1,000USD/kW, an average of 620USD/kW for 20 plants. The annual O&M costs vary widely between 5USD/kW/year and 45USD/kW/year, 24USD/kW/year on average. Thus, normal generation costs range between

40USD/MWh and 60USD/MWh, 48USD/MWh on average.

Internal-combustion plants such as those using diesel engines vary from a few kilowatts to over 60MW, depending on the numbers of units. In the case of Kiira diesel power plant, the specific construction costs are ○○USD/kW. The annual O&M costs are ○○USD/kW/year and fuel costs are ○○USD/MWh. Thus, the normal generation costs are ○○USD/MWh. It is noted that use of diesel engines is restricted in most industrialized countries, due to high fuel costs and air pollution concerns.

Wind power plants vary from several megawatts to hundreds of megawatts, depending on the number of units and wind conditions. Specific construction costs range in most cases between 1,000USD/kW and 1,700USD/kW, 1,310USD/kW on average for 14 plants excluding offshore plants. Annual O&M costs vary widely from country to country even in the same region, ranging between 15USD/kW/year and 60USD/kW/year, 31USD/kW/year on average. Thus, normal generation costs range between 35USD/MWh and 95USD/MWh, 58USD/MWh on average.

Biomass plants generally vary from several megawatts to dozens of megawatts, depending on the feedstock and process. Specific construction costs range between 1,100USD/kW and 5,500USD/kW. Annual O&M costs are unknown, because of lack of data. The normal generation costs are in the range of 50USD/MWh to 130USD/MWh.

Solar power plants generally vary from several megawatts to dozens of megawatts, depending on the number of photovoltaic modules and solar conditions. The specific construction costs range between 3,000USD/kW and 5,500USD/kW, 4,100USD/kW on average for 5 plants. Annual O&M costs vary widely between 10USD/kW/year and 50USD/kW/year, 35USD/kW/year on average. Thus, normal generation costs range between 150USD/MWh and 500USD/MWh, 300USD/MWh on average.

Nuclear power plants tend to have enormous capacities as compared with thermal power plants, more than 1,000MW in order to pursue scale merits. Specific construction costs range between 1,000USD/kW and 2,500USD/kW, 1,700USD/kW on average for 13 plants. Annual O&M costs vary widely between 50USD/kW/year and 80USD/kW/year, 67USD/kW/year on average. Thus, normal generation costs range between 21USD/MWh and 48USD/MWh, 30USD/MWh on average.

The costs for each power source are summarized in Table 5.1-1. For further details, refer to Projected Cost of Generating Electricity 2005; OECD.

Table 5.1-1 The Costs for Each Power Source

	Hydro	Geothermal	Diesel Engine (Heavy Oil)	Wind Power	Biomass Thermal Cogeneration	Solar Thermal	**Nuclear+**	Energy import
Development cost (USD/kW)	500-2000	-		1000-1700	1100-5500	3000-5500		
	C	C	A	E	E	E	E	A
Operation & Maintenance cost (USD/kW/year)	4-90	-		15-60	-	10-50		
	A	C	C	A	C	A	E	A
Unit cost of power generation (USD/MWh)	40-80	27		35-95	50-130	150-500		
	A	A	E	A	C	E	A	E

5.1.1.2 Development potential

5.1.1.2.1 Existing Potential

Table 5.1-2 Existing potential (MW)

	Hydro	Geothermal	Diesel Engine (Heavy Oil)	Wind Power	Biomass Thermal Cogeneration	Solar Thermal	**Nuclear+**	Energy import
Existing potential (MW)	2000	450	500	Micro scale only	1,650	200	600 to 2000	300
Rating	A	C	C	E	B	D	B	D

(1) Renewable Energy

According to "The Renewable Energy Policy for Uganda November 2007," development potential of renewable energy, including existing power plants, is estimated at 5,300 MW in total.

Table 5.1-3 Renewable Energy Power Potential

Energy Source	Estimated Electrical Potential (MW)
Hydro (mainly on the Nile)	2,000
Mini-Hydro	200
Solar	200
Biomass	1,650
Geothermal	450
Peat[*1)]	800
Wind[*2)]	-
Total	5,300

Source: The Renewable Energy Policy for Uganda November 2007

*1) Note: Peat is not technically a renewable energy source; however, the Government of Uganda aims to utilize 10% of peat resources, which will enable generation of about 800MW over the next 50 years. However, in this JICA Study we consider peat resources to be classified into fossil fuel

*2) Note: A recent study by the Electricity Regulatory Authority (herein after mentioned as ERA) indicates that the wind speed in most areas of Uganda is moderate, with average wind speeds being low velocities ranging from 1.8 to about 4 m/s. The wind record indicates that the wind resources in Uganda are only sufficient for small-scale electricity generation and for special application such as water pumping, mainly in the Karamoja region. Small industries in rural areas where targets for a mill range from 2.5kV to 10kV could benefit from the wind resource.

(2) Fossil Thermal

According to GoU survey, current estimates of the country's oil potential are around 1.0 to 1.5 billion. In terms of production levels, Tullow (UK's oil Company) estimates an output of 100,000–150,000 barrels per day (bpd) over a possible 25-year production period, and use of heavy oil for energy production is planned.

Since the energy production rate of heavy oil is around 0.45 MWh per barrel, at least 500MW of thermal power may be developed, which is less than 1% of the theoretical energy of heavy oil resources.

(3) Nuclear

As shown in the following figure, plans for prospective nuclear power holder countries call for 600 to 2000 MW of nuclear development. Therefore, the development potential of the nuclear power in Uganda may be around 600 to 2000MW.

