

Perusahaan Umum Listrik Negara
Republic of Indonesia

STUDY
FOR
REHABILITATION OF HYDROPOWER STATIONS
IN
INDONESIA

FINAL REPORT
(ANNEX)

September 2010

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.

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IN
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ANNEX

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ANNEX A GEOLOGY OF THE PROJECT SITES

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ANNEX A Geology of the Project Sites**1. GENERAL**

This report explains the results of the study on geology for the “Rehabilitation of Hydropower Stations in Indonesia”.

The study, i.e. “Rehabilitation of Hydropower Stations in Indonesia”, was conducted for the purpose to formulate optional rehabilitation plan for the selected hydropower stations in order to recover and maintain the initial functions of the hydropower stations.

The selection of the hydropower stations was done by first, pre-second and second screenings, as mentioned in the Final Report in July 2010. For the secondary screening study considering sedimentation of the dam reservoirs, three (3) power stations in two river basins, i.e. Sutami and Wlingi hydropower stations in the Brantas River basin in East Jawa, and Soedirman (Mrica) hydropower station in the Surayu River basin in Central Jawa were selected.

Geological reconnaissance and study were performed for these two river basins, i.e. the Brantas River basin and Serayu River basin for the purpose of explanation of the geological features related to the sedimentations of the selected dam reservoirs.

2. SENGGURUH DAM, SUTAMI DAM AND WLINGI DAM: BRANTAS RIVER BASIN

2.1 GENERAL

According to the Report on Engineering Studies for the Brantas River and the Bengawan Solo River Basins (Nippon Koei Co., Ltd. and associations, 1995), the river systems and topographies are summarized as follows:

(1) RIVER SYSTEM

The Brantas River is the second largest river on the Java Island with 320 km in length and catchment area of about 11,800 km² lying on East Java province, which covers around 9 % of the total area of the Java Island. The river basin geographically extends between 110°30' and 112°55' of east longitude and between 7°01' and 8°15' of south latitude.

The Brantas River originates from the southeastern side of Mt. Anjasmoro located in the center of its basin. The Brantas River initially flows eastward, turns its course southward around the Semeru volcanic zone, and then runs to the west parallel to the southern hills. The Lesti River (catchment area of 625 km²) of left bank tributary joins the Brantas River at the point where the Brantas River changes its course from the south to the west. After flowing around 75 km to the west parallel to the southern hills, the Brantas River changes its course to the north when it enters the alluvial plain, and the Ngrowo River (catchment area of 1,600 km²) of left bank tributary joins the Brantas River near Tulungagung city. The Brantas River continues its northerly course, and is joined by the Konto (catchment area of 687 km²) of right bank tributary and the Widas (catchment area of 1,538 km²) of left bank tributary. Then it turns to the east and bifurcates to the Porong River and the Surabaya River in Mojokerto city. As stated above, the Brantas River is characterized by clockwise watercourse centering on around Mt. Kelud and this is influenced by the process of mountain uplifts and the volcanic ranges.

In the late 19th century the Porong River was constructed as a floodway to protect Surabaya city from floods, and today all of the flood water from the Brantas main stream, flows the Porong River. The Porong River runs through the Lengkong barrage to the southeast and tributaries of the Kambing and the Sadar join in the middle reaches. After passing through Porong city, it discharges into the Madura Strait.

The Lesti River with a catchment area of 625 km², originates in the northern slope of Mt. Semeru and the uppermost stream starts its course westward, turns southwest gradually, and then runs to west after joining the Genteng River. The main stream of the Lesti River is facing to a sediment related issue caused mainly by surface erosion.

(2) TOPOGRAPHY

The Brantas River basin, having a catchment area of about 11,800 km², is bounded by Mt. Semeru (el. 3,683 m) and Mt. Arjuno (el. 3,387 m) in the east, and by Mt. Wilis (el. 2,196 m) in the west. Mt. Kelud (el. 1,731 m) and Mt. Kawai (el. 2,639 m) lie in its center. In addition, a series of low hills, 300 to 500 m high, separate the basin from the Indian Ocean in the south. The Brantas River basin can be divided into three types of landforms in terms of geomorphology:

- a. Steep Volcano and highland, generally above elevation 1,000 meters, account for about 10% of the basin area. Slopes are steep with more than 30 degrees, and covered almost with dense vegetation.
- b. Midland and hilly land, between the highland and the alluvial plains, occupy 60% of the basin area. This area ranges in altitude from 200 to 1,000 meters with a slope gradient of 10 to 30 degrees, and comprises the main agricultural production area. In addition, hills are often below 500 meters and much vegetation.
- c. Lowland and Alluvial plain, mostly below elevation 200 meters, account for 30% of the basin area. This area consists of the lower basin of the rivers as well as the agricultural production resettlement areas.

2.2 REGIONAL GEOLOGY

The Brantas River basin is located in the eastern part of Java. According to “Geological Map of Eastern Part of Java (1 / 500,000 scale, 1999)”, the geological condition of the eastern part of Java is summarized as follows:

The eastern part of Java is geologically divided into four (4) zones, i.e. Rembang zone, Kendeng zone, Central Volcanic Zone and Southern Mountains Zone, with an east – west trend, as shown in Figure 2.2-1. Each zone is described as below:

Rembang zone: The zone consists of Tertiary Oligocene, Miocene and Pliocene sedimentary rocks, such as marl, claystone, siltstone, sandstone, limestone, and Quaternary Pleistocene sedimentary rocks, such as conglomerate, sandstone, claystone. Quaternary Alluvial deposits are widely developed along the Bengawan Solo River.

In this zone, west - east trending folds are developed well, which are cut by short and normal faults.

Kendeng zone: The zone consists of Tertiary Miocene to Pliocene sedimentary rocks, such as sandstone, claystone, marl, limestone, tuff, and Pliocene to Pleistocene volcanic / sedimentary rocks / deposits, such as andesitic – basaltic breccias, tuff, laharic deposit, tuffaceous sandstone, claystone, conglomerate. Alluvial deposits are widely developed along the Brantas River from the Trugagung area to Surabaya.

Similar conditions on geological structures such as fold, fault, to those in the Rembang zone are seen in this zone also. Some thrust faults, west – east trending, are found in the southern marginal area of this

zone, north of the Mt.Lawu.

Central Volcanic Zone: This zone is generally so called as “Late Cenozoic Volcanic Arc” or “Present-day Volcanic Arc”. The zone consists of mostly Quaternary Pleistocene to Holocene volcanic products, such as volcanic breccias, lava, tuff, tuff breccias, laharic deposit, volcanic ash fall deposit. Many volcanoes, such as Mt.Lawu, Mt.Wilis, Mt.Kelud (1,731 m), Mt.Kawi (2,651 m), Mt.Arjuno (3,339 m), Mt.Semeru (3,676 m), Mt.Bromo, are located in the zone from west to east. Among them, Mt.Kelud, Mt.Semeru and Mt.Bromo had been constantly active in the twentieth (20th) century. Especially, Mt. Kelud erupted five (5) times on a large scale in times past. The volcanic activities of each mountain are described in later chapter 2.3.

The geological structures are dominantly effected by Quaternary volcanic activities.

Southern Mountains Zone: This zone consists of Tertiary Oligocene - Miocene volcanic / sedimentary rocks, such as lava, volcanic breccias, tuff, sandstone, siltstone, claystone, conglomerate, limestone, and Miocene – Pliocene limestone. Miocene intrusive rocks, such as andesite, dacite, basalt, diorite, are sporadically found in the zone. Quaternary Pleistocene volcanic deposits and Alluvial deposits are seen narrowly along the Brantas River and along the Indian ocean coast.

Rather short normal faults of northwest – southeast or southwest – northeast trending which cut to each other are developed in this zone.

As shown in Figure 2.2-1, the Brantas River basin is located in the northern marginal zone of the Southern Mountains Zone, Central Volcanic Zone and Kendeng Zone. The Sengguruh Dam, Sutami Dam and Wlingi Dam are located in the middle to upper reaches of the Brantas River. The area of these dams consists mostly of the rocks of the Southern Mountains Zone, i.e. Tertiary volcanic / sedimentary rocks. However, the catchment areas of these dams consist of the Quaternary volcanic product layers, which belong to the Central Volcanic Zone.

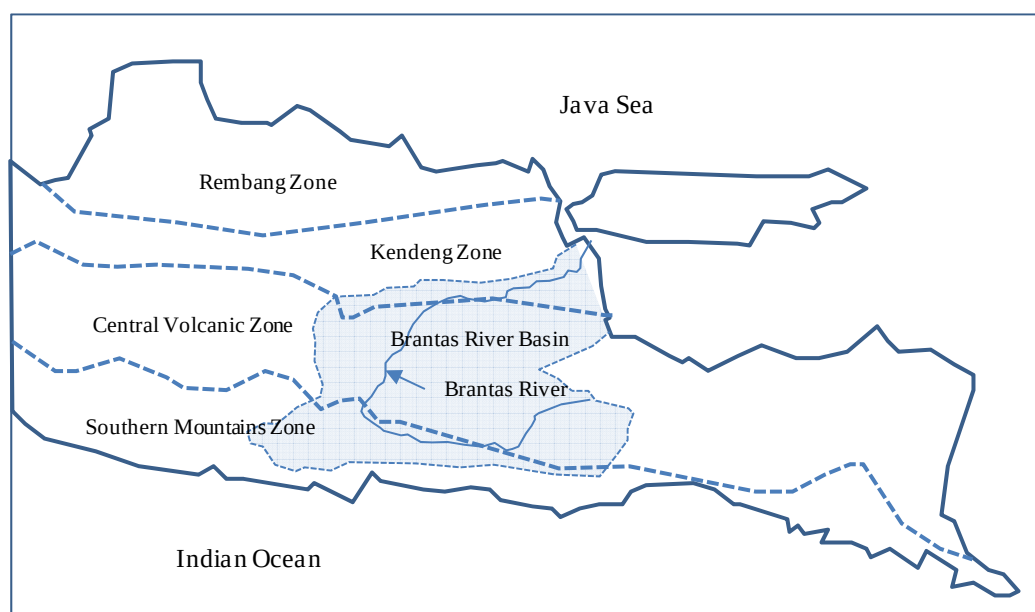


Figure 2.2-1 Geological Setting of East Java and Location of Brantas River Basin

2.3 VOLCANIC ACTIVITY

(1) GENERAL

The active volcanoes, which show very recent eruptions continuously, are Mt. Semeru on the eastern boundary and Mt. Kelud in the center of the basin.

Mt. Semeru erupts continuously and produces pyroclastic flow frequently in the south-eastern slope toward the Indonesian Ocean. There are two major tributaries of the Brantas River, i.e. the Lesti River and Genteng River. Both tributaries originate in the western and south western slope of Mt. Semeru. The uppermost streams start those courses southwest wards, and then run to west, then joining with the Brantas River. Mt. Semeru produces pyroclastic flow frequently in the south-eastern slope, however, only a few ash fall affect the Lesti River and Genteng River basins recently. The ash fall deposits are composed of mostly fine material, such as clay, silt, sand.

Mt. Kelud erupted six (5) times in the twentieth (20th) century an average of once every 15 years, and one time (1) in the twenty first century (21st). The average amount of erupted materials was estimated at 200 million m³ per eruption. The most recent eruption is in 2007, with lava dome only in the caldera.

In the middle Brantas River basin, one of the sediment sources is pyroclastic flow deposits and ash fall deposits from Mt. Kelud. The thickness of ash fall deposits is generally 2 to 20 cm at the distance of 30 km from the summit. After it rains, deposited ash fall are conveyed to the downstream section in the form of wash and suspended loads.

In the lowest reaches of the Brantas River in Sidoarjo district, Mud Volcano activity (eruption of mud and hot water) is seen continuously since May 29, 2006.

(2) MT. KELUD ERUPTION AND DAMAGE

The latest activity was lava dome eruption in the crater in 2007. Because of lava dome eruption, the crater lake has dried up. The latest activity was lava dome eruption in the crater in 2007. Because of lava dome eruption, the crater lake has dried up.

According to the Report on Engineering Studies for the Brantas River and the Bengawan Solo River Basins (Nippon Koei Co., Ltd. and associations, 1995), the Mt. Kelud Eruption and Damage are summarized as follows:

Reliable information about the Mt. Kelud eruption before 1800 is very scarce. The first record of Mt. Kelud eruption was prepared by the Dutch in June 1811. Mt. Kelud erupted five (5) times in the twentieth (20th) Century, an average of once every 15 years: 1901, 1919, 1951, 1966, and 1990.

Mt. Kelud produced 90 million-323 million m³ of ejecta per eruption since 1919.

The May 1919 eruption gushed out water of 38 million m³, which had collected in the crater, and flow down the Badak River in the form of lahar. This lahar caused the serious disaster with a loss of 104 villages, 9,000 houses, and 5,110 lives. After this eruption, the Dutch planned to drain the water in the crater through a drainage tunnel to prevent further disasters resulting from lahar. The tunnel construction commenced in September 1919 and completed in 1923.

The basin on the right bank of the Brantas River can be roughly divided into two areas: one that is highly affected by Mt. Kelud eruptions and the other, that is less affected. The former is the south and west sides of the mountain, covering most of the right bank basin between Kaulon and Kertosono. (The Wlingi dam catchment area is located in the highly affected area by Mt. Kelud eruptions, and the Sengguruh and Sutami dam catchment areas are in the less affected area.)

The damage caused by the past Mt. Kelud eruption is summarized in the Table 2.3.1, and eruptive material and its movement caused the damage are described below.

A. Pyroclastic Flow (Nuee Ardente):

A pyroclastic flow is a common and devastating result of certain explosive volcanic eruptions. The flows are fast-moving currents of hot gas and rock, which travel away from the volcano at speeds generally as great as 700 km/h. The gas can reach temperatures of about 1,000 °C. The flows normally hug the ground and travel downhill, or spread laterally under gravity. Their speed depends upon the density of the current, the volcanic output rate, and the gradient of the slope.

In the case of Mt. Kelud, most eruptions are accompanied by pyroclastic flow (nuee ardent), however, the flow of the hot eruptive materials is generally limited to within 5-7 km from the summit and it flows for a relatively short period following the eruption.

B. Volcanic Ash:

The distribution of volcanic ash and pyroclastic flow is affected largely by the prevailing winds and the height attained by the material during the eruption. In some cases, for instance, eruption in 1901, the ash covered a wide range and it covered the outside of Java Island, however, in the case of eruptions in 1966 and 1990, the material covered only the south and south west quarter of Mt. Kelud. If the ash deposit is significant depth, all of the crops are damaged and roofs are collapsed.

C. Primary Lahar (Volcanic Mud Flow):

Eruptive materials are mixed with the water in the crater lake and forms hot primary lahar. This hazardous hot primary lahar causes devastating damage because of the high velocity and the abrasive nature of the materials. Following the eruption in 1966, primary lahar with maximum width of 6 km reached to Udanawa, 31.5 km from the crater.

Since 1923 the level of water in the crater lake has been controlled by the tunnels and the severity and extent of primary lahar damage has been significantly reduced. During the 1919 and the 1966 eruptions, when damage to the tunnels had allowed water levels in the crater lake to rise, devastating damage and great loss of life were caused by primary lahar. However, primary lahar caused less damage during the 1951 and 1990 eruptions since the water volume in the crater lake were a small amount.

D. Secondary Lahar (Volcanic Mud Flow):

Secondary lahar occurs when the loose material and lahar deposited are eroded owing to heavy rainfall. The secondary lahar is not as destructive as hot primary lahars, however secondary lahars has a high specific gravity and can damage structures.

History of volcanic activities; Mt.Kelud is summarized in Table 2.3-1.

Table 2.3-1 History of Volcanic Activities <Mt. Kelud>

Main Activity	Date	Time of Activity	Type of Activity	Remarks
1000		311	Ep	Square of crater lake : 400.000 m ² and water contents 2.5 x 10 ⁶ m ³ with solfatar gas, explosive eruption with hot cloud and lahar cloud and pyroclastic eruption.
1311		65	Ep	Crater lake eruption and hot lahar, there are sacrifice in the area.
1376		9	Ep, Lv	Constant eruption, build lava dome. There are sacrifice in the area.
1385		10	Ep	No recorded
1395		16	Ep	No recorded
1441		40	Ep	No recorded
1451		11	Ep	No recorded
1462		19	Ep	No recorded
1481		67	Ep	No recorded
1548		38	Ep	No recorded
1586		55	Ep	Crater lake eruption, with hot lahar and hot cloud. Sacrifice: 10.000 persons (Brascamp 1918).
1641		75	Ep	No recorded
1716	20 Jul.	36	Ep	Crater lake eruption, pyroclastic flow sacrifice in the area.
1752	1 May	19	Ep	No recorded
1771	10 Jan.	5	Ep	Crater lake eruption, hot lahar and hot cloud
1776		9	Ep	Crater lake eruption, hot lahar and hot cloud
1785		26	Ep	Crater lake eruption, hot lahar and hot cloud
1811	5 Jun.	14	Ep	Crater lake eruption, hot lahar and hot cloud
1825		1	Ep	Crater lake eruption, pyroclastic flow hot lahar and hot cloud.
1826		9	Ep	Crater lake eruption, hot lahar and hot cloud (by Junghuhn 1953).
1835		13	Ep	No recorded
1848	16 May	3	Ep	Crater lake eruption, hot lahar and hot cloud, sacrifices in the area.
1851	24 Jan.	13	Ep	No recorded
1864	3-4 Jan.	37	Ep	No recorded
1901	23-24 May	18	Ep	Specific gravity of material eruption : 2.3 with renergy of 1.9 x 10 ²² erg, which is equal to Atomic Bomb of 2.3. The total eruption materials were 0.002 x 10 ⁶ m ³ .
1919	20-May	1	Ep	Crater lake eruption, hot lahar and hot cloud sacrifices : 5,160 persons.
1920	6-12 D.	30	Ep, Af, Lv	Constructed lava stopper in crater 1 year after eruption (1921) the lava stopper filled full water.
1951	31 Aug.	15	Ep	The eruption of materials reached until Sumber Glagah Plantation (4 km north of Blitar) and Wlingi.
			Af	Ash rain reached until Bandung City (eruption material vol. was 200 x 10 ⁶ m ³). Crater lake with
			Lv	radius of 6.5 km was created, and laharic flow in all the small rivers. Sacrifice was 7 persons, and field
				land damages were 7,000 ha. Hot water volume was 1.8 x 10 ⁶ m ³ . Energy was 3.9 x 1,024 erg. Part
				of crater loss was 22.1 x 10 ⁶ m ³ (by Hadi Kusumo 1973).
1965				Eruption of lahars flowing towards the rivers Badar, Ngobo, Konto, Putih and Semut. The total
				volume of eruption was 20.3 x 10 ⁶ m ³ .
1966	24 Apr.	24	Ep	Distribution of lahar and ash are seen until Indoensia sea. Laharic flow is seen in Badak, Putih, Ngobo,
			Af	Konto and Semut rivers. The total volume of eruption was 90 x 10 ⁶ m ³ . Sacrifices in Jatilengger and
			Lv	Atas Kedawung was 210 persons. Crater lake became 43 m high. Damages of mountain top was
			Py	radius 2.5 km. Land damages were 12,820.5 ha (Rekso wirogo 1969). The water volume of crater lake
				was 21.6 x 10 ⁶ m ³ , and energy was 1.7 x 10 ²⁴ erg. Landsliding of crater at the end of eruption was 20
				m high, and the volume of sliding was 9.5 x 10 ⁶ m ³ (Hadi Kusumo 1973).
1990	10 Feb.		Ep	Volume of pyroclastic sediment was 120,10 ⁶ m ³ including 57,106 m ³ of hot cloud sediment and
			Af	laharic flow. Volcanic material have flowed through the small rivers until 1991 when rain. No sacrifice
			Lv	was seen.
2007	Nov.		Lv	Crater lake dried up.

Ep : Eruption/explosion, Py: Pyroclastic flow, Lv: Lava dome formation/Lava flow, Af: Ash fall, *: Large scale eruption, VEI: Volcanic Explosivity Index

Sources: - Report on Mt. Kelud Eruption, 10 February 1990, Directorate of Volcanology March 1990

- Buletin of the Volcanological Survey of Indonesia for the years 1964 - 1970

- Volcanological Report in Java Indonesia

(Report on Engineering Studies for the Brantas River and the Bengawan Solo River Basins (Nippon Koei Co., Ltd. and associations, 1995)

2.4 SOIL DISTRIBUTION

According to the soil distribution map prepared by the Central Soil Research Institute of Bogor in 2000, the soil distribution conditions in the catchment areas of the Sengguruh dam, Sutami dam and Wlingi dam are summarized as below:

- The soils of the catchment areas can be classified into three (3) groups considering parent materials, i.e. Alluvial deposits, volcanic products and Tertiary sedimentary rocks (limestone, etc.). The characteristics of the main soil groups are described below.
- Alluvial soil is characterized by a clayey/silty loam texture and distributed narrowly on lowland and plains, especially along the Brantas River. The soil, high productive for agricultural production, is mainly under rice cultivation.
- Andosols and Alfisols, of volcanic product origin, are distributed on the slopes of volcanoes, such as Mt. Mt. Semeru, Mt. Wilis, Mt. Kelud, Mt. Kawai. These soils, especially derived from volcanic ash, are susceptible to erosion.
- Mollisols developed on the area Tertiary formation rocks, which are mostly limestone and volcanic rocks, distributed in the southern mountainous area of the Brantas River. Because of its low productive, the lands of this soil are not intensively cultivated. Accordingly, sediment discharge ratio is also estimated to be lower than those of the soils of volcanic product origin mentioned above.

(The maps are established in 2000, based on the new soil classifications, i.e. Soil Taxonomy of USDA; United States Department of Agriculture.)

2.5 GEOLOGICAL CONDITION OF EACH DAM CATCHMENT AREA:
RESULTS OF SITE RECONNAISSANCE

(1) GENERAL

The damsites selected in this study are the Sutami dam and Wlingi dam from the upstream as shown in Figure 2.5-1. Accordingly, considering the dam reservoir sedimentation, the site reconnaissance on the Brantas River basin was performed for the Brantas River and its tributaries as follows:

Sutami dam and Sengguruh dam: Brantas River, Lesti River, Juog River, Genteng River and Metro River.

Wlingi dam: Lekso River and Jari River.

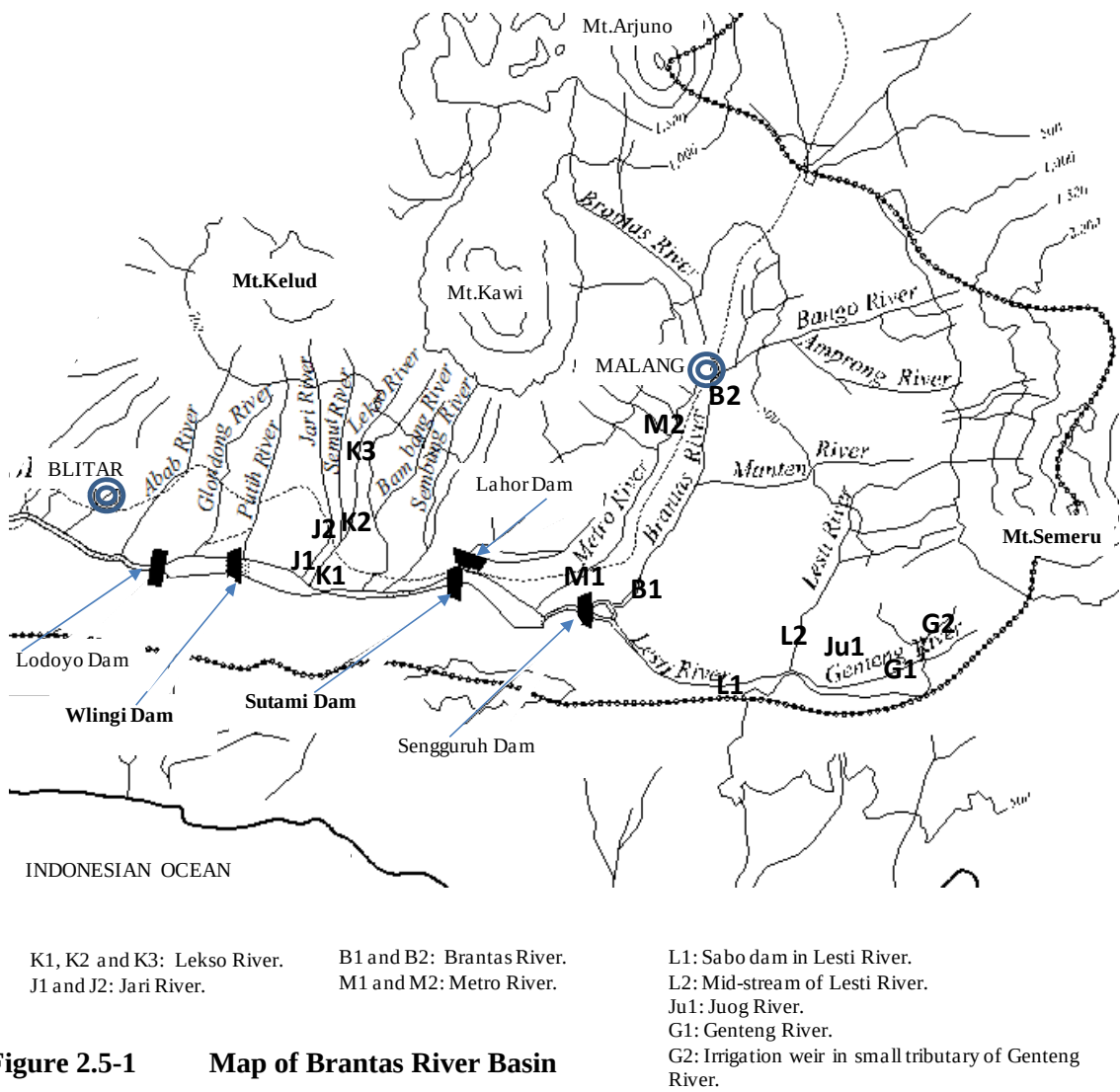


Figure 2.5-1 Map of Brantas River Basin

Each location of the rivers and dam sites are shown in Figure 2.5-1, in which the locations of photographs taken during the reconnaissance are also shown.

(2) SUTAMI DAM AND SENGGURUH DAM

The Brantas River in the section between the Sengguruh dam and Sutami dam flows in the northern margin area of the Southern Mountains Zone as shown in Figure 2.5-1. The zone shows mountainous topography, consists of Tertiary Oligocene – Miocene volcanic sedimentary rocks, such as volcanic sedimentary rocks, sandstone, siltstone, limestone.

The damsites and these dam reservoirs are also located in the area consists of Tertiary rock formations. However, the Brantas river basin, i.e. upstream catchment areas of these dams and reservoirs, are mostly located in the “Central Volcanic Zone” area, which consists of Quaternary Pleistocene to Holocene volcanic products, such as ash fall deposits, laharic deposit, lava, originated from Mt.Arjuno, Mt.Kawi and Mt.Semeru.

Mt.Arjuno and Mt.Kawi show very low volcanic activity in Recent age, however, Mt.Semeru is continuously erupted in Recent, and now also almost every years. The eruptions of Mt.Semeru are mainly volcanic ash falls, and sometimes pyroclastic flows / mud-flows, which are seen mostly on the southeastern slope of the mountain (outside of the Brantas River basin) flowing toward the Indian Ocean.

The rivers are the Brantas River, Lesti River, Juog River, Genteng River and Metro River, as shown in Figure 2.5-1. All these rivers flow into the Sengguruh dam reservoir, except the Metro River. Accordingly, sediments discharged from these rivers are all trapped by the Sengguruh dam, and those do not flow directly into the Sutami dam reservoir. Only the Metro River flows into the Sutami dam reservoir.

The condition observed during the field reconnaissance is as follows:

a. Brantas River: Refer to photographs B1 and B2.

This river has very deep gorge in the lower to middle reaches, i.e. section between the Sengguruh dam and the Malang city, in which both banks are very steep in general. The riverbed seems to be generally Tertiary rock formations or lava flows of Tertiary to Quaternary. The both bank steep slopes consist of Quaternary volcanic products, such as volcanic ash layers, laharic deposit layers, which are unconsolidated or semi consolidated layers. In the Malan city, such condition can be well seen.

The sedimentation on the riverbed seems to be very rare in the section mentioned above of the Brantas river.

b. Lesti River, Juog River and Genteng River: Refer to photographs L1, L2, J1, G1 and G2.

In the Lower reaches of the Lesti River, new sabo-dam is located (refer to Photograph L1). The

dam reservoir is now almost full by fine materials, such as sand, silt, clay. Such sedimentations of fine materials are also seen on the riverbeds of the middle reaches of the Lesti River and the Juog River, which is a small tributary of the Genteng River, in general. However, the sedimentation on the riverbed seems to be less in the upper reaches of the Genteng River. The sedimentations of fine materials seem to be mostly originated from the slope of Mt.Semeru.

c. Metro River: Refer to photographs M1 and M2.

The condition is very similar to those of the Brantas River.

CONSIDERATION ON THE SEDIMENTATION OF THE SENGURUH DAM AND SUTAMI DAM:

From the geological point of view, the following matters can be said:

- The Brantas River between the Sunggulh dam and the Sutami dam flows in the northern margin of the Southern Mountains Zone area as shown in Figure 2.2-1. The area of the zone shows mountainous topography, consists of Tertiary Oligocene – Miocene volcanic rocks and sedimentary rocks. These rocks are soft to medium hard, and considered generally that the sediment discharge ratio is not so high. The tributaries of the Brantas River distributed in the Southern Mountains Zone area are very minor length compared to others. Accordingly, it is estimated that no large amount of sedimentation occurs from this area for these dams.
- The main source area of the sedimentations in both dams is estimated to be the “Central Volcanic Zone” area, which consists of mostly Quaternary Pleistocene to Holocene volcanic products, such as laharic deposits, volcanic ash fall deposits, as shown in Figure 2.5-1. Furthermore, in the Central Volcanic Zone area, many rivers, such as the Mario River, Brantas River, Lesti River, Genteng River, are flowing. Accordingly, it is estimated that the area has rather high sediment discharge ratio in general.
- Mt.Semeru, which is located in the eastern boundary of the Brantas River basin, is one of the most active volcano. Even though Mt.Semeru is continuously erupted now, the mountain slopes in the Brantas River basin seems to be stable condition in general. Because, in recent, only ash falls are seen in this basin area, and pyroclastic flows can be seen only in the southeastern slope of the mountain.
- Rather large amount of sedimentations, which are mostly fine materials, such as sand, silt, clay, are seen in the Sengguruh dam reservoir. Such fine materials can be seen more along the Lesti River, Genteng River and Juog River than the Brantas River and Metro River. However, during a heavy rain, it is estimated that all rivers can bring the fine materials to the dam reservoirs in the forms of wash and suspended loads. It can be estimated that the fine materials originate mostly from surface soil layers, such as vegetable fields, housing lands.

- The surface soil layers, which consist of rather old, highly weathered and semi consolidated volcanic origin (probably ash falls) soil layers, are widely seen on the south – eastern slopes of Mt.Kawi and Mt.Arjuno. The Brantas River and Metro River flows in this area.
- The west – southwest slopes of Mt.Semeru may be covered by new ash fall deposits, which is fresh, rather coarse and very low consolidated. The Genteng River, Juog River and Lesti River flow in this area.
- A critical landslide related to sedimentations of the dam reservoirs is not reported and not found in this study in the catchment areas and in the dam reservoir areas also. However, because of hilly / mountainous topography, small scale surface slope failures are commonly found in the catchment areas consists of volcanic products, and even in the Tertiary rock areas. Such small scale slope failures will also produce sediments of the dam reservoirs.

(3) WLINGI DAM

The damsite and its dam reservoir are located in the area consists of Tertiary rock formation, such as volcanic sedimentary rocks, sandstone, siltstone, limestone. However, the tributaries of the Brantas River, such as the Lekso River, Jari River, are located on the southern slope of Mt.Kelud. The slope is mostly covered by very recent thick Quaternary volcanic products, such as ash fall deposits, laharic deposits, lava, of Mt.Kelud.

Mt.Kelud shows very high volcanic activity in Recent age and now also. The eruption of Mt.Kelud is mainly volcanic ash falls and pyroclastic flows / mud-flows. After Mt.Kelud eruptions, laharic flows occur generally during heavy rains along the tributaries such as the Lekso River, Jari River. Such laharic flows reach to the Brantas River and into the Wlingi dam reservoir directly.

The condition of the Lekso River and Jari River observed during the reconnaissance is as follows:

a. Lekso River: Refer to photographs (3) A1 and B2.

The Lekso River is flowing on the volcanic ash fall deposits and laharic deposits, which seem to be very thick, originated from very recent eruption of Mt.Kelud. The ash fall deposit and laharic deposit layers are seen on both banks of the Lekso River. The riverbed deposits, consisting of sand, gravel and some boulder, are rather coarse compared to those of the upper reaches of the Brantas River and its tributaries, such as Lekso River, Genteng River.

Because of existence of such coarse materials on the riverbed, local people are doing sand mining for constructions in the middle reaches of the Lekso River.

b. Jari River: Refer to photographs (3) A1 and B2.

The river condition is very similar to those of the Lekso River.

CONSIDERATION ON THE SEDIMENTATION OF THE WLINGI DAM:

From the geological point of view, the following matters can be said:

- As mentioned in the explanation for the Sengguruh dam and Sutami dam, the main source area of the sedimentations in the dam reservoir is estimated to be the “Central Volcanic Zone” area, which consists of mostly Quaternary Pleistocene to Holocene volcanic products, such as laharic deposits, volcanic ash fall deposits.
- The riverbed sediments of the tributaries of the Brantas River, such as Lekso River, Jari River, distributed on the southern slope of Mt.Kelud are coarser materials than those in the upper reaches of the Brantas River and its tributaries, such as Lesti River, Genteng River, because of Mt.Kelud eruptions. Mt.Kelud is very active in very recent age and now also. The volcanic products from Mt.Kelud are pyroclastic flow and ash fall.
- After the eruptions of Mt.Kelud, lahars (volcanic mud flows) occur and flow during heavy rain along the existing rivers such as Lekso River, Jari River. Because of such eruption of Mt.Kelud in the recent time, the Wlingi dam reservoir has been almost filled by sediments.
- Consequently, the most critical sediment discharges for the Wlingi dam reservoir is estimated to be the materials discharged from the tributaries of the Brantas River, such as Lekso River, Jari River, distributed on the southern slope of Mt.Kelud.
- Consequently, the most critical sediment discharges for the Wlingi dam reservoir is estimated to be the materials discharged from the tributaries of the Brantas River, such as Lekso River, Jari River, distributed on the southern slope of Mt.Kelud.
- The southern mountainous area of the Wlingi dam reservoir consists of Tertiary volcanic / sedimentary rock formations of the Southern Mountains Zone. Because of very short tributaries of the Brantas River distributed in this area and the geological condition mentioned above, the sediment discharge ratio in such area is estimated to be very low in general.
- The sediments discharged from the upstream of the Brantas River are also estimated to be very minor volume because of existences of the Sutami dam and Sengguruh dam in the upstream of the Wlingi dam.
- A critical landslide related to sedimentations to the dam reservoir is not reported and not found in this study in the catchment areas and in the dam reservoir area during the field reconnaissance study. However, because of hilly / mountainous topography, small scale surface slope failures are commonly found in the catchment areas consist of volcanic products, and even in the Tertiary rock area. Such small scale slope failures will also produce sediments of the dam reservoir.

PHOTOGRAPHS – 1: SENGGURUH DAM, SUTAMI DAM AND WLINGI DAM**(1) Upstream of the Sengguruh Dam**

- A. Brantas River: B1 and B2
- B. Lesti River: L1 and L2
- C. Juog River: J1
- D. Genteng River: G1 and G2

(2) Section between Sutami dam and Sengguruh Dam

- A. Metro River: M1 and M2

(3) Wlingi Dam

- A. Lekso River: K1, K2 and K3
- B. Jari River: J1 and J2

			
Brantas River : B1 The Brantas River (just upstream of the Sengguruh dam). No sedimentation on the riverbed is seen.		Brantas River : B2 The Brantas River in Malang city. No sedimentation on the riverbed is seen.	
			
Lesti River : L1 New Sabo-dam in the lower reaches of the Lesti River.		Lesti River : L1 Just upstream of the new Sabo-dam. The dam reservoir is filled by fine materials, such as sand, silt, clay.	
			
Lesti River : L1 Sedimentation on the riverbed is mostly fine materials. No coarse material, such as gravel, boulders, is seen.		Lesti River : L1 Outcrop of terrace deposits on the right abutment of the Sabo-dam. The deposit consists of mainly sand and silt, with fine to coarse gravel.	
Project Name:		Brantas River Basin	
Study for Rehabilitation of Hydropower Stations in Indonesia			JICA NK

			
Lesti River : L2 Middle reaches of the Lesti River. Upstream of the small weir, which is seen under the bridge as shown photograph below, is filled by fine materials, such as sand, silt, clay.		Lesti River : L2 Small weir in the middle reaches of the Lesti River. Sedimentation on the riverbed just downstream of the weir is very rare.	
			
Juog River : J1 The Juog River, which is small tributary of the Genteng River. Sedimentation, such as sand, silt, is seen on the riverbed. Local people are gathering sand for constructions		Juog River : J1 This is the same place as the left	
			
Genteng River : G1 Middle reaches of the Genteng River. Sedimentation on the riverbed is very rare		Genteng River : G1 Middle reaches of the Genteng River. This is the same location as above. Sedimentation on the river bed is very rare	
Project Name:		Brantas River Basin	
Study for Rehabilitation of Hydropower Stations in Indonesia		JICA NK	

	
Genteng River : G1 Middle reaches of the Genteng River. A pile of garbage is found on the right bank slope beside of the public road	Genteng River : G1 A irrigation weir in the small tributary of the Genteng River. The weir has been broken, and the reservoir is now completely filled by fine materials, which are now utilized as paddy / sugarcane field as shown in above
	
Metro River : M1 Lower reaches of the Metro River.	Metro River : M1 Lower reaches of the Metro River. This is the same location as above. Sedimentation on the riverbed seems to be very rare
	
Metro River : M2 Middle reaches of the Metro River. Small irrigation weir is located near Malan city	Metro River : M2 Local people are gathering sand for constructions in the upstream of the weir. Sedimentation, mostly sand, on the riverbed is seen
Site:	Brantas River Basin
Study for Rehabilitation of Hydropower Stations in Indonesia	
JICA NK	

	
Metro River : M2 Downstream of the weir. The Metro river is flowing on the laharic deposits. Both banks and riverbed consist of the laharic deposits. Therefore, some boulders can be found on the riverbed, and both banks	Lekso River : K1 Lower reaches of the Lekso River. Sedimentation, which consists of mainly sand and silt with gravel and boulder, is seen on the riverbed
	
Lekso River : K2 Sabo-dam near the main public road and railway. The Lekso River flows on the laharic deposits and volcanic ash deposits, which are seen on both banks. Riverbed deposit in the section just downstream of the dam is very rare	Lekso River : K2 Sedimentation in the Sabo-dam reservoir. The sediments consist of mainly sand, silt, gravel and some boulders originated from the laharic deposits, which are widely developed on the slope of Mt.Kelud
	
Lekso River : K3 Small irrigation weir (sabo-dam ?) in the upper reaches of the Lekso River	Lekso River : K3 Downstream of the weir. Many boulders, which originated from the laharic deposits, are seen.
Project Name:	
	JICA NK

	
Lekso River : K3 Upstream of the weir. The reservoir is completely filled by sedimentation, which consists of sand, gravel and some boulders. Local people are gathering sand for construction works	Lekso River : K3 Upstream of the weir. Both banks consist of very recent laharic deposits. The riverbed is covered by deposits, which consist of mainly sand, gravel and boulders. Sand production for constructions is seen on the riverbed
	
Jari River : J1 Lower reaches of the Jari River. Riverbed deposits are sand, gravel and some boulders, which are originated from laharic deposits	Jari River : J2 Middle reaches of the Jari River. Riverbed deposits are the same as those of the lower reaches above
Project Name:	
	JICA NK

3. SOEDIRMAN (MRICA) DAM: SURAYU RIVER BASIN

3.1 REGIONAL GEOLOGY

The Soedirman (Mrica) dam and its reservoir are located in the middle reaches of the Serayu River, near the Banjarnegara Town in the Central Jawa. The Serayu River originates in the area of “Central Volcanic Zone”, in which Quaternary volcanoes, such as Dien Plateau, Mt.Sindoro, Mt.Sumbing, are located.

Main tributaries of the Serayu River in the upstream area of the Soedirman (Mrica) dam are the Merawu River, Begaluh River and Tulis River (refer to Figure 3.3-1).



Figure 3.2-1 Geological Setting of Central Jawa and Location of Serayu River Basin
(Geological Map of Middle Part of Jawa, 1/500,000)

The geological setting of the central Jawa and the location of Serayu River basin are shown in Figure 3.2-1. According to “Geological Map of Middle Part of Jawa (1 / 500,000 scale, 1999)”, the Surayu River basin is mostly located in the Central Volcanic Zone and Southern Jawa Mountain Zone, and partly in the Bogor Zone. Geological condition of each zone is summarized as follows:

Central Volcanic Zone: This zone, which is seen widely in the eastern Jawa also, is generally so called as “Late Cenozoic Volcanic Arc” or “Present-day Volcanic Arc”. The zone consists of mostly Quaternary Pleistocene to Holocene volcanic products, such as volcanic breccias, lava, tuff, tuff breccias, laharic deposit, volcanic ash fall deposit. Many volcanoes, such as Mt.Slamet (El.3,426 m), Dien Plateau, Mt.Sindoro (3,145 m), Mt.Sumbing (3,360 m), Mt.Merapi (2,912 m), Mt.Merbabu (3,116 m), are located in the zone from west to east. Among them, Mt.Slamet and Mt.Merapi are well known as active volcano in the twentieth (20th) century.

The geological structures in this zone are dominantly effected by Quaternary volcanic activities.

Southern Mountains Zone: This zone, which is also seen in the eastern Jawa, consists of Tertiary Oligocene - Miocene volcanic / sedimentary rocks, such as lava, volcanic breccias, tuff, sandstone, siltstone, claystone, conglomerate, limestone, and Miocene – Pliocene limestone. Miocene intrusives, such as andesite, dacite, basalt, diorite, are sporadically found. Quaternary Pleistocene volcanic deposits and Alluvial deposits are seen along the Surayu River and along the Indian ocean coast.

Rather short normal faults of northwest – southeast or southwest – northeast trending which cut to each other are developed in this zone.

Bogor Zone: This zone consists of Tertiary Miocene to Pliocene volcanic / sedimentary rocks, such as lava, volcanic breccias, tuff, conglomerate, limestone, sandstone, siltstone, claystone. Pliocene intrusive rock of diorite is found sporadically in the zone.

Long and continuous thrust faults, dipping toward northeast and trending northwest – southeast, are seen in the zone.

3.2 SOIL DISTRIBUTION

According to the soil distribution map prepared by the Central Soil Research Institute of Bogor in 2000, the soil distribution conditions in the catchment areas of the Soedirman (Mrica) dam are summarized as below:

- The soils of the catchment areas can be classified into three (3) groups considering parent materials, i.e. Alluvial deposits, volcanic products and Tertiary sedimentary rocks (limestone, etc.). The characteristics of the main soil groups are described below.
- Alluvial soil is characterized by a clayey/silty loam texture and distributed narrowly on lowland and plains, especially along the Surayu River. The soil, high productive for agricultural production, is mainly under rice cultivation.
- Andosols, of volcanic product origin, are distributed on the slopes of volcanoes, such as Dien Plateau, Mt.Sindoro, Mt.Sumbing. These soils, especially derived from volcanic ash, are susceptible to erosion.
- Inceptisols and Ultisols, developed on the area Tertiary formation rocks, which are mostly volcanic rocks and sedimentary rocks, developed in the southern area of the Surayu River, and lower reaches of the Merawu River and Tulis River. Because of steep / rocky topography and containing acidic minerals, the lands of this soil are not intensively cultivated, used generally for tree crop. Accordingly, sediment discharge ratio is also estimated to be generally lower than those of the soils of volcanic product origin.

(The maps are established in 2000, based on the new soil classifications, i.e. Soil Taxonomy of USAD; United States Department of Agriculture.)

3.3 GEOLOGICAL CONDITION OF SOEDIRMAN (MRICA) DAM CATCHMENT AREA: RESULTS OF SITE RECONNAISSANCE

The site reconnaissance was performed along the Surayu River and main tributaries, i.e. the Merawu River and Tulis River, except the Begaluh River, for the purpose of examination of dam reservoir sedimentation.

The southern area of the dam and reservoir consists of Southern Mountains Zone, consists of Tertiary Oligocene - Miocene volcanic / sedimentary rocks. Such rocks are soft to medium hard, and have not so high sediment discharge ratio in general. The tributaries distributed in this area are very minor length. Accordingly, it is estimated that no large amount of sedimentation occurs from this area for the dam reservoir.

(1) SERAYU RIVER

The Surayu River originates from the eastern slope of the Dien Plateau, and western slopes of Mt.Sindoro (3,145 m) and Mt.Sumbing (3,360 m). The Begaluh River is one of the tributary of the Serayu River, also originates from the eastern slope of Mt.Sumbing. Those mountain slopes are mostly covered by thick Quaternary Pleistocene volcanic products, such as ash fall deposits, pyroclastic flows, laharic deposits.

The damsite and dam reservoir area are located in the area of Tertiary Miocene to Pliocene rock formations, i.e. Southern Mountains Zone, consists of volcanic / sedimentary rocks, and partly covered by Quaternary Pleistocene volcanic products. The upstream area of the dam reservoir is widely covered by thick Quaternary volcanic products of Dien Plateau, Mt.Sindoro and Mt.Sumbing, such as volcanic ash fall deposit layers, laharic deposits.

The riverbed deposits of the Surayu River consist of sand, gravel and boulders of such volcanic product layers. Both banks of the river are also formed by such layers. The Garung hydropower station is located in the upper reaches of the river (refer to Photograph S4). The riverbed near the powerhouse is covered mostly by large rock blocks and boulders.

(2) MERAWU RIVER

The Merawu River originates from the southwest slope of the Dien Plateau of Quaternary volcanic mountain.

The confluence between the Surayu River and Merawu River is near the upstream end (back-water) of the Soedirman (Mrica) dam reservoir. The lower reaches of the river flows in the area of "Bogor Zone" in Figure 3.2-1, consists of Tertiary Miocene to Pliocene volcanic / sedimentary rocks. The middle to upper reaches of the Merawu River is flowing on the slope covered by thick Quaternary volcanic products layers, such as volcanic ash fall deposits, laharic deposits.

The area, which is mountainous to hilly land, in the surrounding of the Karangobar, Pejawaran and

Batur villages, is cultivated widely, producing many kinds of crops, such as potato, vegetables, corn.

The riverbed deposits consist of mainly sand, gravel and boulders in middle to upper reaches, however, those seems to be finer materials such as silt, sand, gravel and some boulders in lower reaches. Fine materials, such as silt, clay, seem to be much more in the dam reservoir sediments than those of the middle to upper reaches riverbed deposits.

An irrigation weir exists in the lower reaches just upstream of the public road (refer to Photographs M1). The riverbeds in both upstream and downstream are covered by sand, gravel and many boulders. Local people are gathering sand manually for construction materials in an irrigation channel running from the weir to the downstream.

According to “Journal of Applied Sciences in Environmental Sanitation, 3(1): 17-24 (Refer to References), landslides due to very heavy rain in Desa Kabunan (1999) and Desa Sijeruk (January 4th, 2006) in Kecamatan Banjuamangu, Kabupaten Banjarnegara are reported in the right bank mountainous area of the middle to lower reaches (refer to Photograph M3).

Because that the landslide in Desa Kaburan has been occurred on the right bank slope of the Merawu River, which consists of weathered rocks of “Bogor Zone”. The river bank slope close to the river is generally very steep in the area near Desa Kaburan.

The landslide in Desa Sijeruk is summarized as follows:

- The landslide is located in the area about El.800 m – El.900 m, about 2.5 km west from the Merawu River, and about 1 km west from the public road, in the eastern side of Mt.Pawinihan (El. 1,244 m). There is small village, namely Gunungraja, which was damaged by the landslide. The slope from the village to the Merawu River is rather gentle. However, the slope just west of the village is very steep, showing 30° to 45° from horizontal. The landslide has occurred on the steep slope just west of the village.
- The steep slope is mostly covered by forests. According to the photographs of the landslide area in “Analysis Landsline Hazard in Banjarnegara Sub District, Banjarnegara District” (refer to REFERENCES), it is estimated that; (1) The slope failure width and height are approximately 50 m to 100 m for each, and (2) the failure is very typical surface shallow sliding, which means that, the slope failure has occurred in decomposed rock zone (residual soil zone), may be several meters in depth. Accordingly, the landslide debris also consists mostly of fine materials, such as clay, silt, sand, and gravel.

The Desa Sijeruk area is estimated to be located in “Bogor Zone” area. According to the geological map (1/500,000 scale), thrust faults exist in “Bogor Zone”. Existence of the thrust faults may probably be related with such landslide activity, because the thrust faults have generally very wide and large scale fault fractured zones.

The steep slopes of Mt. Pawinihan are covered mostly by forest, and seem to be stable condition at present. Although the landslide scale mentioned above is large, the location is rather far from the Merawu River. Therefore, it had not so strong and critical effectiveness for the sedimentation of the dam reservoir. However, those fine materials in the debris produced by landslides will also flow into the dam reservoir, when such landslides will again occur in future.

(3) TULIS RIVER

The condition of the Tulis River seems to be very similar to those of the Merawu River. As mentioned above, the lower reaches of the river flow in the area of “Bogor Zone” in Figure 3.2-1, consists of Tertiary Miocene to Pliocene volcanic / sedimentary rocks. This area of “Bogor Zone” seems to be more mountainous than the area of the upper reaches, which consists of Quaternary volcanic products. Accordingly, the river of the lower reaches shows narrow gorge, and population and vegetable fields in this area seems to be less than the area of the upper reaches.

As shown in photograph T1, Small intake dam of PLTA (Indonesia Power) exists in the lower reaches. The weir has four (4) large gates for the purpose of drainage of sediments in the reservoir. Accordingly, no sedimentation can be observed at present in the reservoir.

The riverbed deposits are also very similar condition to those of the Merawu River.

(4) LAND USE IN SURROUNDING AREA OF BATUR VILLAGE

The area is located in a highland, altitude of 1,000 m to 2,000 m, of southern slope of the Dien Plateau. The slopes in the surrounding area of the villages are cultivated widely until the top of the hills, as shown in Photographs B1 and B2. The slopes are mostly covered by dry fields of potato, maize, and vegetables. A paddy field is very rarely seen in this area along small creeks.

CONSIDERATION ON SEDIMENTATION OF THE SOEDIRMAN (MRICA) DAM:

From the geological point of view, the following matters can be said:

- As mentioned in the Brantas River basin, the main source area of the sedimentations in the Soedirman (Mrica) dam reservoir is estimated to be the “Central Volcanic Zone” area, which consists of mostly Quaternary Pleistocene to Holocene volcanic products, such as laharic deposits, volcanic ash fall deposits (refer to Figure 3.2-1). Furthermore, many rivers, such as the Surayu River, Merawu River, Tulis River, Begaluh River, are flowing in the area. These rivers may have rather high sediment discharge ratio in general.
- The slopes of the upper reaches area of the Surayu River and its tributaries, which are covered by volcanic products, are cultivated widely. The slopes of both banks in the area middle to upper reaches of the Surayu River are mostly covered by paddy field, however, those of the Merawu

River and Tulis river are mostly covered by dry field, such as maize, potato, vegetables. During heavy rain, surface soil erosion may occur widely and rather strongly in the dry field in the Merawu River and Tulis River basins.

- The riverbed sediments, even in the lower reaches of the Surayu River and its tributaries, are mostly coarser materials than those in the Soedirman (Mrica) dam reservoir observed at present. During heavy rain, much more volumes of finer materials, such as clay, silt, sand, may be discharged to the Soedirman (Mrica) dam reservoir than coarser materials in the form of wash and suspended loads. Consequently, it is estimated that the fine materials originated from surface soil layers is the largest source of the sedimentation in the Soedirman (Mrica) dam reservoir.
- A critical landslide related to sedimentations of the dam reservoir is not reported and not found in the catchment area in this field reconnaissance study. However, because of hilly / mountainous topography, small scale surface slope failures are commonly found in the area consists of volcanic products area, even in Tertiary rock areas. In the catchment area, the landslides in the area of the middle to lower reaches of the Merawu River, such as Sijeruk landslide, are also reported. Such landslides and small scale slope failures will also produce sediments of the dam reservoir.



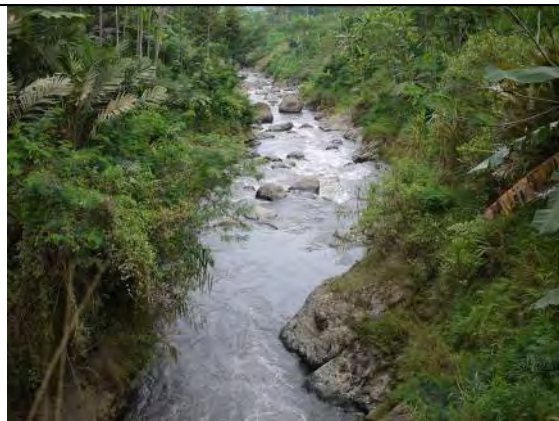
S1, S2 and S3: Surayu River.
 S4: Garung HydroPower Station
 M1, M2 and M3: Merawu River.
 T1: PLTA Tulis Dam in Tulis River.
 B1: Typical land use, such as corn, potato.

Figure 3.3-1 Location Map: Soedirman (Mrica) Dam

PHOTOGRAPHS – 2: SOEDIRMAN (MRICA) DAM

- (1) Soedirman (Mrica) Dam
 - A. Serayu River: S1, S2, S3 and S4
 - B. Merawu River: M1 and M2
 - C. Tulis River: T1
 - D. Land use in the Surrounding area of Batur: B1 and B2

			
Soedirman (Mrica) Dam : S1 Serayu River just upstream of the Mrica dam reservoir. Sedimentation, sand and gravel with boulders, is seen on the riverbed.		Soedirman (Mrica) Dam : S2 Serayu River near the junction with the Tulis River. The riverbed condition, i.e. sedimentation on the riverbed, is the same as that of the left photograph.	
			
Soedirman (Mrica) Dam : S3 Upper reaches of the Serayu River. The riverbed condition seems to be very similar to those of S1 and S2 as shown above.		Soedirman (Mrica) Dam : S4 PLTA Garung Power house. Many boulders are seen on the riverbed.	
			
Merawu River : M1 Lower reaches of the Merawu River. The riverbed is covered by many sand, gravel and boulders		Merawu River : M1 Irrigation weir, located in the upstream of the public road at M1.	
Site	Serayu River Basin		
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Merawu River : M1 Reservoir of the irrigation weir.		Merawu River : M2 Middle reaches of the Merawu River, near Desa Sijeruk, in which landslide has occurred in 2006. Terrace deposits are distributed in both banks. The riverbed is covered by deposits of sand, gravel and boulders. Mountain slopes in this area are mostly covered by forest, and seem to be generally stable at present.	
			
Merawu River : M3 Upper reaches of the Merawu River. The river flows on the laharic deposits. Many boulders are seen on the riverbed.		Tulis River : T1 PLTA Tulis dam	
			
Tulis River : T1 Tulis dam reservoir.		Tulis River : T1 Downstream section of the Tulis dam.	
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Land use in the surrounding area of Batur : B1
The mountain slopes are mostly utilized as dry fields, such as potato, corn, green vegetables.



Land use in the surrounding area of Batur : B1
This photograph is also showing the same condition as the left photograph.

Project Name:	Serayu River Basin	
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		NK

REFERENCES:**Sengguruh Dam, Sutami Dam and Wlingi Dam (Brantas River Basin)**

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Soedirman (Mrica) Dam (Surayu River Basin)

- Geological Map of Middle Part of Jawa (1 / 500,000 scale, 1999).
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ANNEX B

Preliminary Study of Sediment Countermeasure for Soedirman(Mrica)Reservoir(For Reference)

ANNEX B Preliminary Study of Sediment Countermeasure for Soedirman (Mrica) Reservoir (For Reference)

PART A PRELIMINARY STUDY OF SEIMENT BALANCE

BA1. Estimation of Sediment Inflow

BA1.1 Previous Study Results

According to the previous study report of “SEDIMENTATION CONTROL : PART II. INTENSIVE MEASURES THE INSIDE OF THE MRICA RISERVOIR, CENTRAL JAVA” (IMMR), as attached in ANNEX C issued in 2007, average sediment inflow in the Soedirman (Mrica) Reservoir is estimated to be between 4.41MCM/year to 9.71MCM/year. The estimation is based on the observed records, from 1959 to 1981, of the suspended load in the Serayu River basin.

The IMMR concluded that 80% of the gross storage volume of the Mrica Reservoir will be filled with the sediments by 2014, causing slower sediment inflow value of 4.41MCM/year. Also, according to a simple foecast, the reservoir will be fully filled with them by HWL in 2021.

BA1.2 Estimation of Sediment Inflow Based on Historical Records

(1) Objective of the Estimation

The objective of the estimation is to validate the above estimated sediment inflow volume based on the historical record of the trapped sediment (sedimentation) in the Mrica Reservoir so as to formulate the sediment balance study.

(2) Trapping Efficiency Formula

Trapping efficiency is defined as the ratio of the trapped sediment (sedimentation) volume to sediment inflow volume.

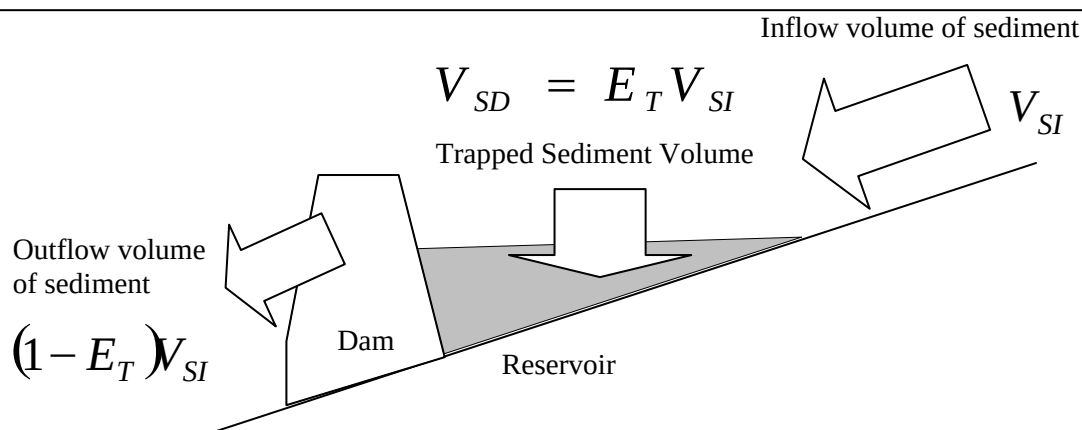
$$E_T = \frac{V_{SD}}{V_{SI}}$$

Where, E_T : Trapping Efficiency (%)

V_{SD} : Trapped Sediment (Sedimentation) Volume in Reservoir

V_{SI} : Sediment Inflow Volume to Reservoir

The diagram of trapping efficiency is illustrated as shown below.



Source : Prepared by JICA Study Team

Figure BA1.1 Diagram of Trapping Efficiency

Generally, the decreasing rate of reservoir storage capacity slows down gradually, while the sediment inflow volume to a reservoir does not change significantly. This process can be understood by taking trapping efficiency into consideration. Some empirical formulas on trapping efficiency were estimated in this study. The ratio of gross storage capacity (C) to annual inflow volume of water to reservoir (I) is used as a parameter (C/I) for the trapping efficiency estimation formulas, which gives the inverse value of turnover rate of the reservoir.