Table 5.1-4 Nuclear Power Development Plan in Prospective Nuclear Holder Countries

Country	Reactors Planned		Reactors Proposed	
	No.	MW	No.	MW
Bangladesh	0	0	2	2000
Belarus	2	2000	2	2000
Egypt	1	1000	1	1000
Indonesia	2	2000	4	4000
Israel	0	0	1	1200
Kazakhstan	2	600	2	600
Poland	0	0	6	6000
Thailand	2	2000	4	4000
Turkey	2	2400	1	1200
UAE	4	5600	10	14400
Vietnam	2	2000	8	8000

Sources: Reactor data: WNA to 4/1/10 IAEA- for nuclear electricity production & percentage of electricity (% e) 5/09.

(4) Energy Import

In the case of obtaining energy from neighbouring countries, a backup power source is required during trouble with power transmission lines. Allowance power of the Nalballe, Killa, and Bujagali power stations can be utilized as the backup power source. Since the total installation capacity of the power stations is 630 MW and dependable output of the power stations is 323MW, about 300MW output of the power stations can be utilized as emergency backup for the imported energy. Hence, development capacity of the energy import may is not more than 300MW.

5.1.1.2.2 Technically Feasible Potential at Present

Based on GDP 2008-2023, Power Sector Investment Plan (draft December 2009), Indicative Rural Electrification Master Plan Report (January 2009), Developments and Information from MEMD and Internet, the following projects might be technically feasible at present. In addition, other large-scale power development plans may be carried out and there are some feasible projects among them.

Table 5.1-5 Technically Feasible Potential at Present

	Project Name	Installed Capacity (MW)	Present Status	Rating
Large-Scale Hydro				A
H-1	Karagara	330	Preliminary Study	
H-2	Ishinba	130	Preliminary Study	
H-3	Karuma	580	Under Feasibility Study	
H-4	Oriang	390	-	
H-5	Ayago	610	Preliminary Study	
H-6	Kiba	290	-	
H-7	Murchison	650	Preliminary Study	
Sub		2980		
Geothermal				C
G-1	Muntnovsky	50	Potential Survey	
Thermal (Diesel Engine on heavy Oil)				D
T-1	Mputa (extension)	35 to 50	Preliminary Study	
Biomass				B
B-1	Kwaala	33	Negotiation in progress	
B-2	Aldwch	50	Preliminary Study	
Sub		83		
Solar				C
S-1	Namgoga Solar-Thermal	50 (10+40)	Contract Negotiation in progress	
Sub		50		

Source: JICA Study Team

5.1.1.2.3 Availability of Energy Sources

Energy sources have to meet 1) supply stability and 2) sufficient reserve volume. Needless to say, renewable energy sources secure sustainability and continuous reserve volume. On the other hand, fossil fuel and nuclear energy sources are not sustainable and are limited. In addition, import energy may be generated by fossil thermal energy; hence, availability of the import energy is evaluated at lower rank.

Availability of energy sources in Uganda is evaluated as shown in the following table.

Table 5.1-6 Availability of Energy Sources in Uganda

Energy Source	Supply Stability	Reserves	Rating
Large-Scale Hydro	B (long-term fluctuation)	A	B
Geothermal	A	A	A
Heavy Oil	A	D (25-50 year)	D
Biomass	C (long term/seasonal fluctuation)	C (depends on plantation management)	D
Solar-thermal	C (seasonal/daily fluctuation)	A	C
Nuclear	E (Unknown)	E (Unknown)	E
Energy Import	E(Unknown)	E(Unknown)	E

Source: JICA Study Team

5.1.1.3 Construction

5.1.1.3.1 Survey Maturity

Table 5.1-7 Survey Maturity of Each Energy Source

Energy Source	Survey Maturity	Rating
Large-Scale Hydro	Under feasibility study.	B
Geothermal	Under potential investigation.	C
Diesel Engine (Heavy oil)	Study not required.	A
Wind Power	Micro scale development only.	-
Biomass	Contract Negotiation in progress.	A
Solar-thermal	Contract Negotiation in progress.	A
Nuclear	Initial study has just started.	E
Energy Import	Not considered.	E

Source: JICA Study Team

5.1.1.3.2 Lead Time for Construction

Lead time for construction of energy development projects depends on financial ability of the country. However, in order to estimate the lead time simply, the financial aspects are eliminated and the lead time is estimated based on experience with similar projects.

Table 5.1-8 Lead Time for Construction

Energy Source	Potential Survey	Pre-FS	FS	DD	Contract & Procurement	Total Lead Time	Rating
Large-Scale Hydro	0.5	0.5	1.0	1.5	1.5	5.0	C
Geothermal	5.0	1.0	1.0	1.5	1.5	10.0	D
Diesel Engine (Heavy oil)	-	-	-	-	0.5	0.5	A
Biomass	0.5	0.5	0.5	-	1.0	2.5	B
Solar-thermal	0.5	0.5	0.5	-	1.0	2.5	B
Nuclear	20	10	10	1.5	1.5	43	E
Energy Import	0.5	0.5	1.0	1.0	1.0	4.0	C

Source: JICA Study Team

5.1.1.4 Operation

5.1.1.4.1 Initial Starting Time

Each energy source has the function of energy stability, and sources are classified into a) spinning reserve, b) hot reserve, and c) cold reserve, based on initial starting time of the power sources. General classification of reserve type depending on initial starting time of the energy sources is as listed below:

Table 5.1-9 Initial Starting Time of Energy Sources

Reserve Type	Initial Starting Time	Energy Sources	Rating
Spinning Reserve	1 to 3	Hydropower	A
Hot Reserve	8 to 10	High-speed diesel engine, Gas turbine	B
Cold Reserve	2 to 3 hours	Biomass thermal, Solar thermal, Geothermal	C
	5 to 6 days	Nuclear Power	D
-	unknown	Energy Import	E

Source: JICA Study Team

5.1.1.4.2 Energy Stability

Energy stability of the energy sources is required to meet the peak demand during night time.

Table 5.1-10 Energy Stability

Energy Source	Energy Stability	Rating
Large-Scale Hydro	Long-term fluctuation*1)	B
Geothermal	Stable	A
Diesel Engine (Heavy oil)	Stable	A
Biomass	seasonal fluctuation*2)	C
Solar-thermal	daily fluctuation*3)	E
Nuclear	Stable	A
Energy Import	seasonal fluctuation*4)	C

Source: JICA Study Team

*1) Note: Large-scale hydro power is a stable energy source to meet the peak demand; however, hydro power has some possibility of falling short of the peak demand due to long-term climate fluctuation. Hence, hydro power is rated lower than the other stable energy sources.

*2) Note: Biomass thermal has possibility of falling short of peak demand due to seasonal fluctuation of procurement of bio materials. Since seasonal discharge volume in the Nile River basin is mostly constant and collecting operation of the biomass material is very difficult, the energy stability of biomass thermal is lower than that of large-scale hydro power.

*3) Note: Solar thermal power can be generated during night time; however, in the case of cloudy conditions, solar thermal power cannot meet the peak demand and cloudy weather condition will happen frequently. Hence, solar thermal power should not count as energy which meets further peak demand.

*4) Energy import will be affected by seasonal power supply fluctuation of the exporting countries.

5.1.1.4.3 Power Supply Stability

Each energy source has characteristics of power supply stability on the time scales of long-term, seasonal, and daily.

(1) Large-Scale Hydro

Large-scale hydro project along the Nile River has secure seasonal power supply stability that can obtain consistent flow from a huge reservoir of Lake Victoria; however, even with a huge reservoir, long-term water inflow fluctuation exists despite a generally sustainable inflow.

(2) Geothermal

Needless to say, the energy source of the geothermal power is stable in all time-scale aspects.

(3) Diesel Engine (Domestic Product Heavy Oil Only)

Heavy oil can be obtained from domestic product; hence, power generation by the diesel engine might not be affected by the seasonal oil price fluctuation. However, oil resources are limited and the full potential of oil resources may not be developed.

(4) Biomass Cogeneration Thermal

Biomass thermal is one form of renewable energy; however, long-term sustainability of a large-scale biomass thermal plant requires an extensive plantation area, a transportation system, and sufficient stock. Even if utilizing waste disposal of crops or garbage, management of long-term or seasonal supply, transportation, and stock is very difficult. In addition, seasonal production of the vegetation is strongly affected by the climate fluctuation. Generally, large-scale biomass thermal plants face such a problem.

(5) Solar Thermal

Solar thermal has improved hourly fluctuation deriving from the sunlight fluctuation. However, daily stability of solar thermal is still lower than that of other energy sources, since solar energy cannot be obtained 24 hours a day. In addition, seasonal and long-term climate fluctuation causes lower stability of the solar energy supply.

(6) Nuclear

Nuclear power is a stable energy source in the short term (less than a few years); however, long-term availability of uranium or other materials is not certain at present.

(7) Energy Import

Power supply stability by energy import is dependent on operation of the exporting country. Short-term power stability of the imported energy may be kept by agreements, but keeping long-term power supply stability is difficult due to energy demand development of the energy-exporting countries.

Table 5.1-11 Power Supply Stability of Energy Source in Uganda

Energy Source	Long-term	Seasonal	Daily	Rating
Large-Scale Hydro	B (long-term climate fluctuation)	A	A	B
Geothermal	A	A	A	A
Diesel Engine (Domestic product heavy oil)	D (limited)	A	A	C
Biomass Cogeneration	C (Difficult to keep sustainability)	C (seasonal climate fluctuation)	A	D
Solar-thermal	B (long-term climate fluctuation)	C (seasonal climate fluctuation)	E (daily climate fluctuation)	E
Nuclear	E (Unknown)	A	A	D
Energy Import	E (Unknown)	A	A	D

Source: JICA Study Team

5.1.1.5 Life Span

Table 5.1-12 Life Span

	Hydro	Geothermal	Diesel Engine (Heavy Oil)	Wind Power	Biomass Thermal Cogeneration	Solar Thermal	**Nuclear+**	Energy import
Life Span (Years)	50 to 100	20 to 40	10 to 20	-	20 to 40	20 to 40	20 to 40	
Rating	A	C	E	C	C	C	C	A

5.1.1.6 Contribution to national economy

Each alternative power source was generically evaluated on contribution to the national economy, from the viewpoints of: GDP growth, improvement of balance of payments, increase/decrease in external debt, and power tariff reduction, although such an evaluation may result in assertive ratings unless specific conditions are given for concrete forms of implementation of each alternative, and all the more so in that these viewpoints are interrelated with each other.

1. Hydro

Hydropower can most contribute to the growth of GDP by enhancing industrial growth, although it requires large capital requirements, resulting in increased external debt. Meanwhile, by enhanced industrial growth, exports will be increased, including the produced power itself, to gain hard currency, resulting in improved balance of payments. At the same time, hydropower can replace thermal power generation to reduce expensive fuel oil imports, which will also improve balance of payments.

2. Geothermal

For geothermal power, the same thing can be said as for hydropower.

3. Diesel

Diesel generation requires a lot of fuel oil, all imported from overseas through Kenya, so that balance of payments will be worsened and power tariff will be raised. At the same time, diesel generators can be leased and returned when they are not needed.

4. Wind

For wind power, the same thing can be said as for hydropower, but its high generation cost will raise power tariff.

5. Biomass

For biomass generation, the same thing can be said as for wind power.

6. Solar power

For solar power, the same thing can be said as for wind power.

7. Nuclear power

For nuclear power, the same thing can be said as for hydropower.

8. Power import

Power import will worsen balance of payments and may result in increased external debt. If higher tariff is imposed on imported power by power exporters, power tariff will be raised.