The Brune's formula, as shown in "Handbook of Applied Hydrology" by Ven Te Chow, is generally used to estimate the trapping efficiency of dams. The Brune's middle curve has been applied for this sediment balance study of the subject reservoirs.

The employed Brune's middle curve formula is as follows:

$$E_T = \frac{(C/I)}{\{0.012 + 1.02(C/I)\}}$$

Where, E_T : Trapping Efficiency

C: Gross Storage Capacity (MCM)

I: Annual Volume of Water Inflow to Reservoir (MCM)

(3) Estimation of Annual Sediment Inflow in Mrica Reservoir

Based on the observed record of gross storage volume and annual inflow record for the Mrica Reservoir, an average annual sediment inflow of 5.6 MCM/year is estimated. According to the previous study, the range of the sediment inflow is between 4.41 MCM/year to 9.71 MCM/year. Hence, the estimated sediment inflow of 5.6 MCM/year may be appropriate.

Table BA1.1 Estimation of Annual Sediment Inflow Volume

Year	A .Gross Storage Volume (MCM)	B. Annual Inflow (MCM)	C .Inflow Capacity Ratio	D. Trapped Sediment Volume (MCM)	E. Trapping Efficiency (%)	F. Sediment Inflow (MCM)
	Observed Record	Observed Record	A./B.	A. Prev. Yr's Rec. - A. Target Year's	C./ (0.012+1.02*C)	D./E.
1988	148.20					
		2,341.6		3.30		
1989	144.90					
		2,293.0	0.063	3.44	82.7%	4.16
1990	141.46					
		2,124.8	0.067	6.06	83.3%	7.27
1991	135.40					
		2,657.5	0.051	3.74	79.6%	4.70
1992	131.66					
		2,712.9	0.049	3.49	78.9%	4.42
1993	128.17					
		2,065.4	0.062	3.47	82.4%	4.21
1994	124.70					
		2,335.8	0.053	4.94	80.3%	6.15
1995	119.76					
		2,691.9	0.044	4.60	77.5%	5.93
1996	115.16					
		1,883.4	0.061	2.18	82.2%	2.65
1997	112.98					
		2,530.4	0.045	6.08	77.6%	7.84
1998	106.90					
		2,845.3	0.038	4.50	74.7%	6.03
1999	102.40					
		2,611.2	0.039	6.98	75.4%	9.26
2000	95.42					
		2,964.2	0.032	3.38	71.8%	4.71
2001	92.04					
		1,992.2	0.046	3.53	78.1%	4.52
2002	88.51					
		2,055.2	0.043	4.43	77.0%	5.75
2003	84.08					
		2,092.5	0.040	2.89	75.8%	3.81
2004	81.19					
		2,268.7	0.036	4.64	73.8%	6.28
2005	76.55					
		2,234.0	0.034	3.99	73.0%	5.47
2006	72.56					
		1,813.7	0.040	4.77	75.8%	6.30
2007	67.79					
		2,113.2	0.032	3.30	71.7%	4.60
2008	64.49					
		2,568.7	0.025	4.76	66.8%	7.13
2009	59.73					
Average		2,342.70		4.26		5.56

Source : Prepared by JICA Study Team

BA1.3 Preliminary Study of Sediment Balance

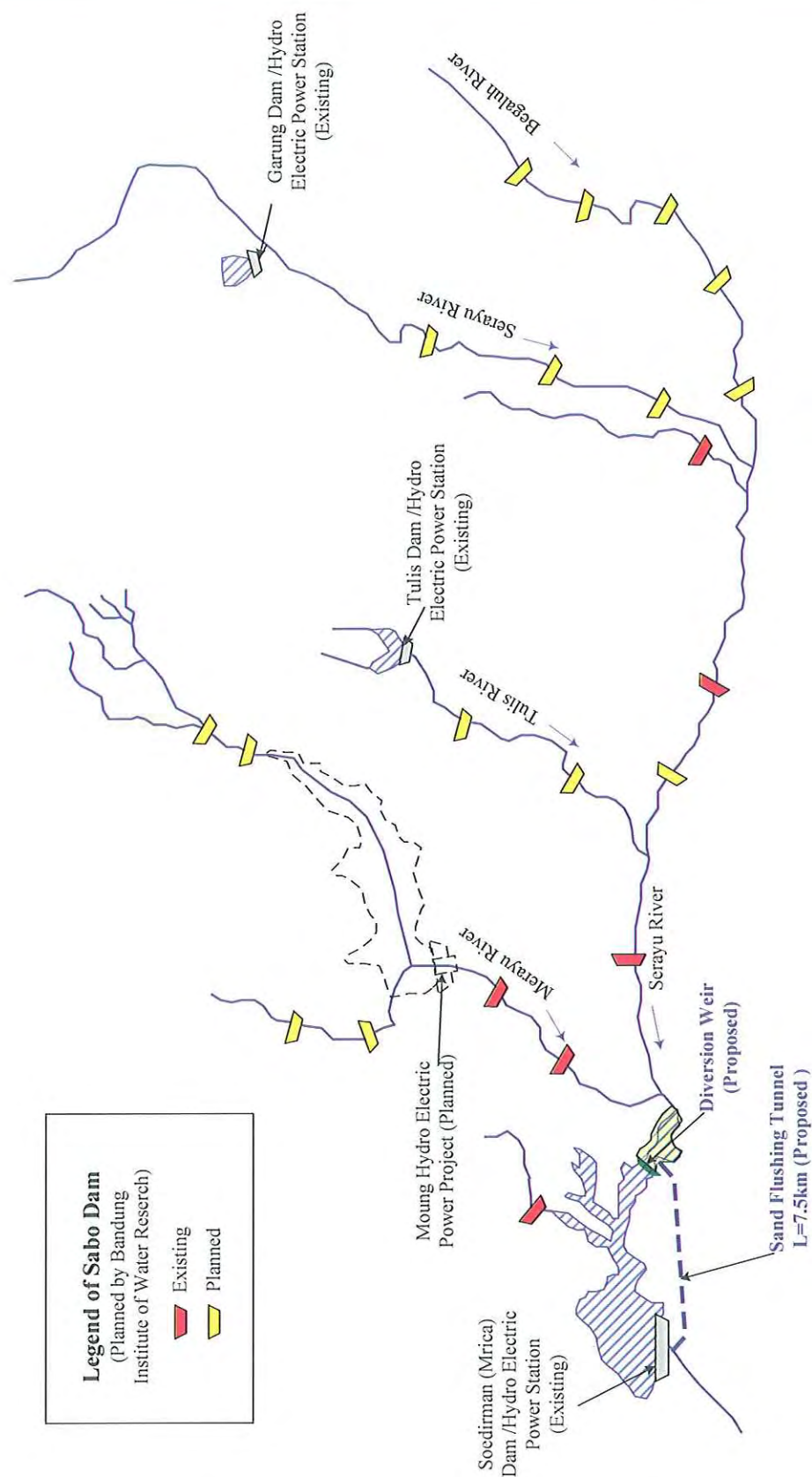
(1) Watershed Sediment Management Plan in the Serayu River Basin

Based on the preliminary study for the watershed sediment management plan in the Serayu River basin, which includes sediment countermeasure in the Mrica reservoir described in Chapter 4.2 of the main report, the following management plan is proposed. General layout plan of the sediment management plan in the Serayu River basin is as shown in Figure BA1.2 and BA1.3.

Table BA1.2 Watershed Sediment Management Plan in the Serayu River Basin

Area	Target of the Sediment Management	Countermeasures to be Implemented / Operation and Maintenance
Up-stream Basin Area	Trapping bed load Reduction of sediment inflow	<u>Sabo dams construction</u> and the maintenance Revival of forest River basin conservation countermeasure
Reservoir Area	Passing of the sediment inflow Recovery of the reservoir storage volume	<u>Construction of sediment bypass tunnel</u> and the appropriate operation and maintenance <u>Execution of dredging in the reservoir</u> and appropriate disposal of the dredged material
Down-stream Basin Area	Improvement of sediment balance Minimizing negative impact in the downstream area and maximizing the positive impact in the whole area	<u>Execution of the environmental monitoring</u> Execution of sustainable sediment monitoring by PDCA cycle

Source: Prepared by JICA Study Team



Source : Prepared by JICA Study based on location map provided by IP

Figure BA1.2 General Layout of Watershed Sediment Management Plan in the Serayu River Basin

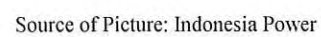


Figure BA1.3 General Layout Plan of Diversion Weir and Sediment Bypass Tunnel

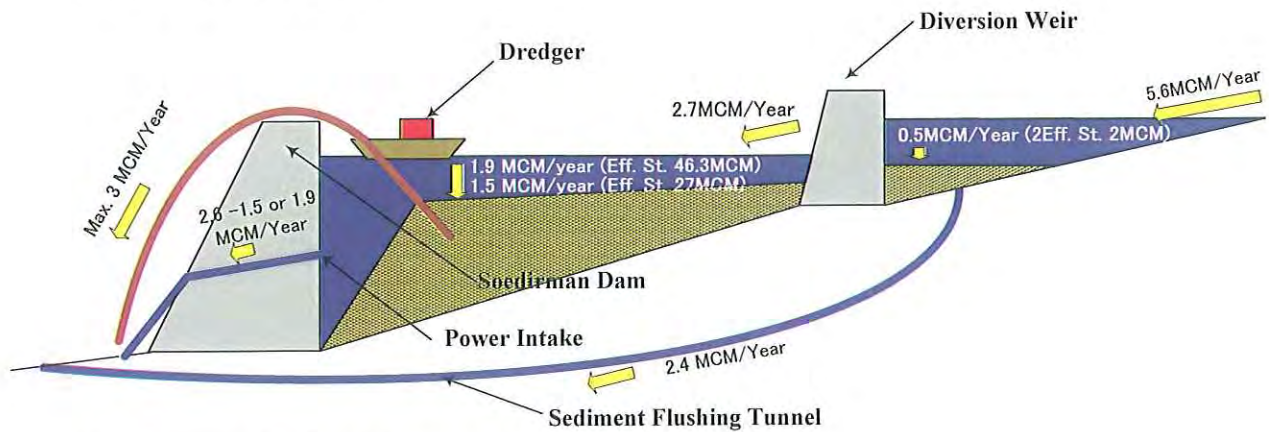
(2) Watershed Sediment Management Plan in the Serayu River Basin

Based on the above watershed sediment management plan, the sediment balance mode has been estimated in this preliminary study with the following assumptions;

- Since prompt effect of afforestation and watershed management will not be expected, sediment reduction by means of the management plan has not been estimated for the sediment balance study.
- The function of the sabo dam is to trap the bed load material which consists of coarse grained materials. Since sediment flushing tunnel can be diverted only suspended load and wash load materials with fine particles, most of the bed load materials should be trapped by the sabo dam structure.
- According to the site survey, the sedimentation in the Mrica Reservoir consists mostly of suspended and the wash load materials. Therefore, volume of the bed load materials is neglected from the sediment balance study.
- Regardless of the above assumption, in order to estimate operation and maintenance cost of the sabo dam facilities, about 5% of the sediment inflow is estimated as the bed load materials, which will be trapped by the sabo dam facilities.
- The function of the diversion weir is to divert muddy water to the sediment bypass tunnel. The pond formed by the weir will be utilized as a sediment settling basin.
- Sediment bypass tunnel will divert the suspended and wash load materials so as to minimize impact to the downstream river channel and prevent scouring of the tunnel lining.
- Sediment trapping efficiency should be applied to the gross storage volume. However, the study aims at recovering effective storage volume of Mrica Reservoir and considering that most of the dead storage volume will be filled with sediment. Therefore, effective storage volume is applied to the sediment efficiency formula in order to estimate sediment trapping volume in the effective storage area.
- Dredging production using 1300PS of bigger capacity of dredger is around 1.0MCM/year/unit. Taking into consideration the reservoir surface area and arrangement of sand transportation pipes, the maximum number of dredgers used at the same time is three. Therefore the annual maximum dredging volume is assumed as 3 MCM/year.
- In order to maintain or increase the effective storage volume of the reservoir, annual sedimentation volume in the Mrica Reservoir should be restricted to less than 3MCM/year.
- Capacity of the sediment bypass tunnel should be determined so as to decrease annual trapping volume of the sediment which is less than 3MCM/year.

(3) Summary of Sediment Balance Model

In accordance with the above management plan and assumptions, sediment balance model has been created by means of the trial and error calculations. Diagram of the sediment balance model is shown in Figure BA1.4.



Source : Prepared by JICA Study Team

Figure BA1.4 Diagram of Sediment Balance Model in the Serayu River Basin

As shown in the above figure, two alternatives are considered. Alternative-1 aims to restore the effective storage volume considered in the original design storage volume which is 46.3 MCM. Alternative-2 meanwhile aims to recover the effective storage volume of up to 27 MCM. As presented in the following discussions, Alternative-2 is selected as a practical option judged from this preliminary study.

Details of the above sediment balance model are described as follows:

(3) Sediment Inflow at Diversion Weir Site

Based on the daily inflow record from 1980 to 2009 at Mrica Reservoir site and water distribution ratio studied by the Indonesia Power(IP), annual inflow at the diversion weir site and stream inflow between the diversion weir and Mrica Reservoir were estimated as follows:

Sediment inflow volume increases in proportion to the squared value of inflow discharge. Therefore, annual sediment inflow from the stream between the diversion weir and the reservoir can be estimated as shown in Table BA1.3

$$Qs_stream = Qs_reservoir \times \left(\frac{qi_stream}{qi_reservoir} \right)^2 = 5.6 \times \left(\frac{4.5}{74.5} \right)^2 = 0.02 MCM$$

The above annual sediment inflow volume is negligible for this sediment balance study.

Table BA1.3 Sediment Inflow at Diversion Weir Site

Site	Annual Inflow $Q_i = \sum q_i (\text{MCM/year})$	Average Inflow $q_i (\text{m}^3/\text{s})$	Annual Sediment Inflow $Q_s = \sum q_s (\text{MCM/year})$
Mrica Reservoir	2,353	74.5	5.6
Diversion Weir site	2,212	70.0	5.6
Stream between Weir and Reservoir	141	4.5	negligible (0.02)

Source : Prepared by JICA Study Team

(4) Trapping Volume at Regulating Pond of the Diversion Weir

Gross storage capacity of the regulating pond of the weir (C) is 2.0 MCM, while annual water inflow volume in the regulating pond (I) is 2,212 MCM. Sediment trapping efficiency can be estimated using Brune's middle curve formula:

$$E_T = \frac{(C/I)}{\{0.012 + 1.02(C/I)\}} = \frac{(2/2,212)}{0.012 + 1.02(2/2,212)} = 9.7\%$$

As described in Table BA1.3, annual sediment inflow volume at the weir site (Q_{s_weir}) is 5.6 MCM/year, while the annual trapped sediment volume can be estimated by considering the computed sediment trapping efficiency.

Annual trapped sediment volume (V_{ts_weir}) = $E_T \times Q_{s_weir} = 0.097 \times 5.6 = 0.5 \text{ MCM/year}$.

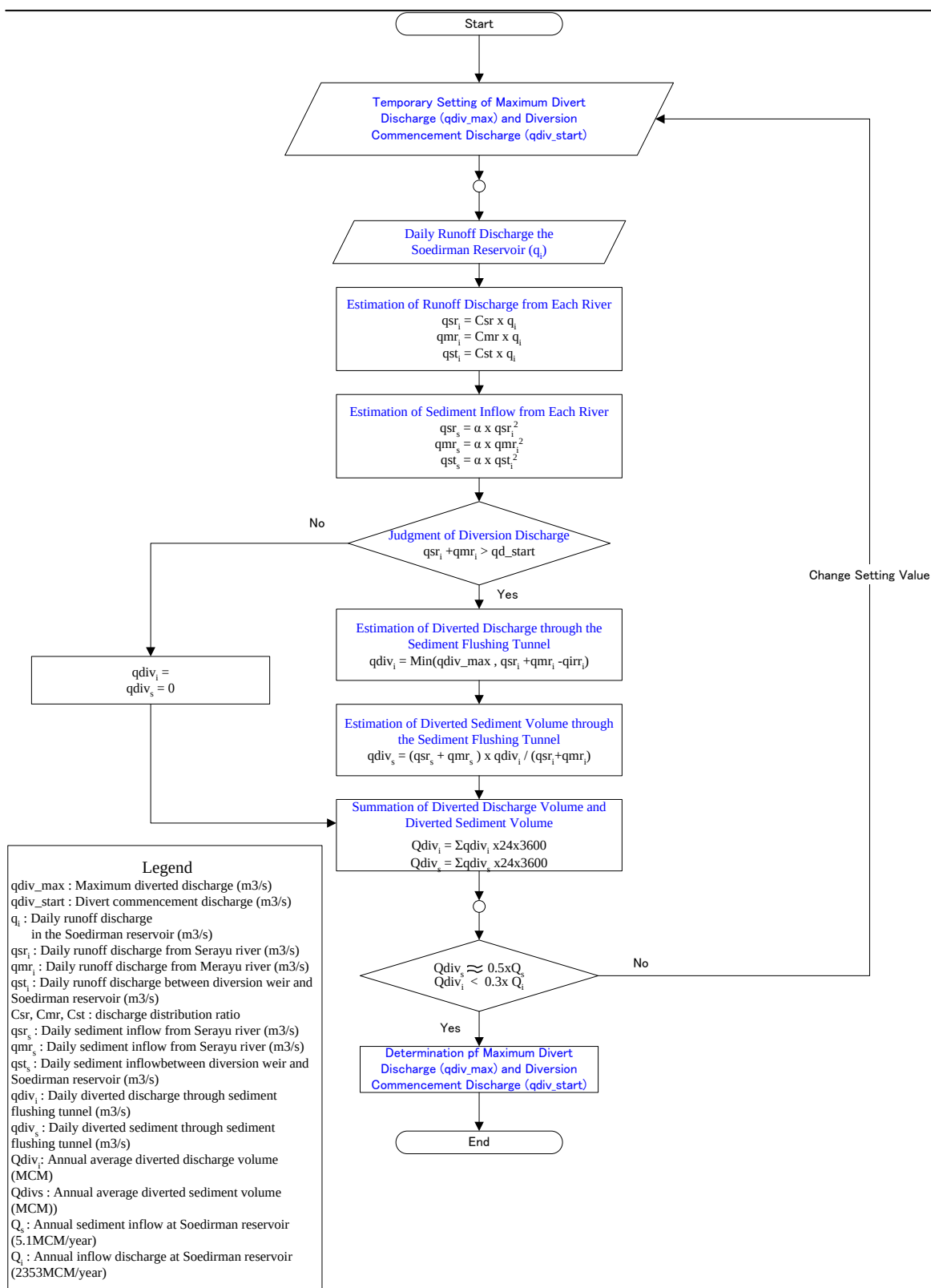
(5) Estimation of Sediment Divert Volume

Annual sediment inflow volume in the diversion weir site is 5.6 MCM/year with 0.5 MCM/year assumed to be trapped in the regulating pond. Therefore, the annual sediment inflow at the sediment bypass tunnel is computed $5.6 - 0.5 = 5.1 \text{ MCM/year}$. Since most of sediment inflow consists of suspended load and wash load, daily sediment inflow volume increases in proportion to the squared value of daily runoff discharge.

$$Q_s = \sum q_s \cdot 60 \times 60 \times 24 \times 365 \div 10^6 = \sum \alpha \cdot q_i^2 \times 31.536$$

Where, Q_s : Annual Sediment Inflow Volume (MCM) (=5.1 MCM)
 q_s : Daily sediment inflow (m^3/s)
 q_i : Daily runoff discharge into the Mrica reservoir (m^3/s)
 α : Sediment content ratio

Based on the daily runoff discharge record from 1989 to 2009, sediment content ratio (α) is estimated at 2.01×10^{-5} . Using the sediment content ratio, capacity of the sediment bypass tunnel and annual diversion volume of the sediment were estimated by trial and error calculations. Procedure for determination the capacity of the sediment bypass tunnel and annual diverted sediment volume is shown in Figure BA1.5.



Source : Prepared by JICA Study Team

Figure BA1.5 Procedure for Determination the Capacity of Sediment Bypass Tunnel

In accordance with the determination procedure shown in Figure BA1.5, capacity of the sediment bypass tunnel and volume of annual diverted sediment were estimated. As described in (2) of this section, required annual dredging volume of the Mrica Reservoir should be less than 3 MCM while the assumed annual trapping efficiency of said Mrica Reservoir is about 60 to 70%. Hence about 40 to 50% of the annual sediment inflow (5.1MCM) should be diverted, determined as follows:

$$((5.1\text{MCM}-0.4\times0.5\text{MCM}) \times 70\% = 2.1\text{MCM} << 3\text{MCM}).$$

However, annual diverted water should be less than 30% of the annual runoff discharge to Mrica Reservoir (2353MCM).

Taking into consideration the above conditions, capacity of the sediment bypass tunnel and commencement discharge of divert operation were determined. Results are summarized below:

Table BA1.4 Summary of Capacity Determination for Sediment bypass Tunnel

Item	Mark	Unit		Note
Annual inflow to reservoir	Q_i	MCM	2,353.4	
Dischagre distribution ratio (Serayu river)	C_{sr}	%	74.5	Report "PELAKASANAAN PENYELIDIKAN SEDIMENTASI WADUK PLTA PB. SOEDIRMAN" November 2009 by Indonesia Power.
Dischagre distribution ratio (Merayu river)	C_{mr}	%	19.5	
Dischagre distribution ratio (Stream between div.weir and resv.)	C_{st}	%	6.0	
Annual inflow form Serayu river	Q_{sr_i}	MCM	1,753.9	
Annual inflow form Merayu river	Q_{mr_i}	MCM	458.3	
Annual inflow from Strem bet. div. and resv.	Q_{st_i}	MCM	141.3	
Sediment Content Ratio	α		2.01E-05	
Annual Seiment inflow at reservoir	Q_s	MCM	5.1	5.6MCM-0.5MCM(trapped in regulating pond as described above)
Annual Sediment inflow from Serayu and Merayu river	$Q_{sr_s}+Q_{mr_s}$	MCM	5.08	$\Sigma \alpha \times (q_{sr_i}+q_{mr_i})^2 \times 24 \times 3600 / 10^6$
Annual Sediment inflow from Stream between div. weir and resv.	Q_{st_s}	MCM	0.02	$\Sigma \alpha \times q_{st_i}^2 \times 24 \times 3600 / 10^6$
Divert commencement discharge from sediment bypass tunnel	q_{div_start}	m ³ /s	130	try and error determination
Maximum discharge capcity of sediment bypass tunnel	q_{div_max}	m ³ /s	200	
Annual diverted discharge	Q_{div_i}	MCM	657	target volume < 0.3 x Q_i
Annual diverted sediment	Q_{div_s}	MCM	2.4	target volume $\approx$ 0.5 x Q_s

Source : Prepared by JICA Study Team

Note :Since this JICA study is only a preliminary case study and that detailed information for the above determination should be collected during further investigation, above results are not optimized.

(6) Dredging Plan of Mrica Reservoir

According to the water depth survey conducted by IP, the remaining effective storage capacity is 32.2 MCM in 2009 and will be filled fully with the sediment by 2021. Judging from this, the effective storage capacity will be annually reduced by around 2.5 MCM/year.

Even if the sediment bypass tunnel will be completed in 2017 and around 2.4MCM of annual sediment inflow will be diverted, around 1.5 to 1.9MCM/year of sediment will be annually trapped in the effective storage area. The sediment trapping ratio will be changed subject to the recovered effective storage volume.

As shown in Figure BA1.6, two alternatives in achieving the target effective storage volume were studied.

Alternative-1 : reservoir volume considered in original design volume of 46.3MCM will be recovered.

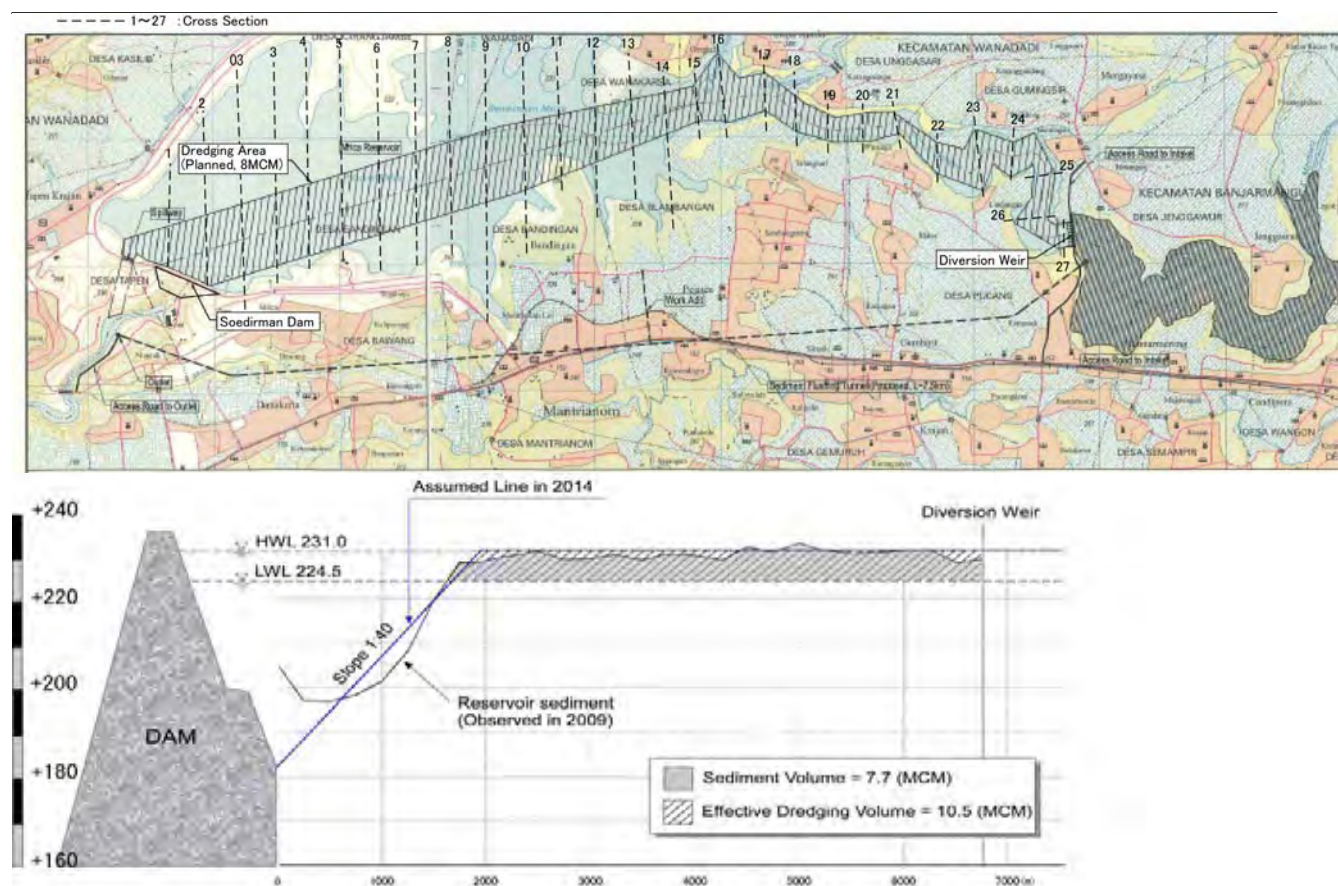
Alternative-2 : reservoir volume of up to 26.8MCM will be recovered by making new a river channel area as shown in Figure BA1.6. This could be carried out by dredging. Hence, the river channel area could maintain periodic discharge operation from the diversion weir. The assumed total dredging volume is around 8 MCM and estimated remaining effective storage volume by 2014 is 18.8MCM. Hence, effective storage volume of up to 26.8MCM can be recovered by means of the dredging operation.

The annual recovery ratio of the effective storage volume for each target effective volume has been estimated using Brune's middle curve formula described above. Corresponding results are as shown in Table BA1.5.

Table BA1.5 Annual Recovery Ratio of Effective Storage Volume

Item	Mark	Unit	Alternative -1	Alternative -2	Note
Target storage volume (effective)	Ve	MCM	46.30	26.80	
Annual inflow	Qi	MCM	2,343	2,343	
Annual diverted flow (MCM)	Qdivi	MCM	657	657	
Capacity inflow Rate	C/I		0.027	0.016	$Ve/(Qi-Qdivi)$
Sediment trapping efficiency	E_T	%	68.6	56.3	$(C/I)/\{0.012+1.02(C/I)\}$
Annual sediment inflow	Q_s	MCM	5.1	5.1	See Table BA1.4
Annual diverted sediment volume	$Qdiv_s$	MCM	2.4	2.4	See Table BA1.4
Annual trapped sediment in Resv.	$Qstrap$	MCM	1.9	1.5	$E_T \times (Q_s - Qdiv_s)$
Autumnal dredging volume	$Qdredge$	MCM	3.0	3.0	1300PS x 3units
Annual recovering ratio of effective storage volume	$Qrecv$	MCM	1.1	1.5	$Qdredge - Qstrap$

Source : Prepared by JICA St Team



Source : Prepared by JICA Study Team

Figure BA1.6 Dredging Plan for Alternative -2

Table BA1.6 Dredging Volume

Cross Section	2009				2014 (Assumed)			
	Sediment Area(m ²)	Average (m ²)	Interval L(m)	Sediment Volume V(m ³)	Dredging Area(m ²)	Average (m ²)	Interval L(m)	Effective Dredging Volume V(m ³)
6	0.0				0.0			
7	1160.0	580.0	250	145,000	1890.0	950.0	250	237,500
8	2150.0	1650.0	260	429,000	3460.0	2680.0	260	696,800
9	1510.0	1830.0	240	439,200	3460.0	3460.0	240	830,400
10	2460.0	1980.0	210	415,800	3330.0	3400.0	210	714,000
11	1390.0	1920.0	290	556,800	2090.0	2710.0	290	785,900
12	1780.0	1580.0	260	410,800	2290.0	2190.0	260	569,400
13	1500.0	1640.0	240	393,600	1990.0	2140.0	240	513,600
14	1340.0	1420.0	250	355,000	2010.0	2000.0	250	500,000
15	1570.0	1460.0	250	365,000	1810.0	1910.0	250	477,500
16	1940.0	1760.0	200	352,000	2580.0	2200.0	200	440,000
17	1440.0	1690.0	300	507,000	1750.0	2170.0	300	651,000
18	1060.0	1250.0	250	312,500	1210.0	1480.0	250	370,000
19	840.0	950.0	250	237,500	1030.0	1120.0	250	280,000
20	1240.0	1040.0	250	260,000	1330.0	1180.0	250	295,000
21	1130.0	1180.0	210	247,800	1440.0	1390.0	210	291,900
22	1200.0	1160.0	290	336,400	1450.0	1440.0	290	417,600
23	2880.0	2040.0	320	652,800	3130.0	2290.0	320	732,800
24	1200.0	2040.0	380	775,200	1400.0	2270.0	380	862,600
25	710.0	960.0	150	144,000	990.0	1190.0	150	178,500
26	690.0	700.0	320	224,000	1250.0	1120.0	320	358,400
27	440.0	570.0	300	171,000	710.0	980.0	300	294,000
TOTAL				7,730,000				10,500,000

Based on the estimated value of annual storage recovery ratio as shown in Table BA1.5, construction plan for the sediment countermeasure work for each alternative has been prepared as shown in Table BA1.7.