Table 5.1-13 Contribution to National Economy

		GDP	Balance of Payments	External debt	Power tariff reduction	Rating
Hydro	rating	A	B	C	A	A
	remark	industrial growth enhanced	Positive side: possible power export & reduction of fuel oil import Negative side: large capital goods import	large capital requirement	low generation cost	
Geothermal	rating	A	B	C	A	A
	remark	ditto	Positive side: reduction of power import & reduction of fuel oil import Negative side: large capital goods import	capital requirement	low generation cost	
Diesel	rating	A	C	B	C	E
	remark	ditto	Increase in fuel oil import	Positive side: generation units can be leased Negative side: fuel oil import	High generation cost	
Wind	rating	B	A	B	C	C
	remark	ditto	Reduction of fuel oil import	capital requirement	High generation cost	
Biomass	rating	B	A	B	C	C
	remark	ditto	Reduction of fuel oil import	capital requirement	High generation cost	
Solar	rating	B	A	B	C	C
	remark	ditto	Reduction of fuel oil import	capital requirement	High generation cost	
Nuclear	rating	A	B	C	A	A
	remark	ditto	Positive side: possible power export & reduction of fuel oil import Negative side: large capital goods import	large capital requirement	Low generation cost	
Power Import	rating	A	C	B	B	C
	remark	ditto	Increase in import	Increase in import	High generation cost	

5.1.2 Environmental aspect

5.1.2.1 Air pollution

The impact on air pollution was estimated based on life cycle assessment, which included the periods of manufacturing, construction, operation, and closing. The results are shown in Table 5.1-14. While the impacts on air pollution by hydropower, geothermal, and nuclear power are relatively low, the impact by diesel engine is the worst. The air pollution substances used for the assessment were SO_2, NO_x, and Particulate Matter. Most figures were quoted from the results in the EIA report. However, the data of solar power are substituted by PV, since the data for solar thermal were not available.

Table5.1-14 Air Pollution of Electricity Generation Technology

Technology	SO_2 (t SO_2/TWh)	NO_x (t NO_x/TWh)	Particulate Matter	Rating*3
Hydro*1	1-60	1-68	1-5	A
Geothermal*2	0.03	0	0	A
Diesel Engine (Heavy Oil) *1	8013-9595+	1386		E
Wind Power*1	21-87	14-50	5-35	B
Biomass*1	12-160	701-2540	190-320	D
Solar*1	24-490	16-340	12-190	B
Nuclear*1	3-50	2-100	2	A
Energy import*1	4-32 321+	0.3-12300	1-663+	D

*1: IEA. May 2000. Hydropower and the Environment: Present Context and Guidelines for Future Action. Vol. II: Main Report, Ch. 3: "Comparative Environmental Analysis of Power Generation Options".

*2: Adam Serchuk 2000. THE ENVIRONMENTAL IMPERATIVE FOR RENEWABLE ENERGY: AN UPDATE. Renewable Energy Policy Project

*3: Evaluation by study team

5.1.2.2 Water pollution

The impact on water pollution was briefly evaluated from possibility, severity, and immitigability, since the quantitative figures by each power source were not available. Wind power is the best, because there is no water pollution except in the manufacturing stage and operation stage, which produce wastewater. Geothermal, nuclear power, and energy import are worse because of thermal water and boiler cleaning wastes.

Table 5.1-15 Water Pollution of Electricity Generation Technology

Technology	Impacts	Probability of occurring	Severity of consequences	Immitigability	Rating
Hydro*1	• Release from reservoirs of anoxic waters. • Modification of the thermal regime. • Proliferation of waterborne diseases in shallow stagnant areas. • Increased turbidity associated with banks erosion. • Modifications to the flow regime.	Medium	Low	Medium	C
Geothermal*2	• Blowouts can pollute surface water. • Spent geothermal fluid with high concentrations of chemicals can pollute surface water.	Medium	Medium	Medium	D
Diesel Engine (Heavy Oil)*3	• Boiler blowdown • Boiler cleaning wastes • Thermal pollution	High	High	Low	C
Wind Power	• Wastewater during Manufacturing process • Sewage contamination during	High	Low	Low	A

Technology	Impacts	Probability of occurring	Severity of consequences	Immitigability	Rating
	operation				
Biomass	• Boiler blowdown • Boiler cleaning wastes • Thermal pollution	High	High	Low	C
Solar	• Wastewater during Manufacturing process • Sewage contamination during operation	High	Low	Low	B
Nuclear	• Boiler blowdown • Boiler cleaning wastes • Thermal pollution	High	High	Low	D
Energy import	• Boiler blowdown • Coal pile run-off • Coal pile run-off • Boiler cleaning wastes • Thermal pollution	High	High	Low	D

*1: IEA. May 2000. Hydropower and the Environment: Present Context and Guidelines for Future Action. Vol. II: Main Report, Ch. 3: "Comparative Environmental Analysis of Power Generation Options".

*2: Mary H. Dickson and Mario Fanelli, "What is Geothermal Energy?" (Pisa, Italy: Istituto di Geoscienze e Georisorse, CNR, February 2004)

*3: How can electricity production impair water quality? (The Power Scorecard Web site http://powerscorecard.org/)

5.1.2.3 Consumption of natural resources

The impact of consumption of natural resource was evaluated based on the extraction of natural resources and dependence on local resources. The evaluations of hydropower, wind power, and solar thermal are high because of availability of local resources.

Table 5.1-16 Natural resource consumption of Electricity Generation Technology

Technology	Extraction*1	Dependence on local resources	Rating
Hydro	No	High	A
Geothermal	No	High	B
Diesel Engine (Heavy Oil)	Yes	Medium	E
Wind Power	No	High	A
Biomass	No	Medium	C
Solar	For manuf. only	High	A
Nuclear	Yes (Uranium)	Low	C
Energy import	Yes (Oil, Coal)	Low	E

*1: Canadian Electricity Association, 2006. POWER GENERATION in CANADA

5.1.2.4 CO_2 emission

CO_2 emission was evaluated by the figures calculated by life cycle assessment. The emissions from hydropower and nuclear power are relatively low and the emissions from diesel engines and energy import are relatively high. The emission from solar thermal is substituted by PV, because of unavailability of data.

Table 5.1-17 CO_2 emission of Electricity Generation Technology

Technology	Greenhouse gas emissions (kt eq.CO_2/TWh)	Rating
Hydro*1	1-48	A
Geothermal*2	47-97	B
Diesel Engine (Heavy Oil) *1	686-726+	E
Wind Power*1	7-124	C
Biomass*1	15-118	C
Solar*1	13-731	D
Nuclear*1	2-59	A
Energy import*1	686-726+	E

*1: IEA. May 2000. Hydropower and the Environment: Present Context and Guidelines for Future Action. Vol. II: Main Report, Ch. 3: "Comparative Environmental Analysis of Power Generation Options".

*2: Adam Serchuk 2000. THE ENVIRONMENTAL IMPERATIVE FOR RENEWABLE ENERGY: AN UPDATE. Renewable Energy Policy Project

5.1.2.5 Waste

Industrial waste from each energy source was evaluated by type of waste and relative amount of waste, due to lack of figures. The results are shown in Table 5.1-18.

The evaluation of wind power and solar thermal is high because of little industrial waste. On the other hand, the evaluation of nuclear power is low because of the difficulty in nuclear waste disposal.

Table 5.1-18 Industrial Waste

Technology	Waste	Amount*1	Rating
Hydro	Drifted waste Sediment Sludge	No	B
Geothermal		Large	C
Diesel Engine (Heavy Oil)	Burned Ash	Large	C
Wind Power	No	No	A
Biomass	Burned Ash	Large	D
Solar	No	No	A
Nuclear	Nuclear waste	Large: Radioactive	E
Energy import		Large	D

*1: Canadian Electricity Association, 2006. POWER GENERATION in CANADA

5.1.2.6 Water use

Impact on water use was evaluated through relative assessment by type of impact, probability, and severity of consequences. The results are shown in Table 5.1-19. The impact by wind power is the lowest because of limited wastewater. The impact by hydropower is the highest because of changing flow pattern downstream.

Table 5.1-19 Impact on Water Use

Technology	Water use impacts*1	Probability of occurring	Severity of consequences	Rating
Hydro	Low: Flow pattern changed	High	High	D
Geothermal	Low	High	Low	B
Diesel Engine (Heavy Oil)	Low-Medium: Thermal discharge	High	Medium	C
Wind Power	None	None	None	A
Biomass	Low	High	Low	B
Solar	Low	High	Low	B
Nuclear	Low: Thermal discharge	High	Medium	C
Energy import	Low-Medium: Thermal discharge	High	Medium	C

*1: Canadian Electricity Association, 2006. POWER GENERATION in CANADA

5.1.2.7 Ecosystem

Impact on the ecosystem was evaluated by type of impact, impact on local ecosystem, impact on biomass, and impact on genetic diversity at the world level. The results are shown in Table 5.1-20. Solar thermal is the best for the ecosystem and hydropower is the worst, because of the big impact which may affect not only the terrestrial ecosystem but also the aquatic ecosystem.

Table 5.1-20 Impact on Natural Ecology

Technology	Source of final significant impacts on biodiversity	Local and regional ecosystem	Biomass	Genetic diversity at world level	Total*2
Hydro*1	• Barriers to migratory fish • Loss of terrestrial habitat • Change in water quality • Modification of water flow	X	X	X	E
Geothermal	• Loss of terrestrial habitat	X			C
Diesel Engine (Heavy Oil) *1	• Climate change • Acid precipitation • Mining and transportation of coal	X	X	X	D
Wind Power*1	• Risks for some species of birds	X			B
Biomass		X	X		C
Solar*1		X			A
Nuclear*1	• Radioactive substances	X			C
Energy import		X	X	X	D

*1: IEA. May 2000. Hydropower and the Environment: Present Context and Guidelines for Future Action. Vol. II: Main Report, Ch. 3: "Comparative Environmental Analysis of Power Generation Options".

*2: Rating by study team

5.1.3 Social aspect

5.1.3.1 Agriculture

Impacts on agriculture were evaluated by types of impact, probability, and land requirements. The results are shown in Table 5.1-21. The evaluations of geothermal, diesel, and nuclear power are relatively high because of small land requirements. The evaluation of hydropower is the lowest because of vast land requirements.

Table 5.1-21 Impact on Agriculture

Technology	Impact	Probability of occurring	Land Requirements*1 (km2/TWh/y)	Rating
Hydro	Loss of land Impact on Irrigation water quantity	High	0.1-152	D
Geothermal	Loss of land Impact on irrigation water quality	High	-	A
Diesel Engine (Heavy Oil)	Loss of land	High	-	A
Wind Power	Loss of land	High	24-117	C
Biomass	Loss of land Create new farming Steep rise in commodity prices	High	0.9-2200	E
Solar	Loss of land	High	27-45	B
Nuclear	Loss of land	High	0.5	A
Energy import	Loss of land	High	-	A

*1: IEA. (May 2000). Hydropower and the Environment: Present Context and Guidelines for Future Action. Vol. II: Main Report, Ch. 3: "Comparative Environmental Analysis of Power Generation Options".

5.1.3.2 Resettlement

The evaluations on resettlement were based on land requirement, severity, and immitigability. The results are shown in Table 5.1-22. The evaluations of geothermal, diesel engine, and nuclear power are relatively high because of small land requirement. The evaluation of hydropower is the lowest because of vast land requirement.