Table BA1.7 Construction Plan for the Sediment Countermeasure Work

Work Items		2014 ^{*1)} ~2017year	2017~completion year	After completion year
Sand flushing tunnel		Construction	Sediment bypass operation	
Alternative-1	Annual trapped sediment volume	2.5MCM/year	1.9MCM/year ^{*2)}	1.9MCM/year
	Dredging work	1MCM/year ^{*3)}	3.0MCM/year ^{*3)}	1.9MCM/year
	Annual recovery ratio of the effective storage capacity	-1.5MCM/year	+1.1MCM/year	Even
Alternative-2	Annual trapped sediment volume	2.5MCM/year	1.5MCM/year ^{*2)}	1.5MCM/year
	Dredging work	1.0MCM/year	3.0MCM/year	1.5MCM/year
	Annual recovery ratio of the effective storage capacity	-1.5MCM/year	+1.5MCM/year	Even

*1) : Commencement date of the countermeasure work is assumed from year of 2014 considering 3-years for design and tender procedure.

*2) : Estimated by the Brune's sediment trapping rate as shown in Table BA.1.5 .

*3) : Due to limitation of dredging area, one dredger (production rate is 1MCM/year) will be installed and operated from 2004 to 2017.

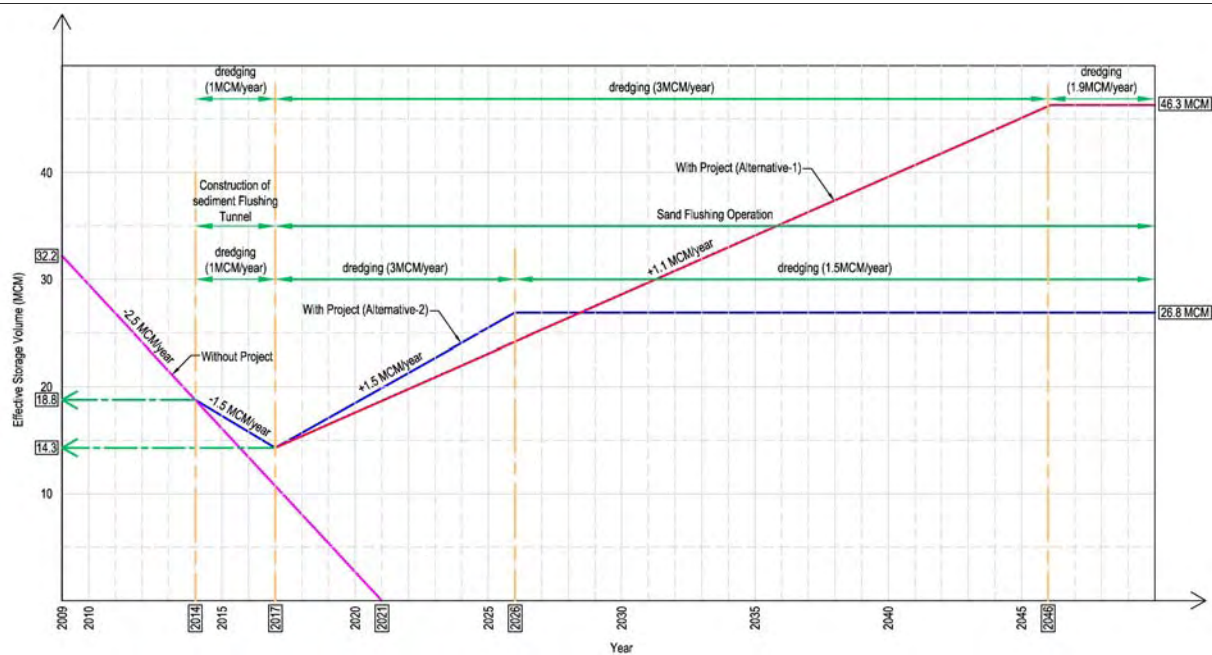
*4) : The maximum number of dredgers used at the same time is three (3) due to practical operation.

Based on the construction plan for the sediment countermeasure work as shown in Table BA1.6, completion dates for each alternative are estimated. As shown in Figure BA1.7, assumed completion year of Alternative-1 (target storage volume is 46.3MCM) and Alternative-2 (target storage volume is 26.8MCM) is year of 2046 and 2026, respectively.

For the optimization of the target effective volume, two dimensional river bed fluctuation analysis, construction cost analysis, benefit analysis, and environmental impacts analysis during the construction work shall be carried out. However this Study does not present such optimization due to the limited data and period for the Study.

In this Study, Alternative-2 is proposed to achieve about 27 MCM target effective volume, which is judged to be the practical option at present.

Based the sediment balance on Alternative-2, structural design and economic analysis have been carried out as shown in Part B and Part C, respectively, of this ANNEX B.



Source : Prepared by JICA Study Team

Figure BA1.7 Schedule for Recovery of Effective Storage Volume by Sediment Countermeasure

PART B PRELIMINARY DESIGN OF DIVERSION STRUCTURES

BB1. Design of Diversion Weir

BB1.1 Selection of Weir Site

There are three conceivable sites for the diversion weir as shown in Figure BB1.1. The principal site conditions of the alternatives are as shown in Table BB1.1.

Axis-D (Downstream Axis) : The weir site is located just downstream of the confluence between the Serayu mainstream river and the Kndangwangi tributary river. Length of the sediment bypass tunnel is the shortest among the alternatives.

Axis-U (Upstream Axis): The weir site is located just downstream of the confluence between the Serayu River and Marawu River. Length of the sediment bypass tunnel is the longest among the alternatives.

Axis-M (Middle stream Axis): The weir site is located in the middle stream section between Axis-D and Aixe-U.

Table BB1.1 Principal Conditions of Weir Site Alternatives

Items	Axis-D	Axis-M	Axis-U
Width of river channel at EL234(m)	350	150	150
Depth of sediment below LWL (m)	30	10	less than 10
Land acquisition for new regulating pond	Not required or limited area	Not required or limited area	Required
Length of sediment bypass tunnel (m)	6.2	7.5	9.5

Source : Prepared by JICA Study Team

Axis-U site requires newly land acquisition for regulating the pond formed by the diversion weir. Moreover, length of the sediment bypass tunnel of the site is the longest among the alternatives. Hence, Axis-U is not suitable for the diversion weir site.

The Axis-D site could require the shortest tunnel length. However, 350m of the river channel width is too long compared to the required weir length of 160m. Longer river width requires most costly weir construction. In addition, thickness of sediment deposit below LWL of Mrica Reservoir is around 30m. Thicker unconsolidated deposits cause difficulty in the construction works for the weir. Hence, Axis-D site is not suitable as construction site for the diversion weir.

Width of the river channel in Axis-M is around 150 m while thickness of sediment deposits below LWL is around 10 m. Therefore, topographic condition of Axis-M is appropriate for the structural requirement and the construction conditions of the weir. In addition, the geological and topographic

conditions are suitable for the construction of the portal of the sediment bypass tunnel. Since Axis-M site has advantage in view of the practical construction work, it is selected as the diversion weir site.



Source : Prepared by JICA Study Team

Figure BB1.1 Location Map of the Alternative Weir Site

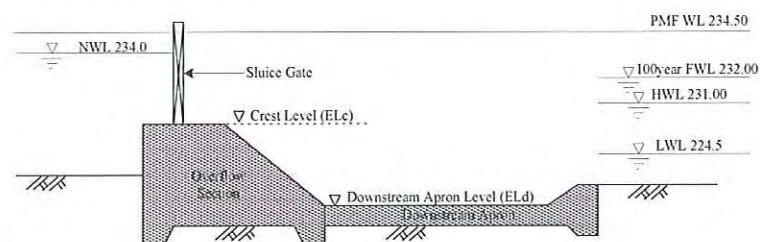
BB1.2 Preliminary Design of Diversion Weir

(1) Design Conditions of Diversion Weir

The diversion tunnel has been designed based on the following conditions;

- Gated type weir is selected to minimize inundation area during flood period.
- The sluice gate can slide up above PMF water level of Mrica Reservoir so as to keep flood way.
- EL 234.00 m of normal operation level is applied to the regulating pond formed by the diversion weir based on the 1:25,000 topographic maps.
- 100 year probable design flood is applied to the design of the diversion weir.
- 4600m³/s of the flood peak is applied to the weir design flood by utilizing the design examination for Mrica Dam.

Typical component of overflow section of the diversion weir is as shown in Figure BB1.2.



Source : Prepared by JICA Study Team

Figure BB1.2 Typical Component of the Diversion Weir (Overflow Section)

(2) Hydraulic Design of Diversion Weir

The principal dimensions of the diversion weir shall be determined so as to ensure 1) hydraulic stability against the downstream river channel erosion, 2) discharge capacity during flood period, and 3) seepage stability.

1) Hydraulic Stability for Downstream River Channel

The diversion weir shall ensure the hydraulic stability to prevent erosion of the downstream river channel due to the hydraulic jump. The principal dimensions of the weir have been determined considering the following critical hydraulic conditions due to the hydraulic jump.

- The hydraulic jump from the design flood shall be settled within the weir structure.
- LWL (224.50) of Mrica Reservoir is adopted as the downstream water level of the weir, since the lowest downstream water level is the most critical for the hydraulic jump.
- Upstream water level of the weir is estimated based on 100 year probability of the design flood considering fully opened gate conditions of the weir.

The above conditions are illustrated in Figure BB1.3 and the procedure. Meanwhile, hydraulic stability check for the downstream river channel against hydraulic jump and determination of the principal dimensions of the diversion weir are shown in Figure BB1.4.

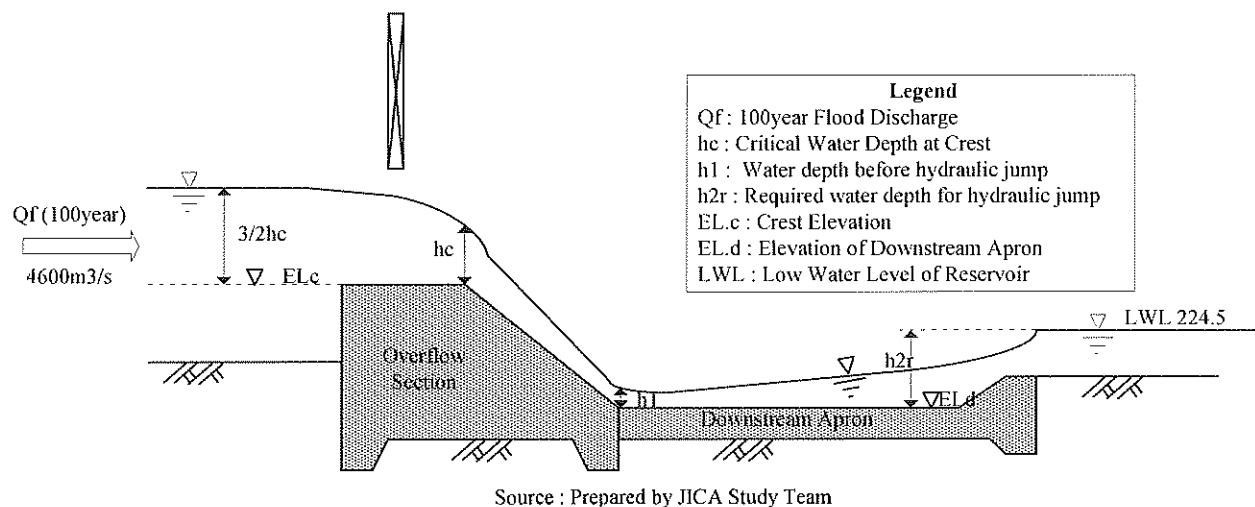
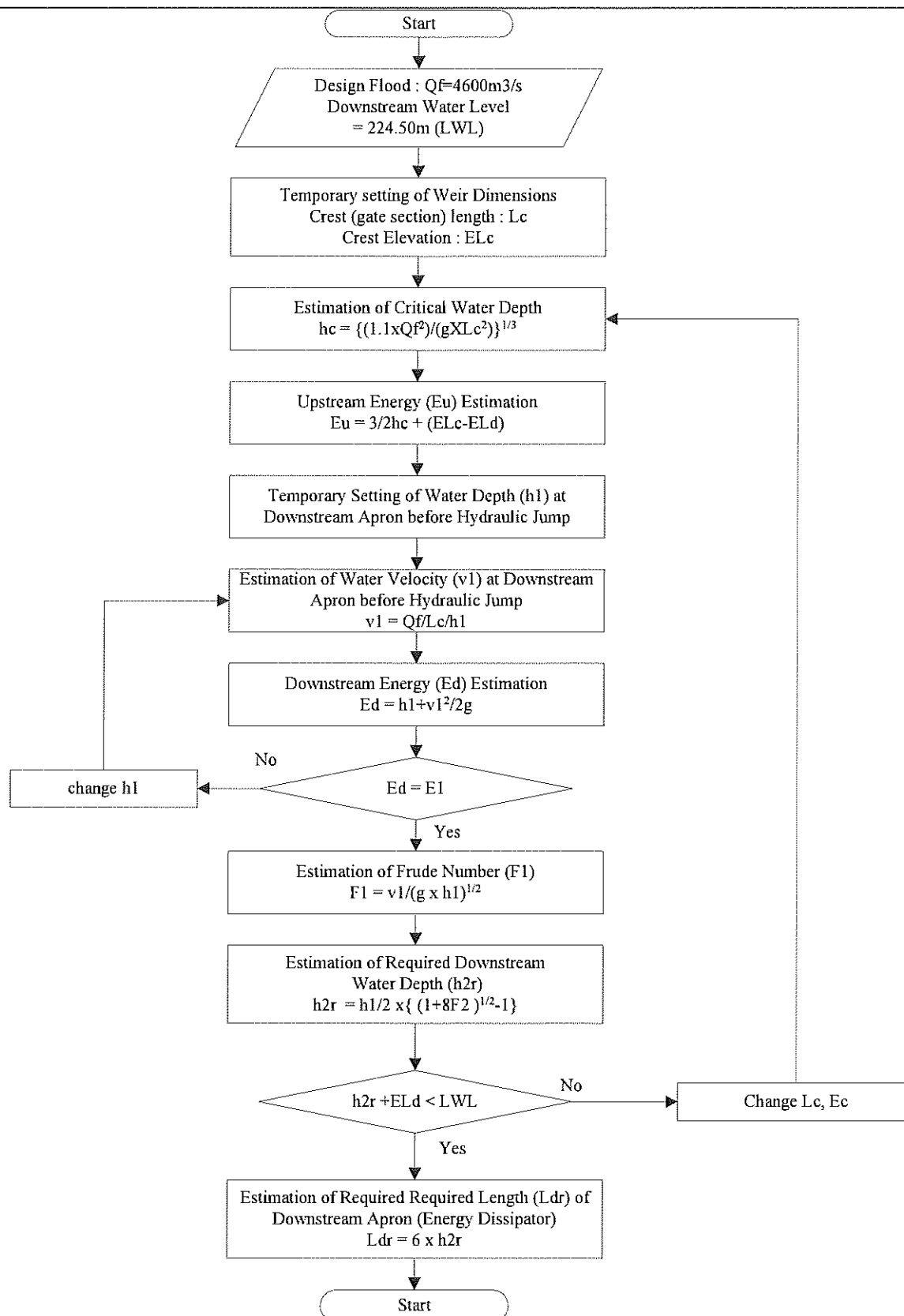


Figure BB1.3 Hydraulic Conditions at 100year Flood with LWL of Reservoir



Source : Prepared by JICA Study Team

Figure BB1.4 Procedure for Hydraulic Stability Check for the Downstream River Channel Stability

In accordance with the above described conditions and procedure, the principal dimensions of the diversion weir have been determined as shown in Table BB1.2.

Table BB1.2 Principal Dimensions of the Diversion Weir

Item	Mark	Unit	Value	Note
Flood discharge	Qf	m ³ /s	4,600	100year probable flood
Crest length	Lc	m	154	22m x 7span
Crest Level	ELc	m	227.000	
Elevation of Downstream Apron	ELd	m	214.600	
Height between crest and apron	D	m	12.400	ELc - ELd
Unit discharge	qf	m ³ /s/m	29.87	Qf/Lc
Energy adjustment factor	α		1.1	
Critical water depth at crest	hc	m	4.644	$\{\alpha * Qf^2 / (g * Lc^2)\}^{1/3}$
Upstream Energy	Eu	m	19.366	$3/2 * hc + (ELc - ELd)$
Downstream water depth before hydraulic jump	h1	m	1.601	
Downstream water velocity before hydraulic jump	v1a	m	18.7	qf/h1
Downstream Energy	Ed	m	19.365	$h1 + v1^2 / (2 * g)$
Energy balance	Eu-Ed	m	9.350E-04	
check			OK	Abs(Eu-Ed) < 0.001 -> "OK"
Froude number before hydraulic jump	F1		4.711E+00	$v1a / (g * h1a)^{0.5}$
Required downstream water depth for hydraulic jump	h2r	m	9.895	
Required downstream water level for hydraulic jump	WL2r	m	224.495	h2+ELd
Downstream water level after hydraulic jump	WL2	m	224.500	
check			OK	WL2 > WL2r => "OK"
Required length of energy dissipater	Ldr	m	59.4	$6 * h2r$

Source : Prepared by JICA Study Team

2) Discharge Capacity Check for Design Flood

Sluice way section of the diversion weir has enough capacity for the 100-year probability of the design flood discharge (4600 m³/s). Hydraulic stability for the discharge capacity of the diversion weir has been determined considering the following critical conditions.

- Maximum flood water level of regulating pond, formed by the weir, shall be lower than the normal water level (234.0 m) of the pond.
- 100 year probable flood water level (232.0 m) of Mrica Reservoir is adopted for the downstream water level of the weir, since the highest downstream water level is the most critical for the flow condition of the weir.
- Sluice gate of the weir shall be fully opened during the design flood condition.

Hydraulic condition of the diversion weir with the above described conditions and calculation procedure of the water rising are shown in Figure BB1.5 and BB1.6, respectively.

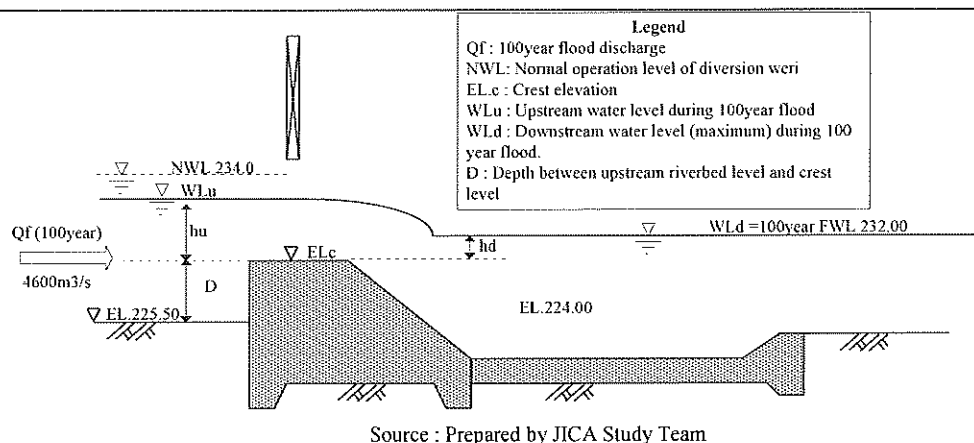


Figure BB1.5 Hydraulic Conditions at 100year Flood with Maximum Reservoir Level

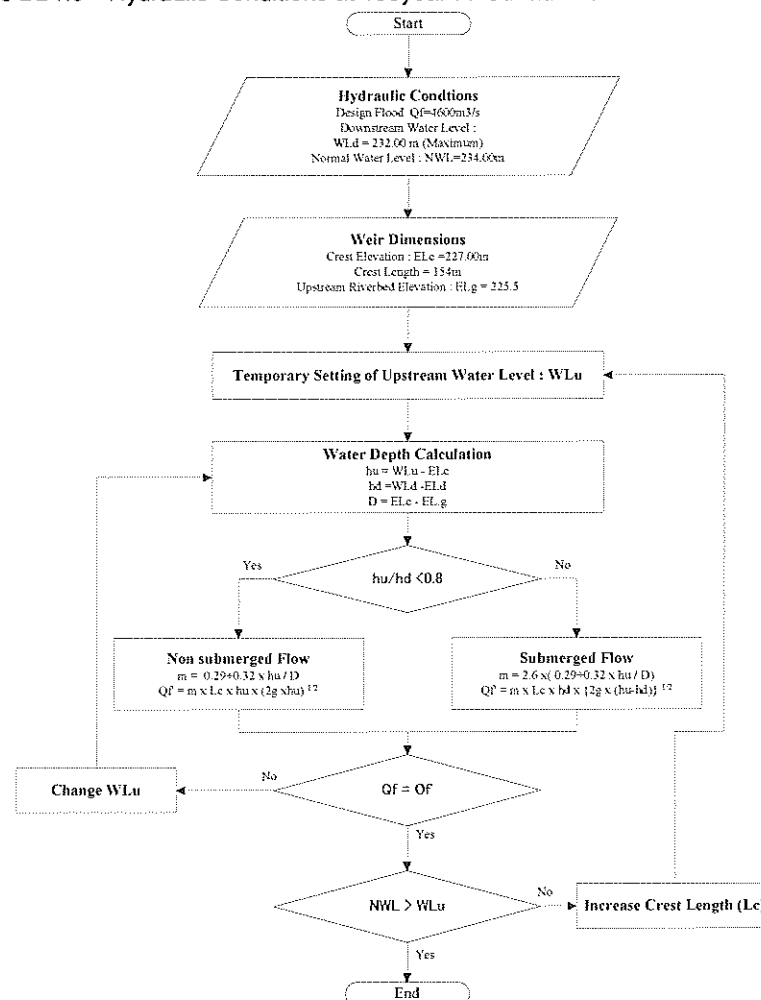


Figure BB1.6 Calculation Procedure to Determine the Water Rising

In accordance with the above described conditions and procedures, discharge capacity of the sluice way section of the weir has been validated. Results are shown in Table BB.1.3

Table BB1.3 Results of Hydraulic Stability Check for Sluice Way Discharge Capacity

	Items	Mark	Unit	Value	Note
1	Flood discharge	Qf	m ³ /s	4,600	100year flood
2	Normal water level of weir pond	NWL	m	234.000	
3	Upstream water level	WLu	m	232.140	
4	Downstream water level	WLd	m	232.000	
5	Crest level	ELc	m	227.000	
6	Crest length	Lc	m	154.000	
7	Upstream riverbed level	ELg	m	225.500	Crest level of sand flushing section
8	Upstream water depth	hu	m	5.140	WLu - ELc
9	Downstream water depth	hd	m	5.000	WLd -ELc
10	Depth between crest and riverbed level	D	m	1.500	
11		hd/hu		0.97	
12	Discharge Coefficient	m	m	3.61	hu/hd < 0.8 : => 0.29+0.32*hu/D, hu/hd >= 0.8 : => 2.6 *(0.29+0.32*hu/D)
13	Estimated Discharge	Qf		4,600	hu/hd < 0.8 : => m x Lc x hu x (2g x hu) ^{1/2} , hu/hd >=0.8: => m x Lc x hd x {2g (hu-hd)} ^{1/2}
14	Qf-Qf			-0.000	
15	check			OK	Qf=Qf and WLu < NWL ->OK

Source : Prepared by JICA Study Team

(3) Seepage Stability Check of Diversion Weir

Seepage stability of the diversion weir has been carried out using Bray's formula as shown below;

$$L_s \geq SF \times L_{sr} = C \cdot dH$$

where, L_c : Seepage length (m)

$$L_s = \frac{1}{3} \cdot L_h + \sum l_{vi}$$

L_h : Horizontal seepage length (m)

l_{vi} : Vertical seepage length (m)

C : Creep ratio (C=8.3, fine sand)

dH : Water head (m)

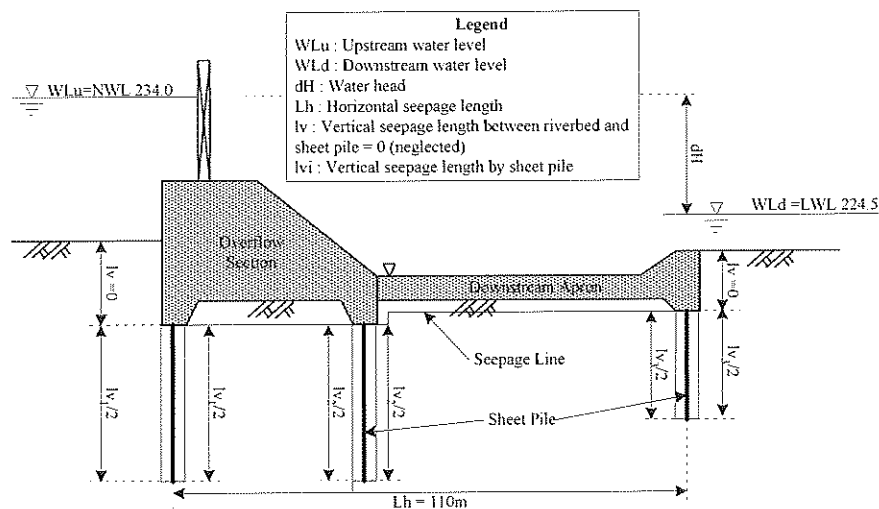
SF : Safety factor (1.25); SF is not defined in the original formula.

The critical conditions of the seepage stability of the weir are as listed below:

- Sluice gate is fully closed
- Normal water level (EL.234.0m) of the regulating pond is set as the upstream water level condition of the weir.
- LWL (224.5m) of Mrica Reservoir is set as the downstream water level condition of the weir.

The above listed critical conditions are illustrated in Figure BB1.7.

As shown in the figure, vertical seepage length between riverbed and the sheet pile is neglected, since the seepage length is unstable.



Source : Prepared by JICA Study Team

Figure BB1.7 Critical Conditions of Seepage Stability

In accordance with the above formula and conditions, 50 m total vertical length, (15m x 2 line + 10m x 1line), of the sheet pile is required to maintain seepage stability. Results are shown in Table BB1.4.

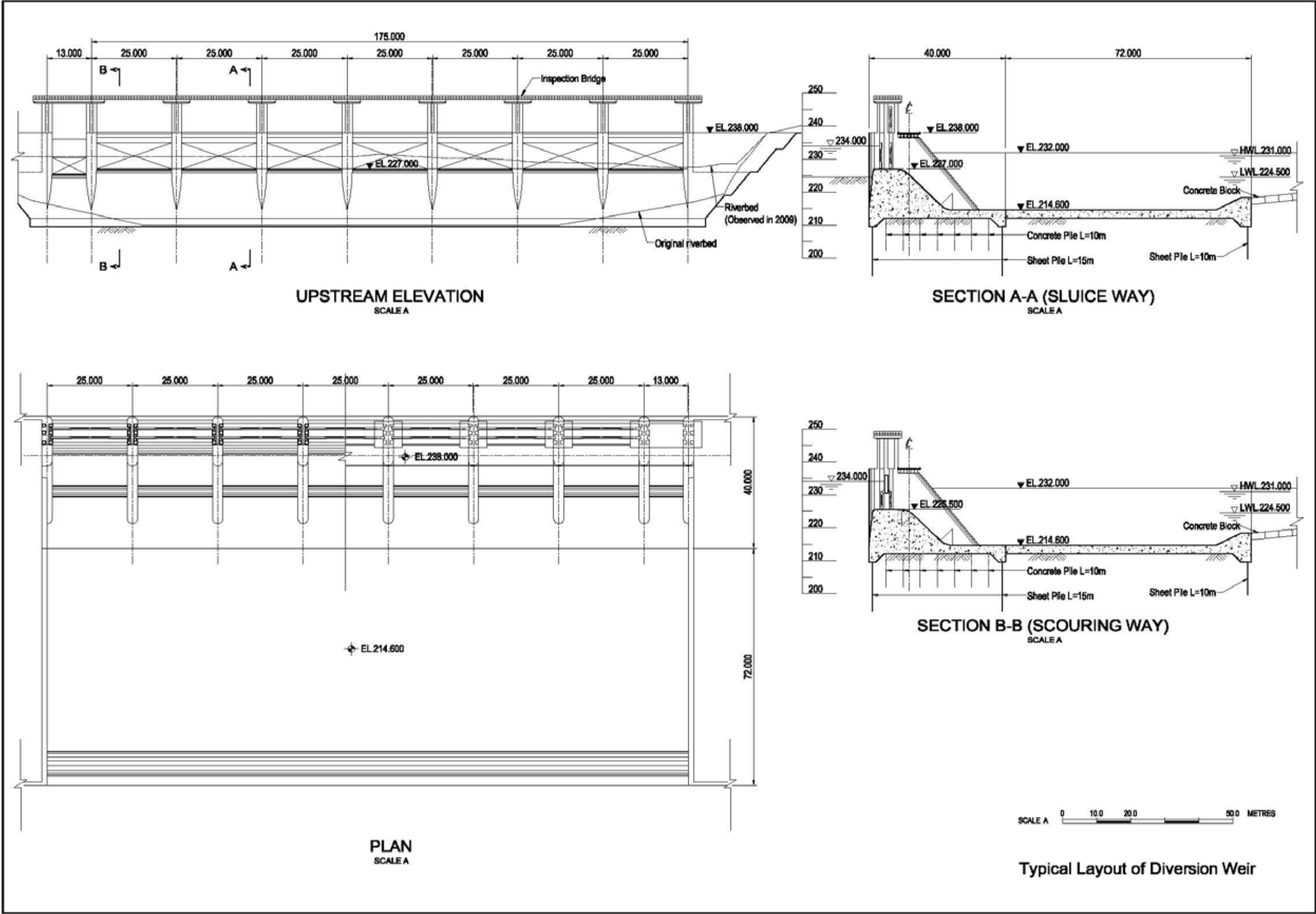
Table BB1.4 Seepage Stability Check of Diversion Weir

Item	Mark	Unit	Value	Note
1. Upstream water level	WLu	m	234.000	NWL of regulating pond
2. Downstream water level	WLd	m	224.500	LWL of reservoir
3. Water head	dh	m	9.500	WLu - WLd
3. Horizontal seepage length of weir and apron	Lh	m	110	
4. Length of sheet pile				
4.1 Sheet pile1	lp1		15	
4.2 Sheet pile2	lp2		15	
4.3 Sheet pile3	lp3		10	
5. Total vertical length	lv	m	80	2 x(lp1+lp2+lp3)
6. Effective Seepage Length	Lc	m	116.7	1/3*Lh + lv
7. Creep Ratio	C		8.3	Fine sand & silt
8. Required Seepage Length	Lcr	m	78.85	C* dh
9. Safety Factor	Fs		1.25	
10. Check			OK	Ls > FS*Lsr

Source : Prepared by JICA Study Team

(3) Layout of the Weir

Based on the hydraulic design, typical layout of the diversion weir has been determined as shown in Figure BB1.8.



Source: Prepared by the JICA Study Team

Figure BB1.8 Typical Layout of the Diversion Weir

BB2 DESIGN OF SEDIMENT BYPASS TUNNEL

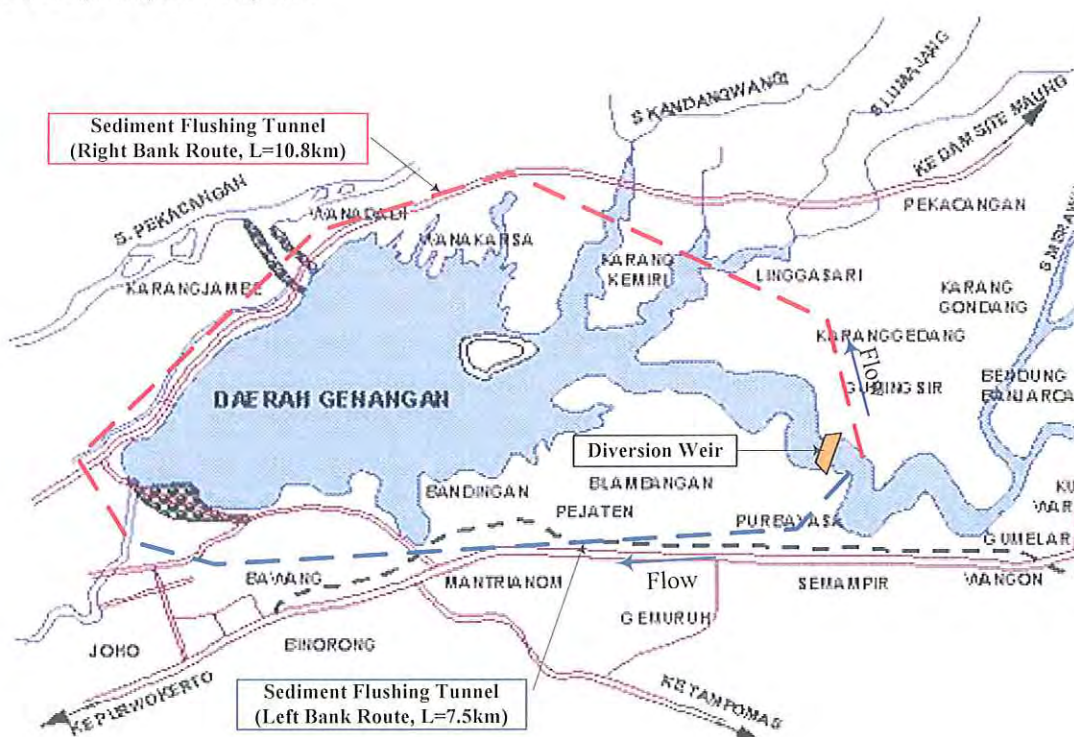
BB2.1 Selection of Tunnel Route

There are two conceivable tunnel routes for the sediment bypass tunnel. The principal features and layout of the alternative routes are shown in Table BB2.1 and Figure BB2.1, respectively. As shown in the figure and table, it is clear that the left bank route is more advantageous than the right bank route in view of the tunnel layout, dimensions, and geological conditions. Hence, the left bank route has been selected as the route of the sediment bypass tunnel.

Table BB2.1 Principal Features of the Alternatives for Sediment Bypass Tunnel Routes

Items	Left Bank Route	Right Bank Route
Length of tunnel	7.5km	10.8km
Tunnel diameter	6.4m	6.6m
Geological conditions	Sedimentary rock (consolidated)	Volcanic deposit (loose consolidated)

Source : Prepared by JICA Study Team



Source : Prepared by JICA Study Team

Figure BB2.1 Location Map of Sediment Bypass Tunnel Alternatives

Note : As shown in Figure BB2.1, there is the other alternative to divert water to the Pekacangan River which flows just at the right bank side of Mrica Reservoir. However, sediment balance of said river will be disrupted due to the diversion. Such unbalanced sediment diversion shall be prohibited and the sediment balance shall be taken within the same river basin.

BB2.2 Hydraulic Design of sediment flusing tunnel

(1) Hydraulic Design Criteria

Hydraulic design of the sediment bypass tunnel has been carried out in accordance with the Japanese design standard for flood diversion tunnels. Hydraulic design criteria for the sediment bypass tunnel are as shown in Table BB.2.2.

Table BB.2.2 Hydraulic Design Criteria for the Sediment Bypass Tunnel

Item	Mark	Unit	Value	Note
Maximum Discharge Capacity	Q _{max}	m ³ /s	200	refer to sediment balance study
Design Discharge	Q _d	m ³ /s	260	130% of max. discharge
Intake water level	W _{Li}	m	234.00	
Tail water level	W _{Lt}	m	130.200	Tail water level of Soedirman PS
Tunnel length	L _t	m	7,500	
Gradient of tunnel	I		1/80	Concrete lining Stream cross section area / Tunnel cross section area
Roughness coefficient	n		0.016	
Void ratio	vr	%	15	

Source : Prepared by JICA Study Team

(2) Hydraulic Design of the Sediment Bypass Tunnel

Cross section of the sediment bypass tunnel has been determined in accordance with the hydraulic design criteria shown in Table B.2.2, using the following Manning's formula;

$$Q = \frac{A}{n} \cdot R^{\frac{2}{3}} \times I^{\frac{1}{2}}$$

where, Q : Discharge (m³/s)

A : Stream cross section area (m²)

n : Roughness coefficient (n=0.016, concrete lining)

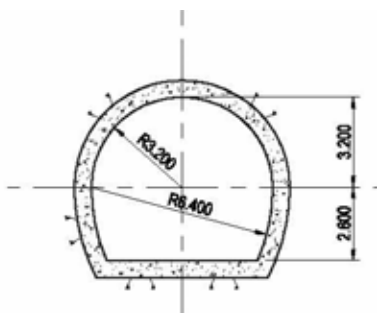
R : Hydraulic radius (m)

$$R = \frac{A}{S}$$

S : Wetted perimeter(m)

I : Slope (=1/80, based on topographic condition)

Based on the trial and error calculations, the cross section of the sediment bypass tunnel has been determined as shown in Figure BB2.2. Hydraulic calculation outputs for the sediment bypass tunnel are as shown in Table BB2.3.



Source : Prepared by JICA Study

Team

Figure BB2.2 Typical Cross Section of the Flushing Tunnel

Table BB2.3 Hydraulic Calculation Outputs for the Sediment bypass Tunnel

[Type of Cross Section] 2R-Hoseshoe Shape Total Width : 5.800m r1 : 3.200m r2 : 6.400m						
[Conditions of Tunnel] Roughness: 0.016 Slope: 1/80.0						
[Maximum Discharge]						
Water Depth(m)	Discharge (m ³ /s)	Velocity(m/s)	Stream Area(m ²)	Wetted Perimeter(m)	Hydraulic Radius (m)	Froude Number
5.4250	316.6636	10.2068	31.0248	17.5743	1.7653	1.3998
[Design Discharge]						
Water Depth)	Discharge (m ³ /s)	Velocity(m/s)	Stream Area(m ²)	Wetted Perimeter(m)	Hydraulic Radius(m)	Froude Number
4.1168	260.0000	10.3871	25.0309	13.8113	1.8123	1.6353
[Hydraulic Character]						
Water Depth)	Discharge (m ³ /s)	Velocity(m/s)	Stream Area(m ²)	Wetted Perimeter(m)	Hydraulic Radius(m)	Froude Number
0.0000	0.0000	—	—	—	—	—
0.5000	10.9804	3.9916	2.7509	6.3716	0.4317	1.8032
1.0000	33.1824	5.8463	5.6758	7.4166	0.7653	1.8675
1.5000	62.3927	7.1469	8.7300	8.4399	1.0344	1.8641
2.0000	96.5881	8.1360	11.8716	9.4492	1.2564	1.8377
2.5000	134.2642	8.9150	15.0604	10.4509	1.4411	1.8011
3.0000	174.0361	9.5343	18.2537	11.4530	1.5938	1.7584
3.5000	214.0069	10.0080	21.3835	12.4755	1.7140	1.7088
4.0000	251.7862	10.3336	24.3658	13.5489	1.7984	1.6505
4.5000	284.5040	10.4974	27.1024	14.7194	1.8413	1.5807
5.0000	308.3234	10.4642	29.4646	16.0784	1.8326	1.4949
5.5000	316.3013	10.1251	31.2393	17.9103	1.7442	1.3791
5.8000	296.0710	9.3145	31.7859	20.6536	1.5390	—

(3) Layout of the Sediment Bypass Tunnel

Based on the hydraulic design, typical layout of the sediment bypass tunnel has been determined as shown in Figure BB2.3.

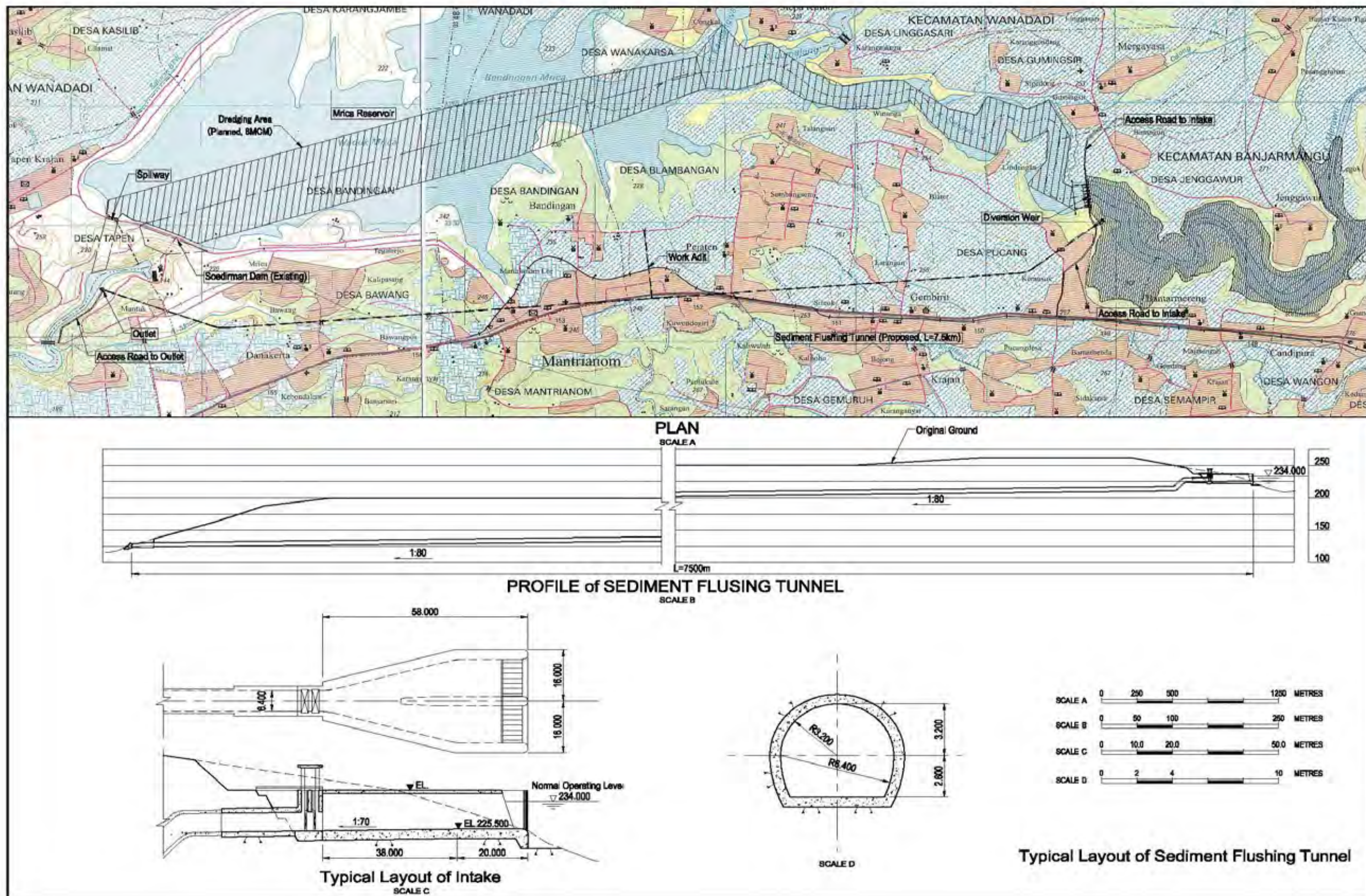


Figure BB2.3 Typical Layout of the Sediment Bypass Tunnel

PART C COST ESTIMATE, ECONOMICAL AND FINANCIAL ANALYSIS (PRELIMINARY LEVEL)

BC1. Estimation of Project Benefit

Benefit of the rehabilitation project is estimated as follows and project life is assumed 50 years.

BC1.1 Economic Benefit of Power Generation

In the original plan, the Soedirman power station has 180.9 MW installed capacity and annual generation power energy of 580GWh (Planned Volume). The mini-hydropower station is also attached at the outlet of the irrigation water supply. After the rehabilitation works, the dependable outlet, and the primary energy are shown below.

(1) Recovery of Storage Capacity

Implementation plan for recovery of the storage capacity of the Mrica reservoir by means of the dredging work and the sediment bypass operation is planned in accordance with the sediment balance study as explained in the Part A of this Annex B. Implementation plan of the storage recovery is as shown in Figure BC1.1.

(2) Simulation Results of Power Generation

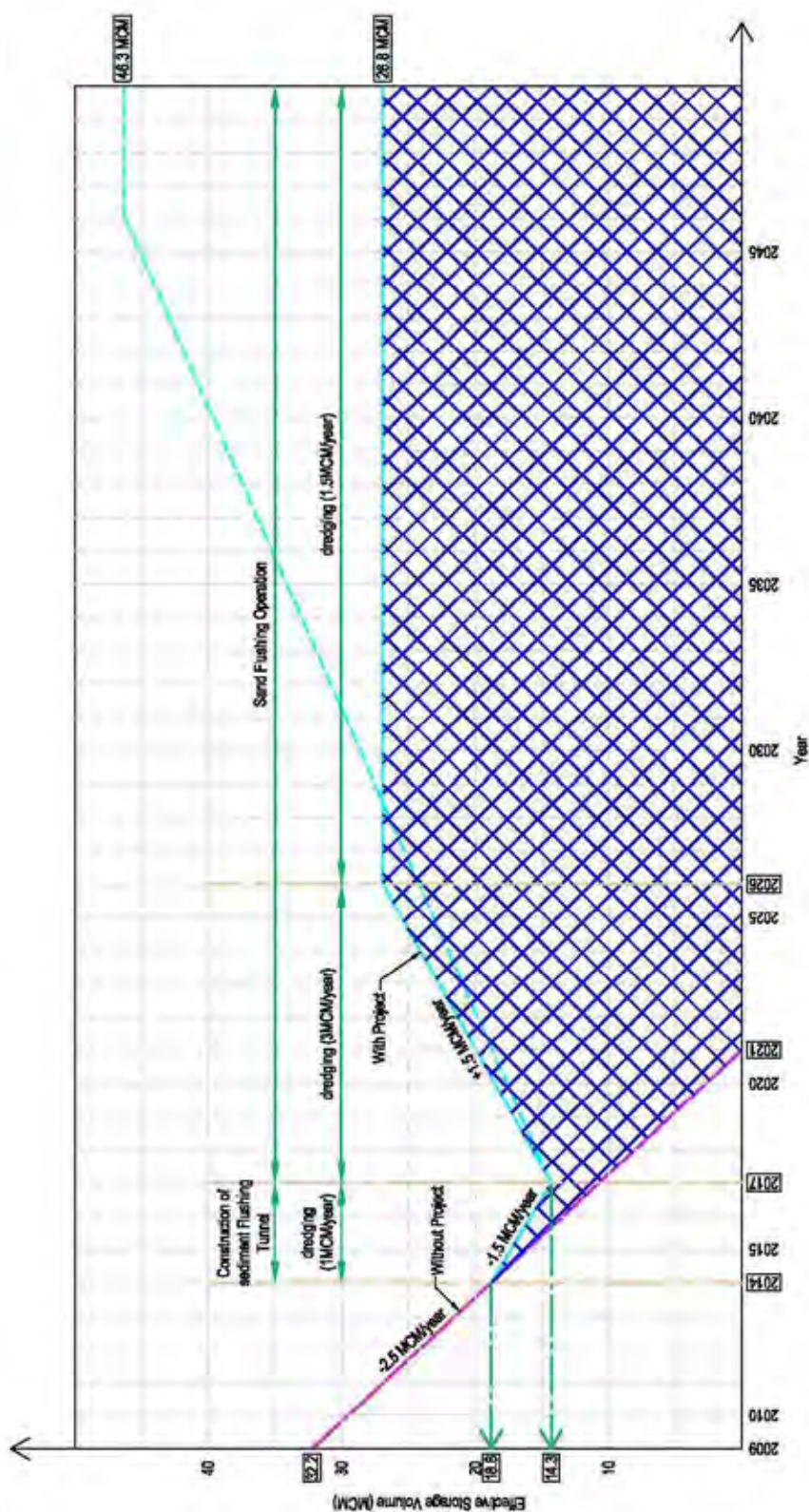
Based on the daily water inflow to the reservoir from 1989 to 2009, the generated power and the annual power energy for 'With Project' and 'Without Project' cases are estimated as shown in PART D of this Annex. Results are summarized as shown in Table BC1.1 and are illustrated as shown in Figure BC1.2.

Table BC1.1 Simulation Results of Power Generation

Year	Without Project				With Project			
	Dependable Output (MW)	Primary Energy (GWh)	Secondary Energy (GWh)	Mini Hydro. (GWh)	Dependable Output (MW)	Primary Energy (GWh)	Secondary Energy (GWh)	Mini Hydro. (GWh)
1989	112	162	282	5	-	-	-	5
2014	89	158	285	5	89	158	285	5
2017	82	158	285	5	86	158	285	5
				5	86	145	160	5
2021	0	0	443	5	91	145	160	5
	0	0	0	0				5
2026	0	0	0	0	96	145	160	5
after 2026	0	0	0	0	96	145	160	5

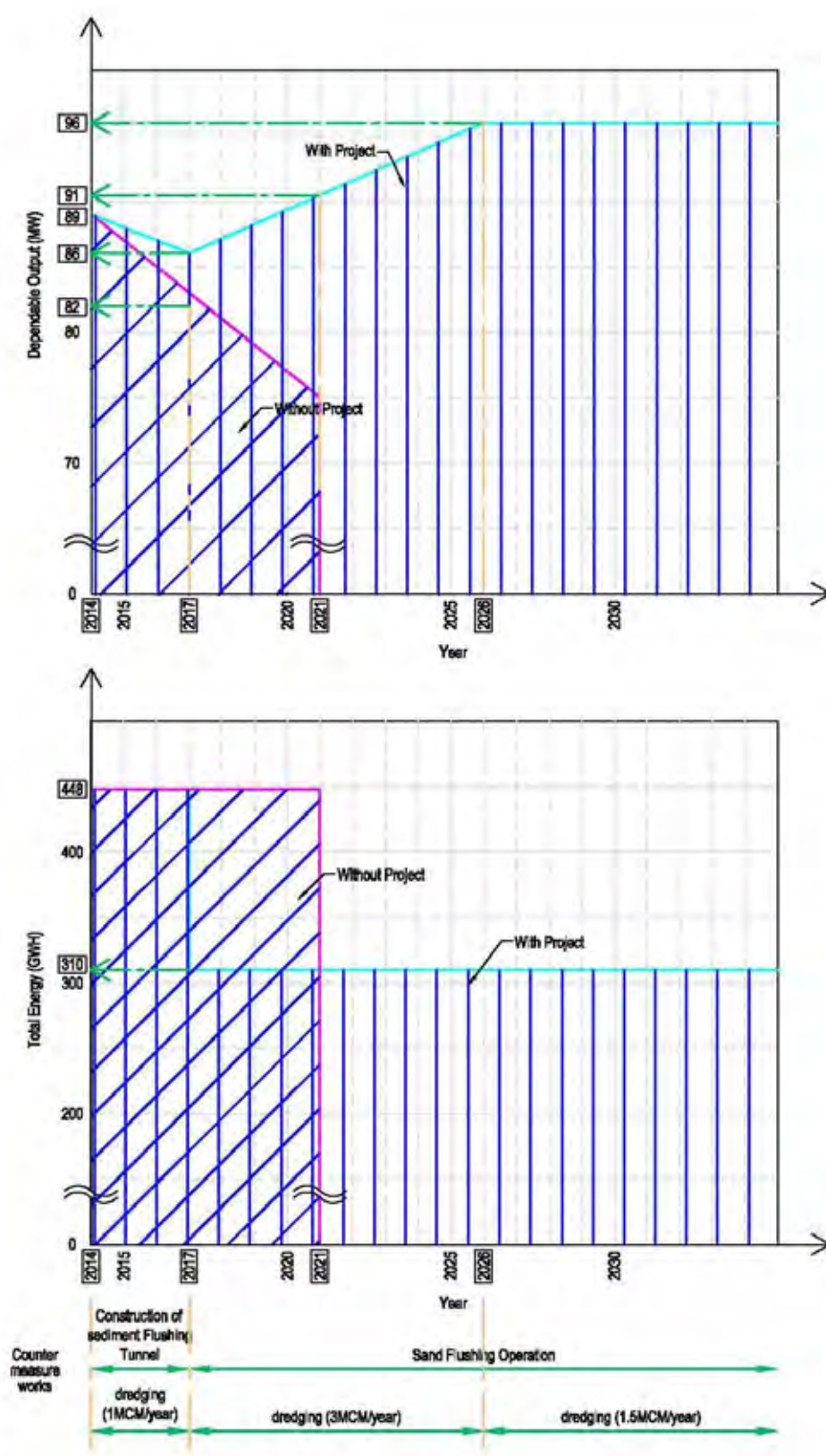
Notes: 1) Available water for the Soedirman power generation is (the natural inflow to the reservoir + the supply water from the reservoir storage water) – irrigation water supply.

2) Available water for the mini-hydro = irrigation water supply



Source : Prepared by JICA Study Team

Figure BC1.1 Operation Plan of Dredging and Sediment bypass



Source : Prepared by JICA Study Team

Figure BC1.2 Summary of Energy Calculation Results

(3) Economic Benefit of Power Generation

In principle, the unit benefit is calculated from the alternative existing and nearby thermal plants with the similar scale. The construction cost and O/M cost of the alternative thermal plant are shown in Tables BC1.3 and BC1.4. kW value is corresponding to the unit construction cost of the alternative plant and kWh value is corresponding to the unit O/M cost of the alternative thermal plant. Further Gas turbine plant will be applied to the estimation of unit benefit of dependable output and primary energy. On the other hand Coal fired plant will be applied to those of secondary energy and mini-hydro.

Based on the above assumption, the annual power benefit are calculated below..

Table BC1.2 Annual Power Generation Benefit (Only Main Year)

(Unit : 10⁶ Rp.)

Year	Soedirman Power Station	Mini-hydro	Total
2014	0		0
2017	-20,327		-20,327
2021	127,463	628	128,091
2026	129,537	628	130,165

Source : Prepared by JICA Study Team

The above economic power benefit will be gradually produced from the beginning of 2014 and reach to 100 % in 2026 in accordance with Figure BC1.2.

Table BC1.3 Capacity Value and Energy Value of Alternative Thermal Plant (1/2) (280MW Gas Turbine Plant)

1	Unit Construction Cost (US\$/kW)	290				
2	Unit Construction Cost (UCC) including Interest during Construction (IDC) (US\$/kW)	290	= 290	x 1.0000	=	290
3	Annual O&M Cost (% of UCC)	2.5				
4	Life Time (Year)	15				
5	Discount Rate (%)	12				
6	Capital Recovery Factor (CRF)	0.146824				
7	Efficiency Component for Adjustment Factor	Efficiency Component on Hydro and Gas Turbine (%)				
			Hydro	Gas Turbine		
	Station Use		0.3	1		
	Transmission Line Loss		5.0	1		
	Forced Outage		0.5	7		
	Scheduled Outage		2.0	10		
8	kW Value Adjustment Factor (KWVAF)	$\frac{(1-0.003) \times (1-0.05) \times (1-0.005) \times (1-0.02)}{(1-0.01) \times (1-0.01) \times (1-0.07) \times (1-0.10)}$ $= \frac{0.997 \times 0.95 \times 0.995 \times 0.98}{0.99 \times 0.99 \times 0.93 \times 0.90} = 1.12583$				
9	Capacity Value	Unit Construction Cost (CRF + O&M) x KWVAF = 290 x (0.14682424 + 0.025) x 1.12583 = 56 US\$/kW/Year				
10	Fuel Cost (US\$/Barrel)	25				
11	Calorific Value (kcal/kg)	9,300				
12	Heat Rate (kcal/kWh)	3,300				
13	Fuel Consumption (kg/kWh)	(3,300 / 9,300)	=		0.3548	
14	Fuel Cost (US\$/kWh: 1Barrel=159L; Oil 1L=0.85kg)	0.3548	x 25	/ 159	/ 0.85	= 0.066
15	O & M Cost for Energy (%)	0.001022				
16	kWh Value Adjustment Factor (KWhVAF)	$\frac{(1-0.003) \times (1-0.05)}{(1-0.01) \times (1-0.01)}$ $= \frac{0.997 \times 0.95}{0.99 \times 0.990} = 0.96638$				
17	Energy Value	(Unit Cost of Fuel per kWh + O&M) x KWhVAF = (0.066 + 0.001) x 0.96638 = 0.0648 US\$/kWh				

Source : Prepared by JICA Study Team

Table BC1.4 Capacity Value and Energy Value of Alternative Thermal Plant (2/2) (800MW Coal steam Plant)

1	Unit Construction Cost (US\$/kW)	818			
2	Unit Construction Cost (UCC) including Interest during Construction (IDC) (US\$/kW)	818	= 818	x 1.0000	= 818
3	Annual O&M Cost (% of UCC)	1.4			
4	Life Time (Year)	25			
5	Discount Rate (%)	12			
6	Capital Recovery Factor (CRF)	0.12750			
7	Efficiency Component for Adjustment Factor	Efficiency Component on Hydro and Gas Turbine (%)			
			Hydro	Coal Steam	
	Station Use		0.3	7	
	Transmission Line Loss		5.0	1.4	
	Forced Outage		0.5	8	
	Scheduled Outage		2.0	12	
8	kW Value Adjustment Factor (KWVAF)	$\frac{(1-0.003) \times (1-0.05) \times (1-0.005) \times (1-0.02)}{(1-0.07) \times (1-0.014) \times (1-0.08) \times (1-0.12)}$ $= \frac{0.997 \times 0.95 \times 0.995 \times 0.98}{0.93 \times 0.99 \times 0.92 \times 0.88} = 1.24405$			
9	Capacity Value	Unit Construction Cost (CRF + O&M) x KWVAF = 818 x (0.12750 + 0.014) x 1.24405 = 143.99 US\$/kW/Year			
10	Thermal Efficiency (%)	32.0			
11	Fuel Cost (US\$/ton)	28			
12	Calorific Value (kcal/kg)	4,800			
13	Heat Rate (kcal/kWh)	2,500			
14	Fuel Consumption (kg/kWh)	(2,500 / 4,800)	=		0.52083
15	Fuel Cost (US\$/kWh)	0.52083 x 28	/ 1000	=	0.01458
17	O & M Cost for Energy	$\frac{\text{KW Construction Cost} \times 1.4\%}{24 \times 365 \times (1-(7\%+8\%+12\%+1.4\%))}$ $= \frac{818 \times 0.014}{8,760 \times 0.716} = 0.001826$			
18	kWh Value Adjustment Factor (KWhVAF)	$\frac{(1-0.003) \times (1-0.05)}{(1-0.07) \times (1-0.014)}$ $= \frac{0.997 \times 0.95}{0.93 \times 0.986} = 1.03290$			
19	Energy Value	(Unit Cost of Fuel per kWh + O&M) x KWhVAF = (0.01458 + 0.001826) x 1.03290 = 0.01695 US\$/kWh			

Source : Prepared by JICA Study Team

BC1.2 Reduction Benefit of CO2

In case 'Without Project', the power generation of the Soedirman power station will be impossible, instead the alternative thermal power station shall be generated. The CO2 produced by this power generation will be benefit of the reduction of CO2.