Table 5.1-22 Impact on Resettlement

Technology	Land Requirements*1 (km^2/TWh/y)	Severity of consequences	Immitigability	Rating
Hydro	0.1-152	Low-Medium	Low	D
Geothermal	-	Low	Low	A
Diesel Engine (Heavy Oil)	-	Low	Low	A
Wind Power	24-117	Low	Low	C
Biomass	0.9-2200	Low-High	Low	E
Nuclear	0.5	Low	Low	A
Solar	27-45	Low	Low	B
Energy import	-	Low	Low	A

*1: IEA. May 2000. Hydropower and the Environment: Present Context and Guidelines for Future Action. Vol. II: Main Report, Ch. 3: "Comparative Environmental Analysis of Power Generation Options".

5.1.3.3 Fisheries

Impacts on fisheries were evaluated by types of impact, probability, severity, and immitigability. The results are shown in Table 5.1-23. The rating of solar thermal and wind power is A, since there is no impact on fisheries. On the other hand, the rating of hydropower is E because of barriers to migratory fish, changing in water quality, and modification of water flow.

Table 5.1-23 Impact on Fishery

Technology	Impacts	Probability of occurring	Severity of consequences	Immitigability	Rating
Hydro	• Barriers to migratory fish • Change in water quality • Modification of water flow	High	High	High	E
Geothermal	•Change in water quality •Change in water temperature	High	Medi um	Low	C
Diesel Engine (Heavy Oil)	•Change in water quality •Change in water temperature	High	Medium	Low	D
Wind Power	-	-	-	-	A
Biomass	•Change in water quality •Change in water temperature	High	Medium	Low	D
Solar	-	-	-	-	A
Nuclear	•Change in water quality •Change in water temperature	High	Medium	Low	D
Energy import	•Change in water quality •Change in water temperature	High	Medium	Low	D

5.1.3.4 Tourism

Impact on tourism was evaluated by types of impact, probability, severity, and immitigability. The results are shown in Table 5.1-24. The ratings of diesel engine, biomass, and energy import are A because of low probability and severity. The ratings of hydropower is E because of the possible impact on fishing, trekking, nature observation, rafting, and landscape.

Table 5.1-24 Impact on tourism

Technology	Impacts	Probability of occurring	Severity of consequences	Immitigability	Rating
Hydro	Fishing, Trekking, Nature watching, Rafting, kayaking Landscape	High	High	High	E
Geothermal	Fishing, Landscape	Medium	Medium	Low	B
Diesel Engine (Heavy Oil)	Fishing, Landscape	Low	Medium	Low	A
Wind Power	Bird Watching, Landscape	High	Medium	High	D
Biomass	Fishing, Landscape	Low	Medium	Low	A
Solar	Landscape	Medium	Medium	High	C
Nuclear	Fishing, Landscape	High	Medium	Low	C
Energy import	Fishing, Landscape	Low	Medium	Low	A

5.1.3.5 Legal aspects

Legal aspects were evaluated from the difficulty of legislative points of view. The results are shown in Table 5.1-25. The ratings of hydropower, diesel engine, and wind power are A because of few legislative problems. The rating of nuclear power is E because of little legislative progress on management of nuclear waste treatment.

Table 5.1-25 Legal Problems of the Energy Sources

Technology	Problems	Rating
Hydro	No regulation on Residual flow	A
Geothermal	No technical Standard or guideline for Geothermal Power Plant	C
Diesel Engine (Heavy Oil)	-	A
Wind Power	-	A
Biomass		A
Nuclear	No regulation or guideline on Impact Assessment, No technical standard on Radioactivity, No technical regulation on Nuclear Power Plant	E
Solar	-	A
Energy import	-	A

5.1.3.6 Human Health

Impact on human health is evaluated by type of impact, probability, severity, and immitigability. The results are shown in Table 5.1-26. The rating of solar thermal is A, since there is no health impact. The ratings of geothermal and diesel engine are D because of wastewater discharge and polluted air emission.

Table 5.1-26 Impact on Human Health

Technology	Impact on Human Health*1	Probability of occurring	Severity of consequences	Immitigability	Rating
Hydro	• Risks from water-borne diseases, particularly when there is irrigation*1 • Polluted water	Medium-Low	High	High	D
Geothermal	• Polluted water • Polluted air	High	High	Low	D
Diesel Engine(Heavy Oil)	• Acid precipitation*1 • Photochemical smog*1 • Particulate matter*1 • Toxic metals*1 • Polluted water	High	High	Low	D
Wind Power	• Low frequency noise	High	Medium	Low	B
Biomass	• Photochemical smog • Particulate matter	High	High	Low	D
Solar	-	-	-	-	A
Nuclear	• Radioactive substances*1	Low	High	High	D
Energy import	• Climate change*1 • Acid precipitation*1 • Photochemical smog*1 • Particulate matter*1	High	High	Low	D

	• Toxic metals*1				

*1: IEA. May 2000. Hydropower and the Environment: Present Context and Guidelines for Future Action. Vol. II: Main Report, Ch. 3: "Comparative Environmental Analysis of Power Generation Options".

5.1.3.7 Risk of accident

The risk of accident was evaluated by number of actual accidents, number of fatalities, and experience of operation in Uganda. The results are shown in Table 5.1-27. The rating of diesel is E because of the high number of accidents. The ratings of wind power and solar thermal are A because of no record of accidents.