-Reduction volume of CO2; 0.644 Ton CO2 / MWh

-Unit price of CO2; 15 US\$/Ton CO2

The annual total energy is 310 GWh / year including mini-hydro (5 GWh) and the benefit will be occurred after 2026.

Therefore, the annual benefit is 24,646 mill. Rp./year

BC1.3 Economic Benefit of Irrigation Water Supply

Economic benefit of the irrigation water supply is defined as returns of ‘With Project’ – returns of ‘Without Project’. However enough data to estimate the benefit of downstream irrigation area (10,000 ha) of the Mrica dam could not be obtained in this Study. Therefore the unit irrigation benefit in the Sutami dam down stream shown in Page 3-1 of the report Volume VI ‘Water Resources Existing Facilities Rehabilitation and Capacity Improvement Project’ is derived for this Study. This unit price is prepared assuming that in case no irrigation water supply from the dam, three time cropping paddy will be changed to two times.

Table BC1.5 Economic Benefit of Irrigation Water Supply for Mrica Dam Downstream Irrigation

	Economic Irrigation Benefit Amount
Economic Irrigation Benefit for Mrica Dam Downstream Irrigation	10,000ha x Rp. 1,003,000/ha = Rp. 10,030 million

Source : Prepared by JICA Study Team

According to the review of the actual irrigation water supply record to the downstream irrigation, the irrigation water supply does not require in particular the effective reservoir capacity of the Mrica dam reservoir. It means that the irrigation water supply can be made as scheduled up-to 2021 when in case ‘Without Project’, the effective reservoir capacity is filled fully with the sedimentation, and the water supply can not be made after 2022.

In conclusion, the above economic irrigation benefit will be fully produced (100 %) from 2022 when the proposed dredging in the reservoir of around 12.5 MCM is completed.

BC1.4 Other benefit

Other benefits such as intangible benefit and the ripple effect benefit by implementation of the rehabilitation works can be counted as 15 % of the above total benefit of the power generation, the reduction of CO₂ and the irrigation water supply.

BC2. PRELIMINARY PROJECT COST

The project financial cost is the end of April, 2010 level and estimated referring to the unit prices of the similar projects in Indonesia. The results are shown in Table BC2.1.

The assumptions are as follows:

- (1) Exchange rate : 1US\$=94.07 JPYen, 1 Rp.=0.01143 JPYen
- (2) The engineering services (E/S) is 8 % of the direct cost. This includes the require cost for the topographical survey, the geological investigation and the environmental survey.
- (3) Project administration cost is 3 % of the direct cost plus the land acquisition and

compensation cost in the indirect cost.

(4) Physical contingencies is 15 % of the direct cost, the land acquisition and compensation cost, E/S and project administration cost in the indirect cost.

(5) Price contingencies is estimated referring to the similar projects in Indonesia as follows:

Foreign currency (FC); 1.3 % per annum, Local currency (LC); 3.2 % per annum

(6) Annual O/M cost:

- Dredging works cost is estimated based on Figure BC1.1 as follows:

2014-2017; 1 MCM/year, 2017-2026; 3 MCM/year, After 2027; 1.6 MCM

- Civil works O/M cost including O/M of gates is 0.1 % of the direct cost.

- Clearing cost of the sedimentation in the diversion weir and check dams

Total estimated sedimentation clearing volume: 280,000 m³/year (Refer to Appendix B)

These O/M works shall be directly made by the Owner of the Project.

The estimation results are shown in Table BC2.2

(7) Replacement cost for the generating equipment (G/E) in the Soedirman power station

The replacement shall be made one unit by one unit in 2033, 2034 and 2035, after 44 years since the commencement of the Soedirman power generation in 1989. The unit cost is estimated 20,000 yen/ kW.

Table BC2.1 Preliminary Project Cost for the Mrica Dam

PROJECT COST ESTIMATION		1Rp.=	0.01143	yen				
Bill No.	Description	Unit	Quantities	Unit / LS Price		Amount		Remarks
				FC(JPY)	LC (IDR)	FC(JPY)	LC (IDR)	
1. Direct Cost								
1.0	Diversion Weir							
1	Care of water	LS	1			18,000,000	1,228,000,000	
2	Open excavation, all classes	m3	540,000	250	14,000	135,000,000	7,560,000,000	
3	Sheet Piles for seepage stoppage	m	28,200	6,600	367,000	186,120,000	10,349,400,000	
4	BH Piling for foundation (0.8 m dia)	m	2,800	5,360	532,000	15,008,000	1,489,600,000	
5	Concrete for Weir	m3	139,000	2,320	334,000	322,480,000	46,426,000,000	
6	Reinforcement bars	ton	5,100	360	8,548,000	1,836,000	43,594,800,000	
7	Plate girder bridge	m2	1,200	48,000	6,480,000	57,600,000	7,776,000,000	
8	Miscellaneous	LS				184,011,000	29,605,950,000	25% of 1 to 7
9	Hydraulic spillway gates and others	ton	1,700	400,000	45,000,000	680,000,000	76,500,000,000	
	Sub-total 1.0					1,600,055,000	224,529,750,000	
2.0	Sediment flushing tunnel							
1	Open excavation, all classes	m3	22,000	250	14,000	5,500,000	308,000,000	
2	Concrete for intake and outlet structure	m3	8,000	2,320	334,000	18,560,000	2,672,000,000	
3	Tunnel excavation, all classes	m3	405,000	3,520	161,000	1,425,600,000	65,205,000,000	
4	Concrete for tunnel lining	m3	114,000	5,610	440,000	639,540,000	50,160,000,000	
5	Reinforcement bars	ton	6,000	2,190	9,036,000	13,140,000	54,216,000,000	
6	Screen	ton	15	200,000	22,500,000	3,000,000	337,500,000	
8	Miscellaneous	LS				315,801,000	25,934,775,000	15% of 1 to 7
	Hydraulic scouring gates and others	ton	130	400,000	45,000,000	52,000,000	5,850,000,000	
	Sub-total 2.0					2,473,141,000	204,683,275,000	
3.0	Compensation work for downstream							
1	Re-placement of downstream bridge	LS					21,000,000,000	
2	River bank protection works	LS					4,370,000,000	
	Sub-total 3.0					0	25,370,000,000	
4.0	Procurement and supply of Dredger system							
1	Cutter suction dredgers with accessories	nos.	3	610,000,000	0	1,830,000,000	0	
	Sub-total 4.0					1,830,000,000	0	
	Total of 1.					5,903,196,000	454,583,025,000	
2. Indirect Cost								
1.0	Land acquisition and compensation cost	m2	100,000		75,000	0	7,500,000,000	
2.0	Engineering services	LS				472,255,680	36,366,642,000	8 % of Total 1
3.0	Project administration	LS					29,131,443,506	3 % of the sum of Total 1 and 1.0 of 2, indirect
4.0	Physical contingencies	LS				956,317,752	79,137,166,576	15 % of Total 1 and, 1,2,3 of indirect cost
5.0	Price contingencies	LS				430,088,972	99,727,945,360	FC: 1.3 %, LC: 3.2 %
	Total of 2.					1,858,662,404	251,863,197,442	
	Grand total of 1 and 2					7,761,858,404	706,446,222,442	

Source : Prepared by JICA Study Team

Table BC2.2 Annual O/M Cost

Bill No.	Description	Unit	Quantities	Unit / LS Price		Amount		Remarks
				FC(JPY)	LC (IDR)	FC(JPY)	LC (IDR)	
1.0	Dredging in the reservoir							
	-2014-2016	m3	1,000,000		10,000		10,000,000,000	
	-2017-2025	m3	3,000,000		10,000		30,000,000,000	
	-After 2026	m3	1,600,000		10,000		16,000,000,000	
2.0	OM cost for diversion weir and sediment flushing tunnel	LS				5,903,000	454,583,000	0.1 % of direct cost
3.0	Cleaning sand and gravel in the check dams	m3	280,000	160	8,000	44,800,000	2,240,000,000	
2. Replacement cost of G/E in 2033,2034 and 2035 185MW								
	-2033					1,233,000,000		kW*20,000yen
	-2034					1,233,000,000		
	-2035					1,233,000,000		

Source : Prepared by JICA Study Team

period subject to evaluation the Soedirman's case is 10 years longer than the Sutami and Wlingi project because of the civil work in reservoir and dam rehabilitation as its main scope of work.

(2) Economic Cost

The economic cost of the rehabilitation work is based on the result of quality survey in the previous chapter. The cost section consists of construction cost, indirect cost and annual O&M cost. To calculate the economic cost, in addition to the exclusion of transfer account like tax and subsidy, the local currency portion of the cost is adjusted with the afore-mentioned value of SCF. Like what have been evaluated in Sutami and Wlingi project, economic cost here includes the following items:

1) Capital Cost (Initial Investment Cost in economic price)

Capital cost of the Soedirman project consists of construction cost (direct cost) and indirect cost. The former includes costs in items of diversion weir, sediment bypass tunnel, compensation work for down-stream, procurement and supply of dredging system, and the latter covers items of land acquisition and compensation cost, engineering services, project administration and physical contingencies. The values of local currency portion are all adjusted with the SCF of 0.9.

Table BC4.1 Capital Cost (Economic Price) (Unit: million Rp.)

Category	Total		1st year	2nd year	3rd year	4th year	5th year	6th year
			(2011)	(2012)	(2013)	(2014)	(2015)	(2016)
1.Construction Cost								
Diversion weir	FC	139,987	-	-	-	46,662	46,662	46,662
	LC	202,077	-	-	-	67,359	67,359	67,359
Sediment flushing tunnel	FC	216,373	-	-	-	72,124	72,124	72,124
	LC	184,215	-	-	-	61,405	61,405	61,405
Compensation work for down-stream	FC	-	-	-	-	-	-	-
	LC	22,833	-	-	-	7,611	7,611	7,611
Procu. and supply of dredging system	FC	160,105	-	-	160,105	-	-	-
	LC	-	-	-	-	-	-	-
Sub-total 1	FC	516,465	0	0	160,105	118,787	118,787	118,787
	LC	409,125	0	0	0	136,375	136,375	136,375
2. Indirect Cost								
Land axquisition and compensation cost	FC	-	-	-	-	-	-	-
	LC	6,750	-	-	6,750	-	-	-
Engineering services	FC	41,317	6,886	6,886	6,886	6,886	6,886	6,886
	LC	32,730	5,455	5,455	5,455	5,455	5,455	5,455
Project administration	FC	-	-	-	-	-	-	-
	LC	26,218	4,370	4,370	4,370	4,370	4,370	4,370
Physical contingencies	FC	83,667	-	-	-	27,889	27,889	27,889
	LC	71,223	-	-	-	23,741	23,741	23,741
Sub-total 2	FC	124,985	6,886	6,886	6,886	34,775	34,775	34,775
	LC	136,922	9,825	9,825	16,575	33,566	33,566	33,566
Total	FC	641,450	6,886	6,886	166,991	153,562	153,562	153,562
	LC	546,046	9,825	9,825	16,575	169,941	169,941	169,941
Grand Total	FC+LC	1,187,496	16,711	16,711	183,566	323,503	323,503	323,503

Source: Prepared by JICA Study Team

2) Annual O&M Cost (Economic price)

Table BC4.2 Annual O&M Cost (Economic Price) (Unit: million Rp.)

Year	Dredging in the Reservoir		O&M Cost for Diversion Weir and Flushing Tunnel			Sand and Gravel Cleaning for Check Dam			Total
	FC	LC	FC	LC	FC+LC	FC	LC	FC+LC	(FC+LC)
2014	-	9,000	-	-	-	-	-	-	9,000
2015	-	9,000	-	-	-	-	-	-	9,000
2016	-	9,000	-	-	-	-	-	-	9,000
2017	-	27,000	516	409	926	3,920	2,016	5,936	33,861
.....	-	14,400	516	409	925	3,920	2,016	5,936	21,261
2067	-	14,400	516	409	925	3,920	2,016	5,936	21,261

Prepared by JICA Study Team

Annual O&M cost is comprised of dredging in the reservoir, O&M Cost for Diversion Weir and Flushing Tunnel, and Sand and Gravel Cleaning for Check Dam. The cost for dredging in the reservoir will be paid out only by local currency, while the other cost items include both foreign currency portion and local currency portion. Again, all the values of local currency portion are converted into economic price with the SCF.

3) Replacement cost (Economic price)

Replacement cost for electric generators is expected to take place in 2033, 2034 and 2035, the value of cost in each of the 3 years will be estimated to be Rp. 107,874 million, with the unit price of 20,000yen/kW. As cost in this item is assumed to be paid out by foreign currency, price adjustment with SCF is not needed in this category.

(3) Economic Benefit

Benefit of this project is estimated through calculating the net increase of benefit resulted from the difference between With Project and Without Project. In the case of economic analysis, the economic benefit is reflected by the value of capacity benefit (kW value) and energy benefit (kWh value), which can be derived from the kW value and kWh value when introducing alternative power supply in the case of Without Project. Moreover, the saving of O&M cost and the value of CO₂ emission reduction are also considered the benefit of this project. Economic benefit mainly consists of the following items:

1) Cost of Alternative Power Supply

As explained in the section regarding economic analysis of Sutami project, the capacity benefit expressed by the difference of power capacity between With Project and Without Project could be understood as the annually averaged kW value of construction cost and constant cost of a new gas turbine plant, as the existing hydropower station is intended mainly for peak load. As for the energy benefit, it could be calculated using the kWh value of gas turbine plant (for peak load) and coal steam plant (for base load) and the difference of energy produced between With

Project and Without Project.

The unit values of capacity and energy for alternative power supply in the case of Without Project are adopted from the previously discussed Table BC1.3 and BC1.4. By using the kW value and kWh value, values of annual power benefit including capacity benefit and energy benefit are derived as shown in the following table.

Table BC4.3 Annual Energy and Capacity Benefit

Item	Unit	Without Project		With Project		Net
		Primary Energy	Secondary Energy	Primary Energy	Secondary Energy	
Annual Energy						
2014	GWh	158	285	158	285	-
2015	GWh	158	285	158	285	-
2016	GWh	158	285	158	285	
2017	GWh	158	285	145	160	-138
.....	GWh	0	0	145	160	305
2021	GWh	0	0	145	160	305
.....	GWh	0	0	145	160	305
2026~	GWh	0	0	145	160	305
Dependable Capacity						
2014	MW	89		89		0
2015	MW	87		88		1
2016	MW	85		87		2
2017	MW	82		86		4
.....	MW	0		86		86
2021	MW	0		91		91
.....	MW	0		91		91
2026~	MW	0		96		96
Energy Benefit: kWh Value						
2014	Rpmillion	111,703		111,703		-
2015	Rpmillion	111,703		111,703		-
2016	Rpmillion	111,703		111,703		-
2017	Rpmillion	111,703		89,717		-21,986
.....	Rpmillion	-		89,717		89,717
2021	Rpmillion	-		89,717		89,717
.....	Rpmillion	-		89,717		89,717
2026~	Rpmillion	-		89,717		89,717
Capacity Benefit: kW Value						
2014	Rpmillion	36,916		36,916		-
2015	Rpmillion	36,087		36,502		415
2016	Rpmillion	35,257		36,087		830
2017	Rpmillion	34,013		35,672		1,659
.....	Rpmillion	-		35,672		35,672
2021	Rpmillion	-		37,746		37,746

.....	Rpmillion	-	37,746	37,746
2026~	Rpmillion	-	39,820	39,820
Total Annual Benefit				
2014	Rpmillion	148,619	148,619	-
2015	Rpmillion	147,790	148,204	415
2016	Rpmillion	146,960	147,790	830
2017	Rpmillion	145,716	125,389	-20,327
.....	Rpmillion	-	125,389	125,389
2021	Rpmillion	-	127,463	127,463
.....	Rpmillion	-	127,463	127,463
2026~	Rpmillion	-	129,537	129,537

Source: Prepared by JICA Study Team

2) Irrigation Benefit

The assumption regarding calculation of irrigation benefit can be referred to (3) for explanation in details. Based on this assumption, the annual irrigation benefit brought by the implementation of the Soedirman project is expected to be Rp. 10,030 million.

3) Net Increase of Mini Hydro Power

With the reservoir assumed to totally stop functioning from 2021 onward in the case of Without Project, the net increase of mini hydro power generation expected to be 5 GWh/year, from which the economic price of this benefit can be derived as Rp. 628 million/year by using the unit cost of coal-generated electricity.

4) Reduction of CO2 Emission

The benefit of CO2 Emission reduction is assumed to be the net increase of energy achieved by the project converted to the money value. The CO2 conversion factor and emissions trading rate adopted for the calculation are referred to (2) in BC 1 of PART C. With respect to this item, two cases are assumed, with Case 1 ignoring the benefit of CO2 reduction and Case 2 taking it into consideration.

5) Other benefits

Other benefits such as intangible benefit and the ripple effect benefit by implementation of the rehabilitation works will be counted as 15 % of the above total benefit of the power generation, the reduction of CO2 and the irrigation water supply.

(4) Calculation of EIRR

EIRR of Case 1 and Case 2 are calculated by using the values of economic cost and benefit, arranged in the two cash flow tables as shown in Tables BC4.5 and BC4.6. Major results are as follows:

Table BC4.5 EIRR (Ignoring Benefit of CO2 Reduction) Soedirman Case1

	Capital Cost	O&M Cost				Total Cost	Benefit						Net Economic Benefit
		Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Power Benefit	Irrigation	Mini Hydro	Reduction of CO2	Other Benefit	Total	
2011	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
12	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
13	183,566	-	-	-	-	183,566	-	-	-	-	-	-	-183,566
14	323,503	9,000	-	-	-	332,503	-	-	-	-	-	-	-332,503
15	323,503	9,000	-	-	-	332,503	415	-	-	-	62	477	-332,026
16	323,503	9,000	-	-	-	332,503	830	-	-	-	125	955	-331,549
17	-	27,000	926	5,936	-	33,861	20,327	-	-	-	-3,049	-23,376	-57,237
18	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
19	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
2020	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
21	-	27,000	926	5,936	-	33,861	127,463	-	628	-	19,214	147,305	113,444
22	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
23	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
24	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
25	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
26	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
27	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
28	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
29	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
2030	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
31	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
32	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
33	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	-	21,029	161,224	32,089
34	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	-	21,029	161,224	32,089
35	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	-	21,029	161,224	32,089
36	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
37	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
38	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
39	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
2040	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
41	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
42	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
43	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
44	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
45	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
46	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
47	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
48	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
49	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
2050	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
51	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
52	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
53	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
54	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
55	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
56	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
57	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
58	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
59	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
2060	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
61	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
62	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
63	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
64	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
65	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
66	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
67	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963

EIRR= 7.861%
 ENPV(US\$)= -201,300
 PV(cost)= 981,170
 PV(benefit)= 779,870
 B/C= 0.7948368

Source: Prepared by JICA Study Team

Table BC4.6 EIRR (Considering Benefit of CO2 Reduction) Soedirman Case2

	Capital Cost	O&M Cost				Total Cost	Benefit						Net Economic Benefit
		Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Power Benefit	Irrigation	Mini Hydro	Reduction of CO2	Other Benefit	Total	
2011	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
12	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
13	183,566	-	-	-	-	183,566	-	-	-	-	-	-	-183,566
14	323,503	9,000	-	-	-	332,503	-	-	-	-	-	-	-332,503
15	323,503	9,000	-	-	-	332,503	415	-	-	-	62	477	-332,026
16	323,503	9,000	-	-	-	332,503	830	-	-	-	125	955	-331,549
17	-	27,000	926	5,936	-	33,861	20,327	-	-	-	-3,049	-23,376	-57,237
18	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
19	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
2020	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
21	-	27,000	926	5,936	-	33,861	127,463	-	628	-	19,214	147,305	113,444
22	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
23	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
24	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
25	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
26	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
27	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
28	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
29	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
2030	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
31	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
32	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
33	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	30,206	25,560	195,961	66,826
34	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	30,206	25,560	195,961	66,826
35	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	30,206	25,560	195,961	66,826
36	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
37	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
38	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
39	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
2040	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
41	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
42	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
43	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
44	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
45	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
46	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
47	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
48	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
49	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
2050	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
51	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
52	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
53	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
54	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
55	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
56	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
57	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
58	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
59	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
2060	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
61	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
62	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
63	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
64	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
65	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
66	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
67	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700

EIRR= 8.829%

ENPV(US\$)= -119,661

PV(cost)= 981,170

PV(benefit)= 861,509

B/C= 0.8780425

Source: Prepared by JICA Study Team

Table BC4.7 Major Results of Economic Analysis for Case 1 and Case 2

Case	EIRR	ENPV	B/C
1	7.9%	Rp.- 201, 300 million	0.8
2	8.8%	Rp. -119,661 million	0.9

Source: Prepared by JICA Survey Team

In Case 1 where the benefit of CO₂ reduction is disregarded, the value of EIRR is 7.9%, more than 2 point falling short of the Social Discount Rate, ENPV comes out as a negative value and the value of B/C is less than 1.

Regarding Case 2 which takes into account the benefit of CO₂ reduction, the value of EIRR rises to 8.8% though still falls short of the social Discount Rate.

(5) Sensitivity Analysis

1) Assumptions for Analysis

Three scenarios are assumed below for Case 1 and Case 2 respectively:

Scenario 1: Construction cost rises by 10% and 20%.

Scenario 2: Fuel cost for alternative power supply lowers by 10% and 20%.

Scenario 3: Construction cost rises by 20% concurrently with the decline of fuel cost by 20% for alternative power supply.

2) Results of Analysis

The results of sensitivity analysis regarding Case 1 and Case 2 are indicated in the following two tables.

The value of EIRR in Case 1 is expected to vary within the range between 5.8% and 7.4% with the change of scenario assumed above. In Case 2, the range within which the EIRR value will change is expected to be between 7.0% and 8.3%.

Table BC4.8 Results of Sensitivity Analysis for Case 1

Scenario	1a	1b	2a	2b	3
EIRR	7.4%	6.9%	7.3%	6.7%	5.8%
ENPV(million Rp)	-261,002	-320,706	-251,755	-300,755	-422,915
B/C	0.7	0.7	0.7	0.7	0.6

Source: Prepared by JICA Study Team

Table BC4.9 Results of Sensitivity Analysis for Case 2

Scenario	1a	1b	2a	2b	3
EIRR	8.3%	7.9%	8.3%	7.8%	7.0%
ENPV(million Rp)	-179,363	-239,068	-170,116	-219,116	-338,523
B/C	0.8	0.8	0.8	0.8	0.7

Source: Prepared by JICA Study Team

BC4.2 Financial Analysis

(1) Financial Cost

The financial cost of the rehabilitation work consists of the following items:

1) Capital Cost (Initial Investment Cost in financial price)

The table below shows the relevant values.

Table BC4.10 Capital Cost (Financial Price) (Unit: million Rp.)

Category	Total		1st year	2nd year	3rd year	4th year	5th year	6th year
			(2011)	(2012)	(2013)	(2014)	(2015)	(2016)
1.Construction Cost								
Diversion weir	FC	139,987	-	-	-	46,662	46,662	46,662
	LC	224,530	-	-	-	74,843	74,843	74,843
Sediment flushing tunnel	FC	216,373	-	-	-	72,124	72,124	72,124
	LC	204,683	-	-	-	68,228	68,228	68,228
Compensation work for down-stream	FC	-	-	-	-	-	-	-
	LC	25,370	-	-	-	8,457	8,457	8,457
Procu. and supply of dredging system	FC	160,105	-	-	160,105	-	-	-
	LC	-	-	-	-	-	-	-
Sub-total 1	FC	516,465	0	0	160,105	118,787	118,787	118,787
	LC	454,583	0	0	0	151,528	151,528	151,528
2. Indirect Cost								
Land axquisition and compensation cost	FC	-	-	-	-	-	-	-
	LC	7,500	-	-	7,500	-	-	-
Engineering services	FC	41,317	6,886	6,886	6,886	6,886	6,886	6,886
	LC	36,367	6,061	6,061	6,061	6,061	6,061	6,061
Project administration	FC	-	-	-	-	-	-	-
	LC	29,131	4,855	4,855	4,855	4,855	4,855	4,855
Physical contingencies	FC	83,667	-	-	-	27,889	27,889	27,889
	LC	79,137	-	-	-	26,379	26,379	26,379
Sub-total 2	FC	124,985	6,886	6,886	6,886	34,775	34,775	34,775
	LC	152,135	10,916	10,916	18,416	37,295	37,295	37,295
Total	FC	641,450	6,886	6,886	166,991	153,562	153,562	153,562
	LC	606,718	10,916	10,916	18,416	188,823	188,823	188,823
Grand Total	FC+LC	1,248,168	17,803	17,803	185,408	342,385	342,385	342,385

Source: Prepared by JICA Study Team

2) Annual O&M Cost (financial price)

The values of foreign currency portion items in annual O&M cost are the same as what can be seen in the case of economic analysis, while the values of local currency portion are different from that of the economic price in that adjustment with SCF is not needed here.

Table BC4.11 Annual O&M Cost (Financial Price) (Unit: million Rp.)

Year	Dredging in the Reservoir		O&M Cost for Diversion Weir and Flushing Tunnel			Sand and Gravel Cleaning for Check Dam			Total
	FC	LC	FC	LC	FC+LC	FC	LC	FC+LC	
2014	0	10,000	0	0	0	0	0	0	10,000
2015	0	10,000	0	0	0	0	0	0	10,000
2016	0	10,000	0	0	0	0	0	0	10,000
2017	0	30,000	516	455	971	3,920	2,240	6,160	37,131
.....	0	16,000	516	455	971	3,920	2,240	6,160	23,131
2067	0	16,000	516	455	971	3,920	2,240	6,160	23,131

Source: Prepared by JICA Study Team

3) Replacement Cost

Replacement cost values used in financial analysis are the same as those in the economic analysis, as cost of this item is assumed to be paid out by yen-loan.

(2) Financial Benefit

Financial benefit consists of increase of electric tariff revenue and irrigation benefit as follows:

1) Increase of Electric Tariff Revenue

Values of annual net increase of energy over the project period are presumed to be as follows.

Table BC4.12 Net Increase of Energy and Tariff Revenue

Year	Without Project			With Project			Net Increase of Energy (GWh)	Net Increase of Tariff Revenue (Milli. Rp)
	Primary Energy (GWh)	Secondary Energy (GWh)	Total of Without Project (GWh)	Primary Energy (GWh)	Secondary Energy (GWh)	Total of With Project (GWh)		
2014	158	285	443	158	285	443	0	0
.....	158	285	443	158	285	443	0	0
2017	158	285	443	145	160	305	- 138	-90,114
.....	0	0	0	145	160	305	305	199,165
2026~	0	0	0	145	160	305	305	199,165

Source: Prepared by JICA Study Team

2) Irrigation Benefit

With respect to Irrigation benefit, as financial price is adopted here, the values are different from that of the economic price denoted in the previous section of economic analysis by the exemption of SCF adjustment.

3) Net Increase of Mini Hydro Power

Net increase of mini hydro power from 2021 onward is supposed to be the same as the value estimated in the section of economic analysis, but the money value of benefit in financial price is calculated as Rp.3,265 million/year by using the average electric tariff as of 2008.

(3) Calculation of FIRR

FIRR is calculated by using the values of financial cost and benefit, which are arranged in the cash flow table as shown in Table BC4.13. Major results are as follows:

Table BC4.13 Major Results of Economic Analysis

FIRR	FNPV	B/C
9.8%	Rp.-18,521 million	0.98

Source: Prepared by JICA Survey Team

The results show that although the FIRR value is 9.8%, slightly lower than the Social Discount Rate, FNPV appears to be a negative value, and the value of B/C is below 1.

(4) Sensitivity Analysis

1) Assumptions for Analysis

Three scenarios are assumed below:

Scenario 1: Construction cost rises by 10% and 20%.

Scenario 2: Electric tariff lowers by 10% and 20%.

Scenario 3: Construction cost rises by 20% concurrently with the decline of electric tariff by 20%.

2) Results of Analysis

The results of sensitivity analysis are indicated in the following table.

The value of FIRR is expected to vary within the range between 6.8% and 9.1% with the change of previous assumptions for the project. Under the strictest conditions assumed in Scenario 3, the value of FIRR is expected to fall 3 points from the original case, and the B/C value will slip to 0.7.

Table BC4.14 Results of Sensitivity Analysis

Scenario	1a	1b	2a	2b	3
FIRR	9.1%	8.5%	8.9%	7.9%	6.8%
FNPV(million Rp)	-99,513	-180,505	-115,227	-211,938	-373,921
B/C	0.9	0.8	0.9	0.8	0.7

Source: Prepared by JICA Study Team

Attachment of Part D (Sensitivity Analysis)

Economic Internal Rate of Return (Ignoring Benefit of CO2 Reduction)

Soedirman Case 1

	Capital Cost	O&M Cost				Total Cost	Benefit						Net Economic Benefit
		Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Power Benefit	Irrigation	Mini Hydro	Reduction of CO2	Other Benefit	Total	
2011	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
12	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
13	183,566	-	-	-	-	183,566	-	-	-	-	-	-	-183,566
14	323,503	9,000	-	-	-	332,503	-	-	-	-	-	-	-332,503
15	323,503	9,000	-	-	-	332,503	415	-	-	-	62	477	-332,026
16	323,503	9,000	-	-	-	332,503	830	-	-	-	125	955	-331,549
17	-	27,000	926	5,936	-	33,861	20,327	-	-	-	-3,049	-23,376	-57,237
18	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
19	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
2020	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
21	-	27,000	926	5,936	-	33,861	127,463	-	628	-	19,214	147,305	113,444
22	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
23	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
24	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
25	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
26	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
27	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
28	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
29	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
2030	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
31	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
32	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
33	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	-	21,029	161,224	32,089
34	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	-	21,029	161,224	32,089
35	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	-	21,029	161,224	32,089
36	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
37	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
38	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
39	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
2040	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
41	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
42	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
43	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
44	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
45	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
46	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
47	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
48	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
49	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
2050	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
51	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
52	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
53	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
54	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
55	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
56	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
57	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
58	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
59	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
2060	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
61	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
62	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
63	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
64	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
65	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
66	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
67	-	14,400	926	5,936	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963

EIRR= 7.861%

ENPV(US\$)= -201,300

PV(cost)= 981,170

PV(benefit)= 779,870

B/C= 0.7948368

Economic Internal Rate of Return (Considering Benefit of CO2 Reduction)

Soedirman Case 2

	Capital Cost	O&M Cost				Total Cost	Benefit						Net Economic Benefit
		Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Power Benefit	Irrigation	Mini Hydro	Reduction of CO2	Other Benefit	Total	
2011	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
12	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
13	183,566	-	-	-	-	183,566	-	-	-	-	-	-	-183,566
14	323,503	9,000	-	-	-	332,503	-	-	-	-	-	-	-332,503
15	323,503	9,000	-	-	-	332,503	415	-	-	-	62	477	-332,026
16	323,503	9,000	-	-	-	332,503	830	-	-	-	125	955	-331,549
17	-	27,000	926	5,936	-	33,861	20,327	-	-	-	-3,049	-23,376	-57,237
18	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
19	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
2020	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
21	-	27,000	926	5,936	-	33,861	127,463	-	628	-	19,214	147,305	113,444
22	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
23	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
24	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
25	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
26	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
27	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
28	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
29	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
2030	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
31	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
32	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
33	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	30,206	25,560	195,961	66,826
34	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	30,206	25,560	195,961	66,826
35	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	30,206	25,560	195,961	66,826
36	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
37	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
38	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
39	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
2040	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
41	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
42	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
43	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
44	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
45	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
46	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
47	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
48	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
49	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
2050	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
51	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
52	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
53	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
54	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
55	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
56	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
57	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
58	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
59	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
2060	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
61	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
62	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
63	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
64	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
65	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
66	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
67	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700

EIRR= 8.829%

ENPV(US\$)= -119,661

PV(cost)= 981,170

PV(benefit)= 861,509

B/C= 0.8780425

Financial Internal Rate of Return (Considering Reduction of CO2 Benefit) Mrica Power Station

(Unit: million Rp)

Year		Capital Cost	O&M Cost				Total Cost	Revenue				Net Economic Benefit
			Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Power Benefit	Irrigation	Reduction of CO2	Total	
1	2011	17,803	-	-	-	-	17,803	-	-	-	-	-17,803
2	12	17,803	-	-	-	-	17,803	-	-	-	-	-17,803
3	13	185,408	-	-	-	-	185,408	-	-	-	-	-185,408
4	14	342,385	10,000	-	-	-	352,385	-	-	-	-	-352,385
5	15	342,385	10,000	-	-	-	352,385	-	-	-	-	-352,385
6	16	342,385	10,000	-	-	-	352,385	-	-	-	-	-352,385
7	17	-	30,000	971	6,160	-	37,131	199,165	-	-	199,165	162,034
8	18	-	30,000	971	6,160	-	37,131	126,846	-	-	126,846	89,715
9	19	-	30,000	971	6,160	-	37,131	54,527	-	-	54,527	17,396
10	2020	-	30,000	971	6,160	-	37,131	17,792	-	-	-17,792	-54,923
11	21	-	30,000	971	6,160	-	37,131	200,990	-	-	200,990	163,859
12	22	-	30,000	971	6,160	-	37,131	200,990	11,144	-	212,134	175,003
13	23	-	30,000	971	6,160	-	37,131	200,990	11,144	-	212,134	175,003
14	24	-	30,000	971	6,160	-	37,131	200,990	11,144	-	212,134	175,003
15	25	-	30,000	971	6,160	-	37,131	200,990	11,144	-	212,134	175,003
16	26	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
17	27	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
18	28	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
19	29	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
20	2030	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
21	31	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
22	32	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
23	33	-	16,000	971	6,160	107,874	131,005	200,990	11,144	24,226	236,360	105,355
24	34	-	16,000	971	6,160	107,874	131,005	200,990	11,144	24,226	236,360	105,355
25	35	-	16,000	971	6,160	107,874	131,005	200,990	11,144	24,226	236,360	105,355
26	36	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
27	37	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
28	38	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
29	39	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
30	2040	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
31	41	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
32	42	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
33	43	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
34	44	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
35	45	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
36	46	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
37	47	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
38	48	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
39	49	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
40	2050	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
41	51	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
42	52	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
43	53	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
44	54	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
45	55	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
46	56	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
47	57	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
48	58	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
49	59	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
50	2060	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
51	61	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
52	62	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
53	63	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
54	64	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
55	65	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
56	66	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229
57	67	-	16,000	971	6,160	-	23,131	200,990	11,144	24,226	236,360	213,229

FIRR= 10.024%

FNPV(millionRp)= 2,647

PV(cost)= 1,036,621

PV(benefit)= 1,039,268

B/C= 1.0

Financial Internal Rate of Return							Soedirman					
							(Unit: million Rp)					
Year		Capital Cost	O&M Cost				Total Cost	Revenue				Net Economic Benefit
			Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Increase of Tariff Revenue	Mini Hydro	Irrigation	Total	
1	2011	17,803	-	-	-	-	17,803	-	-	-	-	17,803
2	12	17,803	-	-	-	-	17,803	-	-	-	-	17,803
3	13	185,408	-	-	-	-	185,408	-	-	-	-	185,408
4	14	342,385	10,000	-	-	-	352,385	-	-	-	-	352,385
5	15	342,385	10,000	-	-	-	352,385	-	-	-	-	352,385
6	16	342,385	10,000	-	-	-	352,385	-	-	-	-	352,385
7	17	-	30,000	971	6,160	-	37,131	90,114	-	-	90,114	127,245
8	18	-	30,000	971	6,160	-	37,131	199,165	-	-	199,165	162,034
9	19	-	30,000	971	6,160	-	37,131	199,165	-	-	199,165	162,034
10	2020	-	30,000	971	6,160	-	37,131	199,165	-	-	199,165	162,034
11	21	-	30,000	971	6,160	-	37,131	199,165	3,265	-	202,430	165,299
12	22	-	30,000	971	6,160	-	37,131	199,165	3,265	11,144	213,574	176,443
13	23	-	30,000	971	6,160	-	37,131	199,165	3,265	11,144	213,574	176,443
14	24	-	30,000	971	6,160	-	37,131	199,165	3,265	11,144	213,574	176,443
15	25	-	30,000	971	6,160	-	37,131	199,165	3,265	11,144	213,574	176,443
16	26	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
17	27	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
18	28	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
19	29	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
20	2030	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
21	31	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
22	32	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
23	33	-	16,000	971	6,160	107,874	131,005	199,165	3,265	11,144	213,574	82,569
24	34	-	16,000	971	6,160	107,874	131,005	199,165	3,265	11,144	213,574	82,569
25	35	-	16,000	971	6,160	107,874	131,005	199,165	3,265	11,144	213,574	82,569
26	36	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
27	37	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
28	38	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
29	39	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
30	2040	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
31	41	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
32	42	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
33	43	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
34	44	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
35	45	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
36	46	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
37	47	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
38	48	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
39	49	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
40	2050	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
41	51	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
42	52	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
43	53	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
44	54	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
45	55	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
46	56	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
47	57	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
48	58	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
49	59	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
50	2060	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
51	61	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
52	62	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
53	63	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
54	64	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
55	65	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
56	66	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
57	67	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443
FIRR=												9.826%
FNPV(millionRp)=												18,521
PV(cost)=												1,036,621
PV(benefit)=												1,018,100
B/C=												0.982132861

Economic Internal Rate of Return (Ignoring Benefit of CO2 Reduction)

Soedirman Case 1

		Capital Cost	O&M Cost				Total Cost	Benefit						Net Economic Benefit
			Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Power Benefit	Irrigation	Mini Hydro	Reduction of CO2	Other Benefit	Total	
2011	16,711	-	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
12	16,711	-	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
13	199,575	-	-	-	-	-	199,575	-	-	-	-	-	-	-199,575
14	349,019	9,000	-	-	-	-	358,019	-	-	-	-	-	-	-358,019
15	349,019	9,000	-	-	-	-	358,019	415	-	-	-	62	477	-357,542
16	349,019	9,000	-	-	-	-	358,019	830	-	-	-	125	955	-357,065
17	-	27,000	926	5,936	-	-	33,861	20,327	-	-	-	-3,049	-23,376	-57,237
18	-	27,000	926	5,936	-	-	33,861	125,389	-	-	-	18,808	144,197	110,336
19	-	27,000	926	5,936	-	-	33,861	125,389	-	-	-	18,808	144,197	110,336
2020	-	27,000	926	5,936	-	-	33,861	125,389	-	-	-	18,808	144,197	110,336
21	-	27,000	926	5,936	-	-	33,861	127,463	-	628	-	19,214	147,305	113,444
22	-	27,000	926	5,936	-	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
23	-	27,000	926	5,936	-	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
24	-	27,000	926	5,936	-	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
25	-	27,000	926	5,936	-	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
26	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
27	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
28	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
29	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
2030	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
31	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
32	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
33	-	14,400	926	5,936	107,874	-	129,135	129,537	10,030	628	-	21,029	161,224	32,089
34	-	14,400	926	5,936	107,874	-	129,135	129,537	10,030	628	-	21,029	161,224	32,089
35	-	14,400	926	5,936	107,874	-	129,135	129,537	10,030	628	-	21,029	161,224	32,089
36	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
37	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
38	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
39	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
2040	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
41	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
42	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
43	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
44	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
45	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
46	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
47	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
48	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
49	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
2050	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
51	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
52	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
53	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
54	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
55	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
56	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
57	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
58	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
59	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
2060	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
61	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
62	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
63	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
64	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
65	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
66	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
67	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963

EIRR= 7.380%
ENPV(US\$)= -261,002
PV(cost)= 1,040,872
PV(benefit)= 779,870
B/C= 0.74924668

Economic Internal Rate of Return (Ignoring Benefit of CO2 Reduction)

Soedirman Case 1

		Capital Cost	O&M Cost				Total Cost	Benefit						Net Economic Benefit
			Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Power Benefit	Irrigation	Mini Hydro	Reduction of CO2	Other Benefit	Total	
2011	16,711	-	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
12	16,711	-	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
13	215,587	-	-	-	-	-	215,587	-	-	-	-	-	-	-215,587
14	374,535	9,000	-	-	-	-	383,535	-	-	-	-	-	-	-383,535
15	374,535	9,000	-	-	-	-	383,535	415	-	-	-	62	477	-383,058
16	374,535	9,000	-	-	-	-	383,535	830	-	-	-	125	955	-382,581
17	-	27,000	926	5,936	-	-	33,861	20,327	-	-	-	-3,049	-23,376	-57,237
18	-	27,000	926	5,936	-	-	33,861	125,389	-	-	-	18,808	144,197	110,336
19	-	27,000	926	5,936	-	-	33,861	125,389	-	-	-	18,808	144,197	110,336
2020	-	27,000	926	5,936	-	-	33,861	125,389	-	-	-	18,808	144,197	110,336
21	-	27,000	926	5,936	-	-	33,861	127,463	-	628	-	19,214	147,305	113,444
22	-	27,000	926	5,936	-	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
23	-	27,000	926	5,936	-	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
24	-	27,000	926	5,936	-	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
25	-	27,000	926	5,936	-	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
26	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
27	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
28	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
29	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
2030	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
31	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
32	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
33	-	14,400	926	5,936	107,874	-	129,135	129,537	10,030	628	-	21,029	161,224	32,089
34	-	14,400	926	5,936	107,874	-	129,135	129,537	10,030	628	-	21,029	161,224	32,089
35	-	14,400	926	5,936	107,874	-	129,135	129,537	10,030	628	-	21,029	161,224	32,089
36	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
37	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
38	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
39	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
2040	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
41	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
42	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
43	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
44	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
45	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
46	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
47	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
48	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
49	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
2050	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
51	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
52	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
53	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
54	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
55	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
56	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
57	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
58	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
59	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
2060	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
61	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
62	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
63	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
64	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
65	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
66	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963
67	-	14,400	926	5,936	-	-	21,261	129,537	10,030	628	-	21,029	161,224	139,963

EIRR= 6.947%
ENPV(US\$)= -320,706
PV(cost)= 1,100,576
PV(benefit)= 779,870
B/C= 0.70860133

Economic Internal Rate of Return (Ignoring Benefit of CO2 Reduction)

Soedirman Case 1

		Capital Cost	O&M Cost				Total Cost	Benefit						Net Economic Benefit
			Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Power Benefit	Irrigation	Mini Hydro	Reduction of CO2	Other Benefit	Total	
2011	16,711	-	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
12	16,711	-	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
13	183,566	-	-	-	-	-	183,566	-	-	-	-	-	-	-183,566
14	323,503	9,000	-	-	-	-	332,503	-	-	-	-	-	-	-332,503
15	323,503	9,000	-	-	-	-	332,503	415	-	-	-	62	477	-332,026
16	323,503	9,000	-	-	-	-	332,503	830	-	-	-	125	955	-331,549
17	-	27,000	926	5,936	-	-	33,861	18,207	-	-	-	-2,731	-20,938	-54,799
18	-	27,000	926	5,936	-	-	33,861	116,552	-	-	-	17,483	134,035	100,174
19	-	27,000	926	5,936	-	-	33,861	116,552	-	-	-	17,483	134,035	100,174
2020	-	27,000	926	5,936	-	-	33,861	116,552	-	-	-	17,483	134,035	100,174
21	-	27,000	926	5,936	-	-	33,861	118,626	-	628	-	17,888	137,142	103,281
22	-	27,000	926	5,936	-	-	33,861	118,626	10,030	628	-	19,393	148,677	114,816
23	-	27,000	926	5,936	-	-	33,861	118,626	10,030	628	-	19,393	148,677	114,816
24	-	27,000	926	5,936	-	-	33,861	118,626	10,030	628	-	19,393	148,677	114,816
25	-	27,000	926	5,936	-	-	33,861	118,626	10,030	628	-	19,393	148,677	114,816
26	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
27	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
28	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
29	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
2030	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
31	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
32	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
33	-	14,400	926	5,936	107,874	-	129,135	120,700	10,030	628	-	19,704	151,062	21,927
34	-	14,400	926	5,936	107,874	-	129,135	120,700	10,030	628	-	19,704	151,062	21,927
35	-	14,400	926	5,936	107,874	-	129,135	120,700	10,030	628	-	19,704	151,062	21,927
36	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
37	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
38	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
39	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
2040	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
41	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
42	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
43	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
44	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
45	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
46	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
47	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
48	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
49	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
2050	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
51	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
52	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
53	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
54	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
55	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
56	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
57	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
58	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
59	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
2060	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
61	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
62	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
63	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
64	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
65	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
66	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801
67	-	14,400	926	5,936	-	-	21,261	120,700	10,030	628	-	19,704	151,062	129,801

EIRR= 7.283%

ENPV(US\$)= -251,755

PV(cost)= 981,170

PV(benefit)= 729,415

B/C= 0.74341383

Economic Internal Rate of Return (Ignoring Benefit of CO2 Reduction)

Soedirman Case 1

		Capital Cost	O&M Cost				Total Cost	Benefit						Net Economic Benefit
			Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Power Benefit	Irrigation	Mini Hydro	Reduction of CO2	Other Benefit	Total	
2011	16,711	-	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
12	16,711	-	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
13	183,566	-	-	-	-	-	183,566	-	-	-	-	-	-	-183,566
14	323,503	9,000	-	-	-	-	332,503	-	-	-	-	-	-	-332,503
15	323,503	9,000	-	-	-	-	332,503	415	-	-	-	62	477	-332,026
16	323,503	9,000	-	-	-	-	332,503	830	-	-	-	125	955	-331,549
17	-	27,000	926	5,936	-	-	33,861	16,221	-	-	-	-2,433	-18,654	-52,515
18	-	27,000	926	5,936	-	-	33,861	107,977	-	-	-	16,197	124,174	90,312
19	-	27,000	926	5,936	-	-	33,861	107,977	-	-	-	16,197	124,174	90,312
2020	-	27,000	926	5,936	-	-	33,861	107,977	-	-	-	16,197	124,174	90,312
21	-	27,000	926	5,936	-	-	33,861	110,051	-	628	-	16,602	127,281	93,420
22	-	27,000	926	5,936	-	-	33,861	110,051	10,030	628	-	18,106	138,815	104,954
23	-	27,000	926	5,936	-	-	33,861	110,051	10,030	628	-	18,106	138,815	104,954
24	-	27,000	926	5,936	-	-	33,861	110,051	10,030	628	-	18,106	138,815	104,954
25	-	27,000	926	5,936	-	-	33,861	110,051	10,030	628	-	18,106	138,815	104,954
26	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
27	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
28	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
29	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
2030	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
31	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
32	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
33	-	14,400	926	5,936	107,874	-	129,135	112,125	10,030	628	-	18,417	141,200	12,065
34	-	14,400	926	5,936	107,874	-	129,135	112,125	10,030	628	-	18,417	141,200	12,065
35	-	14,400	926	5,936	107,874	-	129,135	112,125	10,030	628	-	18,417	141,200	12,065
36	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
37	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
38	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
39	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
2040	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
41	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
42	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
43	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
44	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
45	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
46	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
47	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
48	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
49	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
2050	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
51	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
52	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
53	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
54	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
55	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
56	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
57	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
58	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
59	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
2060	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
61	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
62	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
63	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
64	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
65	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
66	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939
67	-	14,400	926	5,936	-	-	21,261	112,125	10,030	628	-	18,417	141,200	119,939

EIRR= 6.703%

ENPV(US\$)= -300,755

PV(cost)= 981,170

PV(benefit)= 680,414

B/C= 0.69347269

Economic Internal Rate of Return (Ignoring Benefit of CO2 Reduction)

Soedirman Case 1

	Year	Capital Cost	O&M Cost				Total Cost	Benefit					Net Economic Benefit
			Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Power Benefit	Irrigation	Reduction of CO2	Other Benefit	Total	
2011	12	16,711	-	-	-	-	16,711	-	-	-	-	-	-16,711
	13	16,711	-	-	-	-	16,711	-	-	-	-	-	-16,711
	14	215,587	-	-	-	-	215,587	-	-	-	-	-	-215,587
	15	374,535	9,000	-	-	-	383,535	-	-	-	-	-	-383,535
	16	374,535	9,000	-	-	-	383,535	415	-	-	62	477	-383,058
	17	374,535	9,000	-	-	-	383,535	830	-	-	125	955	-382,581
	18	-	27,000	926	5,936	-	33,861	16,221	-	-	-2,433	-18,654	-52,515
	19	-	27,000	926	5,936	-	33,861	107,977	-	-	16,197	124,174	90,312
	20	-	27,000	926	5,936	-	33,861	107,977	-	-	16,197	124,174	90,312
	21	-	27,000	926	5,936	-	33,861	110,051	-	-	16,508	126,559	92,698
	22	-	27,000	926	5,936	-	33,861	110,051	10,030	-	18,012	138,093	104,232
	23	-	27,000	926	5,936	-	33,861	110,051	10,030	-	18,012	138,093	104,232
	24	-	27,000	926	5,936	-	33,861	110,051	10,030	-	18,012	138,093	104,232
	25	-	27,000	926	5,936	-	33,861	110,051	10,030	-	18,012	138,093	104,232
	26	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	27	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	28	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	29	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	30	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	31	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	32	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	33	-	14,400	926	5,936	107,874	129,135	112,125	10,030	-	18,323	140,478	11,343
	34	-	14,400	926	5,936	107,874	129,135	112,125	10,030	-	18,323	140,478	11,343
	35	-	14,400	926	5,936	107,874	129,135	112,125	10,030	-	18,323	140,478	11,343
	36	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	37	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	38	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	39	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	40	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	41	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	42	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	43	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	44	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	45	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	46	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	47	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	48	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	49	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	50	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	51	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	52	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	53	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	54	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	55	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	56	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	57	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	58	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	59	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	60	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	61	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	62	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	63	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	64	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	65	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	66	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217
	67	-	14,400	926	5,936	-	21,261	112,125	10,030	-	18,323	140,478	119,217

EIRR= 5.843%

ENPV(US\$)= -422,915

PV(cost)= 1,100,576

PV(benefit)= 677,661

B/C= 0.61573344

Economic Internal Rate of Return (Considering Benefit of CO2 Reduction)

Soedirman Case 2

	Capital Cost	O&M Cost				Total Cost	Benefit						Net Economic Benefit
		Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Power Benefit	Irrigation	Mini Hydro	Reduction of CO2	Other Benefit	Total	
2011	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
12	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
13	199,575	-	-	-	-	199,575	-	-	-	-	-	-	-199,575
14	349,019	9,000	-	-	-	358,019	-	-	-	-	-	-	-358,019
15	349,019	9,000	-	-	-	358,019	415	-	-	-	62	477	-357,542
16	349,019	9,000	-	-	-	358,019	830	-	-	-	125	955	-357,065
17	-	27,000	926	5,936	-	33,861	20,327	-	-	-	-3,049	-23,376	-57,237
18	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
19	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
2020	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
21	-	27,000	926	5,936	-	33,861	127,463	-	628	-	19,214	147,305	113,444
22	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
23	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
24	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
25	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
26	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
27	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
28	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
29	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
2030	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
31	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
32	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
33	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	30,206	25,560	195,961	66,826
34	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	30,206	25,560	195,961	66,826
35	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	30,206	25,560	195,961	66,826
36	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
37	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
38	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
39	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
2040	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
41	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
42	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
43	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
44	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
45	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
46	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
47	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
48	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
49	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
2050	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
51	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
52	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
53	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
54	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
55	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
56	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
57	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
58	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
59	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
2060	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
61	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
62	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
63	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
64	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
65	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
66	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
67	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700

EIRR= 8.338%

ENPV(US\$)= -179,363

PV(cost)= 1,040,872

PV(benefit)= 861,509

B/C= 0.82767988

Economic Internal Rate of Return (Considering Benefit of CO2 Reduction)

Soedirman Case 2

	Capital Cost	O&M Cost				Total Cost	Benefit						Net Economic Benefit
		Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Power Benefit	Irrigation	Mini Hydro	Reduction of CO2	Other Benefit	Total	
2011	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
12	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
13	215,587	-	-	-	-	215,587	-	-	-	-	-	-	-215,587
14	374,535	9,000	-	-	-	383,535	-	-	-	-	-	-	-383,535
15	374,535	9,000	-	-	-	383,535	415	-	-	-	62	477	-383,058
16	374,535	9,000	-	-	-	383,535	830	-	-	-	125	955	-382,581
17	-	27,000	926	5,936	-	33,861	20,327	-	-	-	-3,049	-23,376	-57,237
18	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
19	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
2020	-	27,000	926	5,936	-	33,861	125,389	-	-	-	18,808	144,197	110,336
21	-	27,000	926	5,936	-	33,861	127,463	-	628	-	19,214	147,305	113,444
22	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
23	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
24	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
25	-	27,000	926	5,936	-	33,861	127,463	10,030	628	-	20,718	158,839	124,978
26	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
27	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
28	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
29	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
2030	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
31	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
32	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
33	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	30,206	25,560	195,961	66,826
34	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	30,206	25,560	195,961	66,826
35	-	14,400	926	5,936	107,874	129,135	129,537	10,030	628	30,206	25,560	195,961	66,826
36	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
37	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
38	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
39	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
2040	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
41	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
42	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
43	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
44	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
45	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
46	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
47	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
48	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
49	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
2050	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
51	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
52	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
53	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
54	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
55	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
56	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
57	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
58	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
59	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
2060	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
61	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
62	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
63	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
64	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
65	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
66	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700
67	-	14,400	926	5,936	-	21,261	129,537	10,030	628	30,206	25,560	195,961	174,700

EIRR= 7.896%

ENPV(US\$)= -239,068

PV(cost)= 1,100,576

PV(benefit)= 861,509

B/C= 0.78277967

Economic Internal Rate of Return (Considering Benefit of CO2 Reduction)

Soedirman Case 2

	Capital Cost	O&M Cost				Total Cost	Benefit						Net Economic Benefit
		Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Power Benefit	Irrigation	Mini Hydro	Reduction of CO2	Other Benefit	Total	
2011	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
12	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
13	183,566	-	-	-	-	183,566	-	-	-	-	-	-	-183,566
14	323,503	9,000	-	-	-	332,503	-	-	-	-	-	-	-332,503
15	323,503	9,000	-	-	-	332,503	415	-	-	-	62	477	-332,026
16	323,503	9,000	-	-	-	332,503	830	-	-	-	125	955	-331,549
17	-	27,000	926	5,936	-	33,861	18,207	-	-	-	-2,731	-20,938	-54,799
18	-	27,000	926	5,936	-	33,861	116,552	-	-	-	17,483	134,035	100,174
19	-	27,000	926	5,936	-	33,861	116,552	-	-	-	17,483	134,035	100,174
2020	-	27,000	926	5,936	-	33,861	116,552	-	-	-	17,483	134,035	100,174
21	-	27,000	926	5,936	-	33,861	118,626	-	628	-	17,888	137,142	103,281
22	-	27,000	926	5,936	-	33,861	118,626	10,030	628	-	19,393	148,677	114,816
23	-	27,000	926	5,936	-	33,861	118,626	10,030	628	-	19,393	148,677	114,816
24	-	27,000	926	5,936	-	33,861	118,626	10,030	628	-	19,393	148,677	114,816
25	-	27,000	926	5,936	-	33,861	118,626	10,030	628	-	19,393	148,677	114,816
26	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
27	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
28	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
29	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
2030	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
31	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
32	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
33	-	14,400	926	5,936	107,874	129,135	120,700	10,030	628	30,206	24,235	185,799	56,664
34	-	14,400	926	5,936	107,874	129,135	120,700	10,030	628	30,206	24,235	185,799	56,664
35	-	14,400	926	5,936	107,874	129,135	120,700	10,030	628	30,206	24,235	185,799	56,664
36	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
37	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
38	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
39	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
2040	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
41	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
42	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
43	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
44	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
45	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
46	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
47	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
48	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
49	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
2050	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
51	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
52	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
53	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
54	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
55	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
56	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
57	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
58	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
59	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
2060	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
61	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
62	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
63	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
64	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
65	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
66	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538
67	-	14,400	926	5,936	-	21,261	120,700	10,030	628	30,206	24,235	185,799	164,538

EIRR= 8.315%

ENPV(US\$)= -170,116

PV(cost)= 981,170

PV(benefit)= 811,054

B/C= 0.82661953

Economic Internal Rate of Return (Considering Benefit of CO2 Reduction)

Soedirman Case 2

	Capital Cost	O&M Cost				Total Cost	Benefit						Net Economic Benefit
		Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Power Benefit	Irrigation	Mini Hydro	Reduction of CO2	Other Benefit	Total	
2011	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
12	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
13	183,566	-	-	-	-	183,566	-	-	-	-	-	-	-183,566
14	323,503	9,000	-	-	-	332,503	-	-	-	-	-	-	-332,503
15	323,503	9,000	-	-	-	332,503	415	-	-	-	62	477	-332,026
16	323,503	9,000	-	-	-	332,503	830	-	-	-	125	955	-331,549
17	-	27,000	926	5,936	-	33,861	16,221	-	-	-	-2,433	-18,654	-52,515
18	-	27,000	926	5,936	-	33,861	107,977	-	-	-	16,197	124,174	90,312
19	-	27,000	926	5,936	-	33,861	107,977	-	-	-	16,197	124,174	90,312
2020	-	27,000	926	5,936	-	33,861	107,977	-	-	-	16,197	124,174	90,312
21	-	27,000	926	5,936	-	33,861	110,051	-	628	-	16,602	127,281	93,420
22	-	27,000	926	5,936	-	33,861	110,051	10,030	628	-	18,106	138,815	104,954
23	-	27,000	926	5,936	-	33,861	110,051	10,030	628	-	18,106	138,815	104,954
24	-	27,000	926	5,936	-	33,861	110,051	10,030	628	-	18,106	138,815	104,954
25	-	27,000	926	5,936	-	33,861	110,051	10,030	628	-	18,106	138,815	104,954
26	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
27	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
28	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
29	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
2030	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
31	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
32	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
33	-	14,400	926	5,936	107,874	129,135	112,125	10,030	628	30,206	22,948	175,937	46,802
34	-	14,400	926	5,936	107,874	129,135	112,125	10,030	628	30,206	22,948	175,937	46,802
35	-	14,400	926	5,936	107,874	129,135	112,125	10,030	628	30,206	22,948	175,937	46,802
36	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
37	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
38	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
39	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
2040	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
41	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
42	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
43	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
44	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
45	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
46	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
47	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
48	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
49	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
2050	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
51	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
52	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
53	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
54	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
55	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
56	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
57	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
58	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
59	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
2060	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
61	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
62	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
63	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
64	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
65	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
66	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
67	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676

EIRR= 7.805%

ENPV(US\$)= -219,116

PV(cost)= 981,170

PV(benefit)= 762,053

B/C= 0.77667838

Economic Internal Rate of Return (Considering Benefit of CO2 Reduction)

Soedirman Case 2

	Capital Cost	O&M Cost				Total Cost	Benefit						Net Economic Benefit
		Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Power Benefit	Irrigation	Mini Hydro	Reduction of CO2	Other Benefit	Total	
2011	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
12	16,711	-	-	-	-	16,711	-	-	-	-	-	-	-16,711
13	215,587	-	-	-	-	215,587	-	-	-	-	-	-	-215,587
14	374,535	9,000	-	-	-	383,535	-	-	-	-	-	-	-383,535
15	374,535	9,000	-	-	-	383,535	415	-	-	-	62	477	-383,058
16	374,535	9,000	-	-	-	383,535	830	-	-	-	125	955	-382,581
17	-	27,000	926	5,936	-	33,861	16,221	-	-	-	-2,433	-18,654	-52,515
18	-	27,000	926	5,936	-	33,861	107,977	-	-	-	16,197	124,174	90,312
19	-	27,000	926	5,936	-	33,861	107,977	-	-	-	16,197	124,174	90,312
2020	-	27,000	926	5,936	-	33,861	107,977	-	-	-	16,197	124,174	90,312
21	-	27,000	926	5,936	-	33,861	110,051	-	628	-	16,602	127,281	93,420
22	-	27,000	926	5,936	-	33,861	110,051	10,030	628	-	18,106	138,815	104,954
23	-	27,000	926	5,936	-	33,861	110,051	10,030	628	-	18,106	138,815	104,954
24	-	27,000	926	5,936	-	33,861	110,051	10,030	628	-	18,106	138,815	104,954
25	-	27,000	926	5,936	-	33,861	110,051	10,030	628	-	18,106	138,815	104,954
26	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
27	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
28	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
29	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
2030	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
31	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
32	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
33	-	14,400	926	5,936	107,874	129,135	112,125	10,030	628	30,206	22,948	175,937	46,802
34	-	14,400	926	5,936	107,874	129,135	112,125	10,030	628	30,206	22,948	175,937	46,802
35	-	14,400	926	5,936	107,874	129,135	112,125	10,030	628	30,206	22,948	175,937	46,802
36	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
37	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
38	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
39	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
2040	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
41	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
42	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
43	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
44	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
45	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
46	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
47	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
48	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
49	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
2050	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
51	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
52	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
53	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
54	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
55	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
56	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
57	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
58	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
59	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
2060	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
61	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
62	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
63	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
64	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
65	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
66	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676
67	-	14,400	926	5,936	-	21,261	112,125	10,030	628	30,206	22,948	175,937	154,676