Table 5.1-27 Risk of accident

Technology	Impact	Number of Severe accidents with fatalities, worldwide	Number of immediate fatalities (per GWe year)	Experience in Uganda	Rating
Hydro	Dam failure	9	$8.8*10^{-1}$	Yes	D
Geothermal		No data	No data	No	B
Diesel Engine (Heavy Oil)	Road accidents during Transport to Refinery and Regional Distribution (oil)	334 (oil)	$4.2*10^{-1}$ (oil)	Yes	E
Wind Power		No data	No data	No	A
Biomass		No data	No data	No	B
Solar		No data	No data	No	A
Nuclear	Nuclear reactor accidents	1	$8.4*10^{-3}$	No	D
Energy import				?	E

*1: Hirschberg S., Spiekerman G., Dones R. & Burgherr P. (2001) Comparison of severe accident risks in fossil, nuclear, and hydro electricity generation", Invited paper, EAE 2001, International Conference on Ecological Aspects of Electric Power Generation, 14-16 November 2001, Warsaw, Poland.

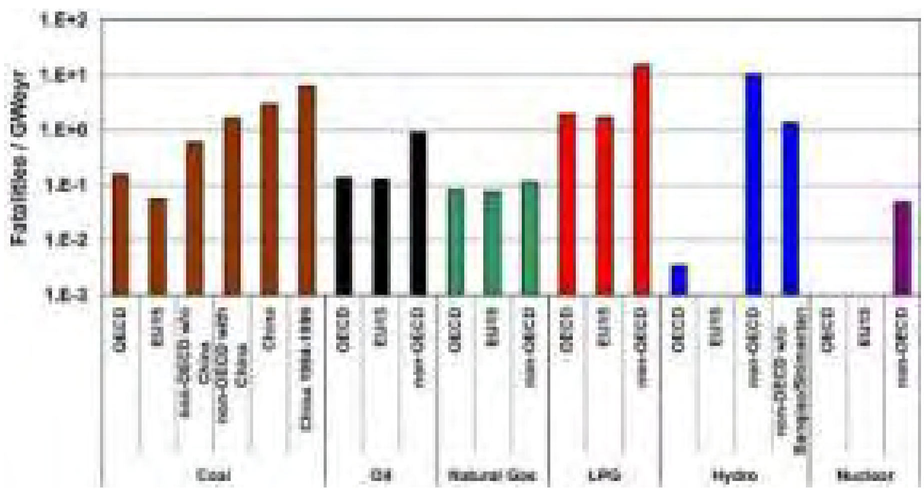


Figure 5.1-1 Comparison of aggregated, normalized, energy-related damage rates*2

*2: Comparison of aggregated, normalized, energy-related damage rates, based on historical experience of severe accidents that have occurred in OECD countries, non-OECD countries, and EU15 for the period 1969-2000, except for data from the China Coal Industry Yearbook, which were only available for the years 1994-1999. For the Hydro chain, non-OECD values were given with and without the largest accident that ever happened in China, which resulted in 26,000 fatalities. No reallocation of damages between OECD and non-OECD countries was used in this case. Note that only immediate fatalities were considered here, although latent fatalities are of particular relevance for the nuclear chain.

5.1.4 General Evaluation

5.1.4.1 Evaluation criteria

The general evaluation method of alternative energy sources is multi-criteria decision analysis. The total number of criteria was twenty seven, including economic and technical items such as development cost and existing potential, environmental items such as air pollution and waste, and social items such as resettlement and tourism. After giving ratings from A to E, the ratings were converted into the value of 5 to 1 for each, multiplied by weight, and summed up by energy source. The weighting patterns were divided into three cases; namely, even case, environmental weighting case, and economic weighting case. The weighting patterns are shown in Table 5.1-28.

Table 5.1-28 Evaluation Items and Weighting

Evaluation items			Even Case			Environment weighting case			Economic Weighting Case		
Economic and technical	Cost	Development cost(USD/kW)	34	12	4	25	9	3	55	6	2
		Operation & Maintenance cost (USD/kW/year)			4			3			2
		Unit cost of power generation (USD/MWh)			4			3			2
	Development potential	Existing potential (MW)		12	4		9	3		24	2
		Technically feasible potential at present (MW)			4			3			20
		Availability of Energy Source			4			3			2
	Construction	Survey maturity		5	3		2	1		10	9
		Lead time for construction			2			1			1
	Operation	Initial Starting Time		4	1		4	1		13	1
		Energy stability			1			1			10
		Power supply stability			1			1			1
		Life Span (Years)			1			1			1
	Contribution to national economy			1	1		1	1		2	2
Environmental	Air pollution		33		4	42		5	23		2
	Water pollution				5			5			3
	Consumption of natural resources				5			7			4
	CO_2 emission				4			5			3
	Waste				4			5			3
	Water rights/ water resources				5			7			3
	Impact on natural ecology				6			8			5
Social	Impact on Agriculture		33		5	33		5	22		3
	Resettlement				5			5			3
	Impact on fisheries				6			6			4
	Impact on tourism				5			5			3
	Legal aspects				4			4			2
	Human health hazard+				4			4			3
	Risk of accident				4			4			4

5.1.4.2 Evaluation result

All evaluations, from 6.1.1 to 6.1.3, were gathered and calculated based on the several scenarios. The results show that hydropower, geothermal, and solar thermal had relatively high scores (see Table 5.1-29).