EIRR= 6.952%

ENPV(US\$)= -338,523

PV(cost)= 1,100,576

PV(benefit)= 762,053

B/C= 0.69241303

Financial Internal Rate of Return				Soedirman									
				(Unit: million Rp)									
Year		Capital Cost	O&M Cost				Total Cost	Increase of Tariff Revenue	Revenue			Net Economic Benefit	
			Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E			Mini Hydro	Irrigation	Total		
1	2011	19,583	-	-	-	-	19,583	-	-	-	-	-19,583	
2	12	19,583	-	-	-	-	19,583	-	-	-	-	-19,583	
3	13	203,949	-	-	-	-	203,949	-	-	-	-	-203,949	
4	14	376,624	10,000	-	-	-	386,624	-	-	-	-	-386,624	
5	15	376,624	10,000	-	-	-	386,624	-	-	-	-	-386,624	
6	16	376,624	10,000	-	-	-	386,624	-	-	-	-	-386,624	
7	17	-	30,000	971	6,160	-	37,131	90,114	-	-	-90,114	-127,245	
8	18	-	30,000	971	6,160	-	37,131	199,165	-	-	199,165	162,034	
9	19	-	30,000	971	6,160	-	37,131	199,165	-	-	199,165	162,034	
10	2020	-	30,000	971	6,160	-	37,131	199,165	-	-	199,165	162,034	
11	21	-	30,000	971	6,160	-	37,131	199,165	3,265	-	202,430	165,299	
12	22	-	30,000	971	6,160	-	37,131	199,165	3,265	11,144	213,574	176,443	
13	23	-	30,000	971	6,160	-	37,131	199,165	3,265	11,144	213,574	176,443	
14	24	-	30,000	971	6,160	-	37,131	199,165	3,265	11,144	213,574	176,443	
15	25	-	30,000	971	6,160	-	37,131	199,165	3,265	11,144	213,574	176,443	
16	26	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
17	27	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
18	28	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
19	29	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
20	2030	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
21	31	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
22	32	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
23	33	-	16,000	971	6,160	107,874	131,005	199,165	3,265	11,144	213,574	82,569	
24	34	-	16,000	971	6,160	107,874	131,005	199,165	3,265	11,144	213,574	82,569	
25	35	-	16,000	971	6,160	107,874	131,005	199,165	3,265	11,144	213,574	82,569	
26	36	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
27	37	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
28	38	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
29	39	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
30	2040	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
31	41	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
32	42	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
33	43	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
34	44	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
35	45	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
36	46	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
37	47	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
38	48	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
39	49	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
40	2050	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
41	51	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
42	52	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
43	53	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
44	54	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
45	55	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
46	56	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
47	57	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
48	58	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
49	59	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
50	2060	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
51	61	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
52	62	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
53	63	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
54	64	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
55	65	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
56	66	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
57	67	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	

FIRR= 9.130%

FNPV(millionRp)= - 99,513

PV(cost)= 1,117,613

PV(benefit)= 1,018,100

B/C= 0.910959076

Financial Internal Rate of Return							Soedirman						
							(Unit: million Rp)						
Year		Capital Cost	O&M Cost				Total Cost	Revenue				Net Economic Benefit	
			Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Increase of Tariff Revenuet	Mini Hydro	Irrigation	Total		
1	2011	21,364	-	-	-	-	21,364	-	-	-	-	-21,364	
2	12	21,364	-	-	-	-	21,364	-	-	-	-	-21,364	
3	13	222,490	-	-	-	-	222,490	-	-	-	-	-222,490	
4	14	410,862	10,000	-	-	-	420,862	-	-	-	-	-420,862	
5	15	410,862	10,000	-	-	-	420,862	-	-	-	-	-420,862	
6	16	410,862	10,000	-	-	-	420,862	-	-	-	-	-420,862	
7	17	-	30,000	971	6,160	-	37,131	90,114	-	-	-90,114	-127,245	
8	18	-	30,000	971	6,160	-	37,131	199,165	-	-	199,165	162,034	
9	19	-	30,000	971	6,160	-	37,131	199,165	-	-	199,165	162,034	
10	2020	-	30,000	971	6,160	-	37,131	199,165	-	-	199,165	162,034	
11	21	-	30,000	971	6,160	-	37,131	199,165	3,265	-	202,430	165,299	
12	22	-	30,000	971	6,160	-	37,131	199,165	3,265	11,144	213,574	176,443	
13	23	-	30,000	971	6,160	-	37,131	199,165	3,265	11,144	213,574	176,443	
14	24	-	30,000	971	6,160	-	37,131	199,165	3,265	11,144	213,574	176,443	
15	25	-	30,000	971	6,160	-	37,131	199,165	3,265	11,144	213,574	176,443	
16	26	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
17	27	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
18	28	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
19	29	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
20	2030	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
21	31	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
22	32	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
23	33	-	16,000	971	6,160	107,874	131,005	199,165	3,265	11,144	213,574	82,569	
24	34	-	16,000	971	6,160	107,874	131,005	199,165	3,265	11,144	213,574	82,569	
25	35	-	16,000	971	6,160	107,874	131,005	199,165	3,265	11,144	213,574	82,569	
26	36	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
27	37	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
28	38	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
29	39	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
30	2040	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
31	41	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
32	42	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
33	43	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
34	44	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
35	45	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
36	46	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
37	47	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
38	48	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
39	49	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
40	2050	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
41	51	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
42	52	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
43	53	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
44	54	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
45	55	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
46	56	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
47	57	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
48	58	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
49	59	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
50	2060	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
51	61	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
52	62	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
53	63	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
54	64	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
55	65	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
56	66	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	
57	67	-	16,000	971	6,160	-	23,131	199,165	3,265	11,144	213,574	190,443	

FIRR= 8.521%

FNPV(millionRp)= - 180,505

PV(cost)= 1,198,605

PV(benefit)= 1,018,100

B/C= 0.84940406

Financial Internal Rate of Return							Soedirman					
							(Unit: million Rp)					
Year		Capital Cost	O&M Cost				Total Cost	Revenue				Net Economic Benefit
			Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Increase of Tariff Revenue	Mini Hydro	Irrigation	Total	
1	2011	17,803	-	-	-	-	17,803	-	-	-	-	-17,803
2	12	17,803	-	-	-	-	17,803	-	-	-	-	-17,803
3	13	185,408	-	-	-	-	185,408	-	-	-	-	-185,408
4	14	342,385	10,000	-	-	-	352,385	-	-	-	-	-352,385
5	15	342,385	10,000	-	-	-	352,385	-	-	-	-	-352,385
6	16	342,385	10,000	-	-	-	352,385	-	-	-	-	-352,385
7	17	-	30,000	971	6,160	-	37,131	- 81,103	-	-	-81,103	-118,234
8	18	-	30,000	971	6,160	-	37,131	179,249	-	-	179,249	142,118
9	19	-	30,000	971	6,160	-	37,131	179,249	-	-	179,249	142,118
10	2020	-	30,000	971	6,160	-	37,131	179,249	-	-	179,249	142,118
11	21	-	30,000	971	6,160	-	37,131	179,249	3,265	-	182,514	145,383
12	22	-	30,000	971	6,160	-	37,131	179,249	3,265	11,144	193,658	156,527
13	23	-	30,000	971	6,160	-	37,131	179,249	3,265	11,144	193,658	156,527
14	24	-	30,000	971	6,160	-	37,131	179,249	3,265	11,144	193,658	156,527
15	25	-	30,000	971	6,160	-	37,131	179,249	3,265	11,144	193,658	156,527
16	26	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
17	27	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
18	28	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
19	29	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
20	2030	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
21	31	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
22	32	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
23	33	-	16,000	971	6,160	107,874	131,005	179,249	3,265	11,144	193,658	62,653
24	34	-	16,000	971	6,160	107,874	131,005	179,249	3,265	11,144	193,658	62,653
25	35	-	16,000	971	6,160	107,874	131,005	179,249	3,265	11,144	193,658	62,653
26	36	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
27	37	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
28	38	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
29	39	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
30	2040	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
31	41	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
32	42	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
33	43	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
34	44	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
35	45	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
36	46	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
37	47	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
38	48	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
39	49	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
40	2050	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
41	51	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
42	52	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
43	53	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
44	54	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
45	55	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
46	56	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
47	57	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
48	58	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
49	59	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
50	2060	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
51	61	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
52	62	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
53	63	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
54	64	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
55	65	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
56	66	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
57	67	-	16,000	971	6,160	-	23,131	179,249	3,265	11,144	193,658	170,527
FIRR=												8.891%
FNPV(millionRp)=												- 115,227
PV(cost)=												1,036,621
PV(benefit)=												921,394
B/C=												0.888843317

Financial Internal Rate of Return							Soedirman					
							(Unit: million Rp)					
Year		Capital Cost	O&M Cost				Total Cost	Revenue				Net Economic Benefit
			Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Increase of Tariff Revenue	Mini Hydro	Irrigation	Total	
1	2011	17,803	-	-	-	-	17,803	-	-	-	-	-17,803
2	12	17,803	-	-	-	-	17,803	-	-	-	-	-17,803
3	13	185,408	-	-	-	-	185,408	-	-	-	-	-185,408
4	14	342,385	10,000	-	-	-	352,385	-	-	-	-	-352,385
5	15	342,385	10,000	-	-	-	352,385	-	-	-	-	-352,385
6	16	342,385	10,000	-	-	-	352,385	-	-	-	-	-352,385
7	17	-	30,000	971	6,160	-	37,131	72,091	-	-	-72,091	-109,222
8	18	-	30,000	971	6,160	-	37,131	159,332	-	-	159,332	122,201
9	19	-	30,000	971	6,160	-	37,131	159,332	-	-	159,332	122,201
10	2020	-	30,000	971	6,160	-	37,131	159,332	-	-	159,332	122,201
11	21	-	30,000	971	6,160	-	37,131	159,332	3,265	-	162,597	125,466
12	22	-	30,000	971	6,160	-	37,131	159,332	3,265	11,144	173,741	136,610
13	23	-	30,000	971	6,160	-	37,131	159,332	3,265	11,144	173,741	136,610
14	24	-	30,000	971	6,160	-	37,131	159,332	3,265	11,144	173,741	136,610
15	25	-	30,000	971	6,160	-	37,131	159,332	3,265	11,144	173,741	136,610
16	26	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
17	27	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
18	28	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
19	29	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
20	2030	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
21	31	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
22	32	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
23	33	-	16,000	971	6,160	107,874	131,005	159,332	3,265	11,144	173,741	42,736
24	34	-	16,000	971	6,160	107,874	131,005	159,332	3,265	11,144	173,741	42,736
25	35	-	16,000	971	6,160	107,874	131,005	159,332	3,265	11,144	173,741	42,736
26	36	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
27	37	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
28	38	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
29	39	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
30	2040	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
31	41	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
32	42	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
33	43	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
34	44	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
35	45	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
36	46	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
37	47	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
38	48	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
39	49	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
40	2050	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
41	51	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
42	52	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
43	53	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
44	54	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
45	55	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
46	56	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
47	57	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
48	58	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
49	59	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
50	2060	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
51	61	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
52	62	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
53	63	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
54	64	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
55	65	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
56	66	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
57	67	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	150,610
FIRR=												7.904%
FNPV(millionRp)=												211,938
PV(cost)=												1,036,621
PV(benefit)=												824,683
B/C=												0.79554936

Financial Internal Rate of Return							Soedirman					Net Economic Benefit
							(Unit: million Rp)					
Year	Capital Cost	O&M Cost				Total Cost	Revenue					
		Dredging in the reservoir	OM Cost for diversion weir and sediment	Cleaning sand and gravel in the check dam	Replacement cost of G/E		Increase of Tariff Revenue	Mini Hydro	Irrigation	Total		
1	2011	21,364	-	-	-	21,364	-	-	-	-	-21,364	
2	12	21,364	-	-	-	21,364	-	-	-	-	-21,364	
3	13	222,490	-	-	-	222,490	-	-	-	-	-222,490	
4	14	410,862	10,000	-	-	420,862	-	-	-	-	-420,862	
5	15	410,862	10,000	-	-	420,862	-	-	-	-	-420,862	
6	16	410,862	10,000	-	-	420,862	-	-	-	-	-420,862	
7	17	-	30,000	971	6,160	-	37,131	72,091	-	-	-72,091	
8	18	-	30,000	971	6,160	-	37,131	159,332	-	-	159,332	
9	19	-	30,000	971	6,160	-	37,131	159,332	-	-	159,332	
10	2020	-	30,000	971	6,160	-	37,131	159,332	-	-	159,332	
11	21	-	30,000	971	6,160	-	37,131	159,332	3,265	-	162,597	
12	22	-	30,000	971	6,160	-	37,131	159,332	3,265	11,144	173,741	
13	23	-	30,000	971	6,160	-	37,131	159,332	3,265	11,144	173,741	
14	24	-	30,000	971	6,160	-	37,131	159,332	3,265	11,144	173,741	
15	25	-	30,000	971	6,160	-	37,131	159,332	3,265	11,144	173,741	
16	26	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
17	27	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
18	28	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
19	29	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
20	2030	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
21	31	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
22	32	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
23	33	-	16,000	971	6,160	107,874	131,005	159,332	3,265	11,144	173,741	
24	34	-	16,000	971	6,160	107,874	131,005	159,332	3,265	11,144	173,741	
25	35	-	16,000	971	6,160	107,874	131,005	159,332	3,265	11,144	173,741	
26	36	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
27	37	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
28	38	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
29	39	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
30	2040	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
31	41	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
32	42	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
33	43	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
34	44	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
35	45	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
36	46	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
37	47	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
38	48	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
39	49	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
40	2050	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
41	51	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
42	52	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
43	53	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
44	54	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
45	55	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
46	56	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
47	57	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
48	58	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
49	59	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
50	2060	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
51	61	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
52	62	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
53	63	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
54	64	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
55	65	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
56	66	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
57	67	-	16,000	971	6,160	-	23,131	159,332	3,265	11,144	173,741	
FIRR=											6.777%	
FNPV(millionRp)=											- 373,921	
PV(cost)=											1,198,605	
PV(benefit)=											824,683	
B/C=											0.688036093	

PART D POWER AND ENERGY CALCULATION

BD1. Energy Calculation of Soedirman Power Station

BD1.1 Objectives of the Study

Seodirman hydropower station has been operated so as to meet night peak demand mainly. Therefore primary energy of the power station is generated power during peak operation time. The other energy is classified into the secondary energy.

Due to decreasing effective storage volume of the Mrica reservoir by the sediment, the dependable peak output of the power station will be reduced. In order to recover the function of the storage, the sediment diversion system and dredging work have been proposed as described in the Part A and Part B of this Annex B.

Objectives of the study are to estimate the dependable output, as well as the primary energy, depending on the effective storage volume in each state of the countermeasure works. In addition, decreased dependable output and primary energy of without countermeasure works also has been estimated to compare the effectiveness of the works.

BD1.2 Conditions of Energy Estimation

(1) Effective Storage Volume

As described in the Part B, effective storage volumes of the reservoir in each year have been estimated as shown in Table BD1.1.

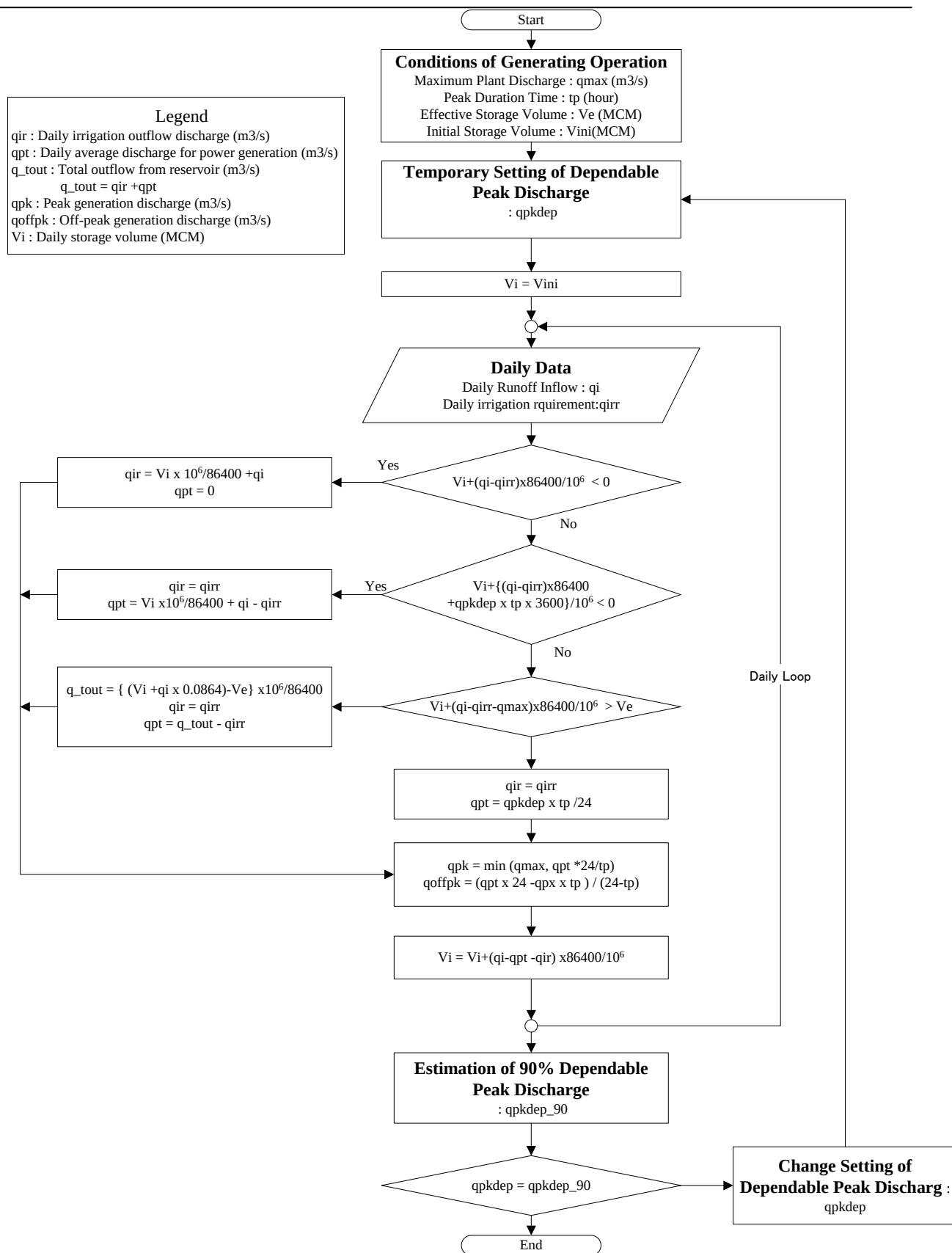
Table BD1.1 Effective Storage Volume

Year	Without Project	With Project
2014	18.8MCM	18.8 MCM
2017	10.7MCM	14.3 MCM
2021	0MCM	19.9MCM
2026 and after 2026	-	26.9MCM

Source : Prepared by JICA Study Team

(2) Reservoir Oepration Rule

Reservoir operation rule of the Mrica reservoir is as shown in Figure BD1.1.



Source : Prepared by JICA Study Team

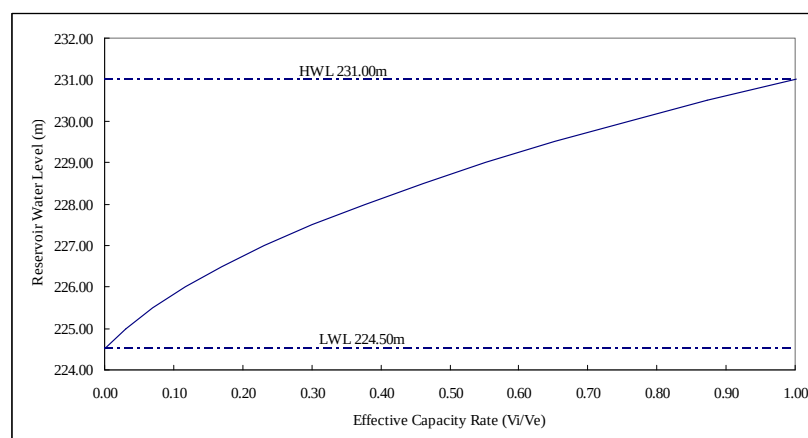
Figure BD1.1 Reservoir Operation Rule of Mrica Reservoir

As seen the Figure BD1.1, irrigation discharge from the reservoir is first priority and second priority is peak power generation. Off-peak power can be generated by utilizing excess runoff discharge when the storage capacity is full storage volume.

(3) Conditions for Estimation of Power Generation

1) Reservoir Water Level

Reservoir water level is estimated by effective capacity ration – reservoir water level relationship as shown in Figure BD1.2. The relationship is estimated by the survey results in 2009 carried out Indonesia power.

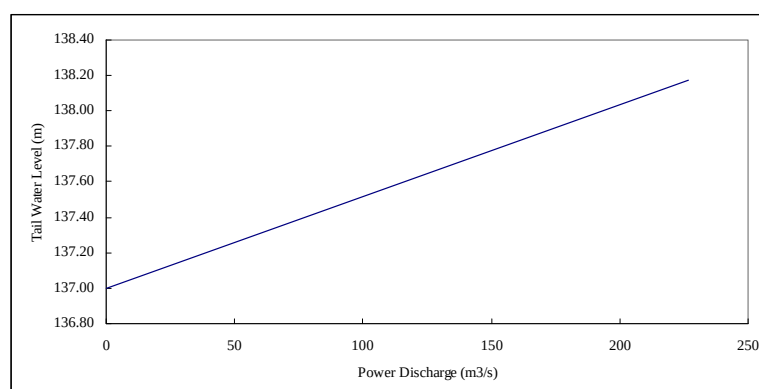


Source : Prepared by JICA Study Team

Figure BD1.2 Effective Storage Capacity Rate – Water Level Relationship

2) Tail Water Level

Maximum tail water level is 138.20m with maximum power discharge of 226.8m³/s and minimum tail water level is around 137.0m with no power discharge. The other tail water level depending on the power discharge is estimated by following linear relationship between the power discharge and the tail water level.



Source : Prepared by JICA Study Team

Figure BD1.3 Power Discharge – Tail Water Level Relationship

3) Head Loss and Effective Head

Assumed head loss is 4.6m with 226.8m³/s of maximum power discharge operation. The head loss increases in proportion to the power discharge squared.

Head losses depending on various power discharge volume are estimated by following formula.

$$h_{loss} = \alpha \times q_p^2$$

where, h_{loss} : Head loss (m)

α : Head loss coefficient

$$\alpha = \frac{4.6}{226.8^2} = 8.9 \times 10^{-5}$$

q_p : Power discharge (m³/s)

Effective head is estimated by following formula.

$$h_e = WL_r - WL_t - h_{loss}$$

where, h_e : Effective head (m)

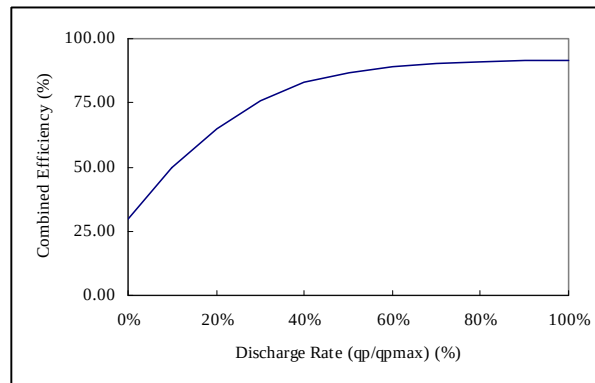
WL_r : Reservoir water level (m)

WL_t : Tail water level water level (m)

h_{loss} : Head loss (m)

4) Combined efficiency of Turbine and Generator

Assumed combined efficiency of turbine and generator is as shown in Figure BD1.4.



Source : Prepared by JICA Study Team

Figure BD1.4 Combined Efficiency of Turbine and Generator

5) Peak duration time

Peak duration time of the Soedirman power station is about 4 to 5 hours, however, due to decreasing storage capacity and decreasing runoff inflow, dependable peak duration time will be reduced until 3 hours. Hence 3 hour of peak duration time is applied to this Study.

BD1.3 Results of Energy Calculation

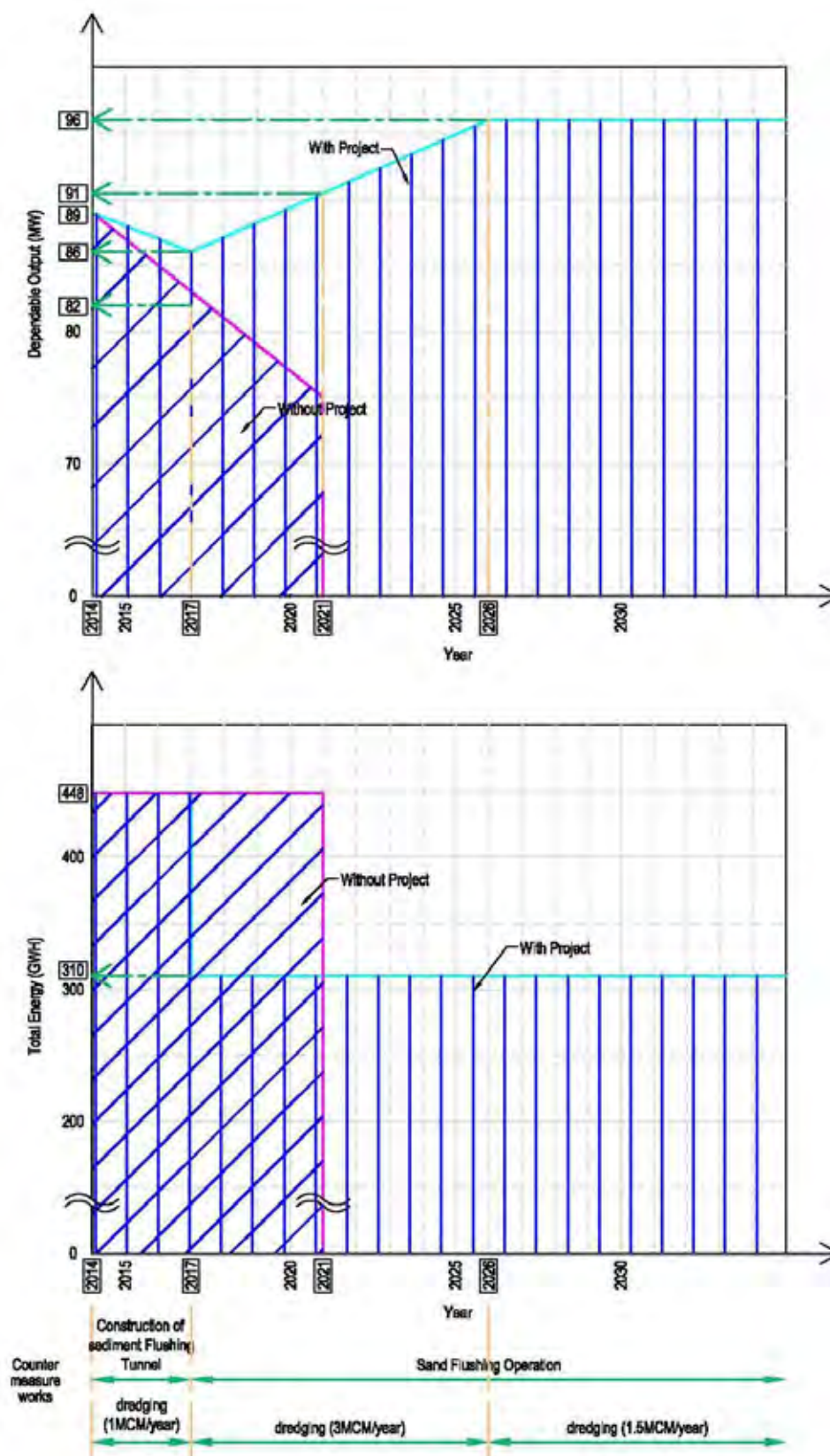
Based on the runoff inflow data from 1980 to 2009, energy calculation has been carried out. Total inflow discharge with project has been reduced by means of the sediment diversion as described in ANNEX B.

Summary of the energy calculation is as shown in Table BD1.2 and Figure BD1.5 respectively.

Table BD1.2 Summary of Energy Calculation (Soedirman PS)

Year	Without Project				With Project			
	Dependable Output (MW)	Primary Energy (GWh)	Secondary Energy (GWh)	Mini Hydro. (GWh)	Dependable Output (MW)	Primary Energy (GWh)	Secondary Energy (GWh)	Mini Hydro. (GWh)
1989	112	162	282	5	-	-	-	5
2014	89	158	285	5	89	158	285	5
2017	82	158	285	5	86	158	285	5
				5	86	145	160	5
2021	0	0	443	5	91	145	160	5
	0	0	0	0				5
2026	0	0	0	0	96	145	160	5
after 2026	0	0	0	0	96	145	160	5

Source : Prepared by JICA Study Team



Source : Prepared by JICA Study Team

Figure BD1.5 Summary of Energy Calculation of Soedirman Power Station