Table 5.1-29 General Evaluation of Various Energy Sources

Evaluation items			Weight			Hydro	Geothermal	Diesel Engine (Heavy Oil)	Wind Power	Biomass Thermal Cogeneration	Solar Thermal	Nuclear+	Energy import
Economic and technical	Cost**	Development cost (USD/kW)	34	12	4	3	3	5	1	1	1	1	5
		Operation & Maintenance cost (USD/kW/year)			4	5	3	3	5	3	5	1	5
		Unit cost of power generation (USD/MWh)			4	5	5	1	5	3	1	5	1
	Development potential**	Existing potential (MW)		12	4	5	3	3	1	4	2	4	2
		Technically feasible potential at present (MW)			4	5	3	2	1	4	3	1	1
		Availability of Energy Source+			4	4	5	2	1	2	3	1	1
	Construction*	Survey maturity		5	3	4	3	5	1	5	5	1	1
		Lead time for construction			2	3	2	5	1	4	4	1	3
	Operation	Initial Starting Time		4	1	5	3	4	1	3	3	2	1
		Energy stability			1	4	5	5	1	3	1	5	3
		Power supply stability			1	4	5	3	1	2	1	2	2
		Life Span (Years)			1	5	4	3	4	4	4	4	5
	Contribution to national economy*			1	1	5	5	1	3	5	3	5	3
Environmental	Air pollution		33		4	5	5	1	4	2	4	5	2
	Water pollution				5	3	2	3	5	3	4	2	2
	Consumption of natural resources*				5	5	4	1	5	3	5	3	1
	CO_2 emission				4	5	4	1	3	3	2	5	1
	Waste				4	4	3	3	5	2	5	1	2
	Water rights/ water resources*				5	2	4	3	5	4	4	3	3
	Impact on natural ecology**				6	1	3	2	4	3	5	3	2
Social	Impact on Agriculture		33		5	2	5	5	3	1	4	5	5
	Resettlement				5	2	5	5	3	1	5	4	5
	Impact on fisheries				6	1	3	2	5	2	5	2	2
	Impact on tourism				5	1	4	5	2	5	3	3	5
	Legal aspects				4	5	3	5	5	5	1	5	5
	Human health hazard+				4	2	2	2	4	2	5	2	2
	Risk of accident				4	2	4	1	5	4	5	2	1
General Evaluation	Even Case					328	363	291	344	295	368	285	264
						B	A	C	B	C	A	C	C
	Environment weighting case					320	367	277	367	291	378	298	261
						B	A	C	A	C	A	C	C
	Economic Weighting Case					367	361	299	266	332	348	260	219
						A	A	C	C	B	B	C	C

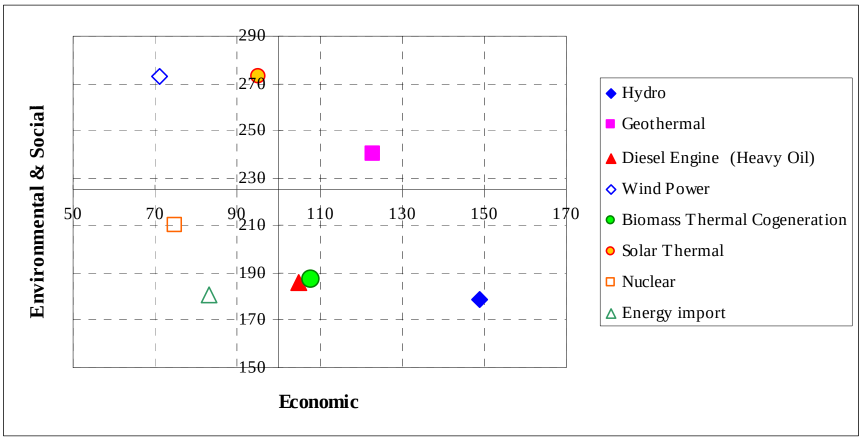


Figure 5.1-2 Evaluation Results (Neutral Case)

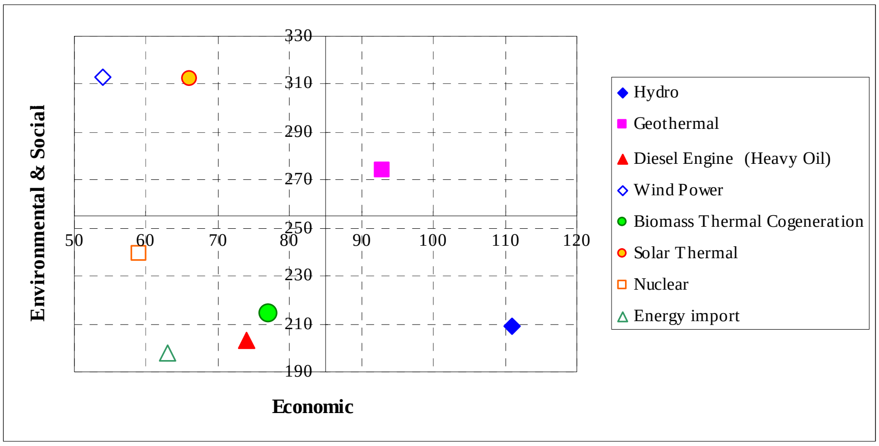


Figure 5.1-3 Evaluation Results (Priority for Environment Case)

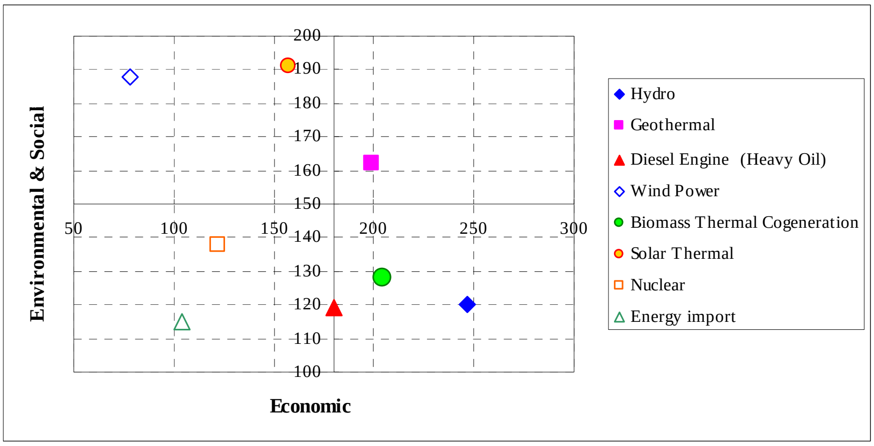


Figure 5.1-4 Evaluation Results (Priority for Economy Case)