Republic of Indonesia, Ministry of Public Works

Directorate General of Water Resources

# Indonesia
# Expert Dispatch Scheme
# Dam Design and Construction Advisory Services

# Completion Report
## Supporting Report 2

# Study on
# Dam Related Issues on Ongoing 61 Dams

February 2025

Japan International Cooperation Agency

CTI Engineering International Co., Ltd.
CTI Engineering Co., Ltd.

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| | Kalimantan | Sulawesi | Bali-NTT-NTB |
|---|---|---|---|
| Canceled from Original | Lambakan | Pelosika | Mbay |
| | Riam Kiwa | Jenelata | |
| Added | Marangkayu | Amerono | Tiu Suntuk |
| | Sepaku Semoi | Budong-Budong | |

**47 Dams Completed at end of 2024**

| Jawa (20) | | | Sumatera (6) | Kalimantan (3) | Sulawesi (7) | Bali-NTT-NTB (11) | |
|---|---|---|---|---|---|---|---|
| Jatigede | Bendo | Karian | Raju | Teritip | Karaloe | Raknamo | Napun Gete |
| Bajulamati | Gongsen | Cipanas | Paya Seunara | Sepaku Semoi | Lolak | Titab | Temef |
| Nipah | Tukul | Lewikeris | Muara Sei Gong | Tapin | Passeloreng | Tanju | Tiu Suntuk |
| Gondang | Pidekso | Randugunting | Sukoharjo/ Way | | Kuwil Kawangkoan | Mila | Beringin Sila |
| Logiung | Tugu | Semantok | Sekampung | | Ladongi | Rotiklot | |
| Sindang Heula | Ciawi | Sadawarna | Lausimeme | | Pamukkulu | Bintang Bano | |
| Kuningan | Sukamahi | | Marga Tiga | | Amerono | Tamblang | |

**5 Dams Currently under Impounding**

| Jawa (1) | Sumatera (2) | Kalimantan (1) | Bali-NTT-NTB (1) |
|---|---|---|---|
| Jlantah | Keureuto | Marangkayu | Sidan |
| | Rukoh | | |

**9 Dams Currently under Construction**

| Jawa (3) | Sumatera (1) | Sulawesi (2) | Bali-NTT-NTB (2) | Maluk-Papua (1) |
|---|---|---|---|---|
| Benar | Komering II/ Tigadihadji | Budong-Budong | Manikin | Wey Apu |
| Bagong | | Bulango Ulu | Meninting | |
| Jragung | | | | |

Location Map of Objective 61Dams & Progress as of Dec. 2024

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## ATTACHMENTS

Attachment 1 Dam Technical Data
Attachment 2 Summary of Dam Issues

# 1. INTRODUCTION

## 1.1 BACKGROUND

Water-related disasters are becoming more common in Indonesia, and many people live in flood-prone areas, making disaster damage a serious issue for domestic development. To address this issue, the Government of Indonesia and the Ministry of Public Works and Housing (PUPR) have built new multipurpose dams for water utilization and flood control as part of integrated water resources management.

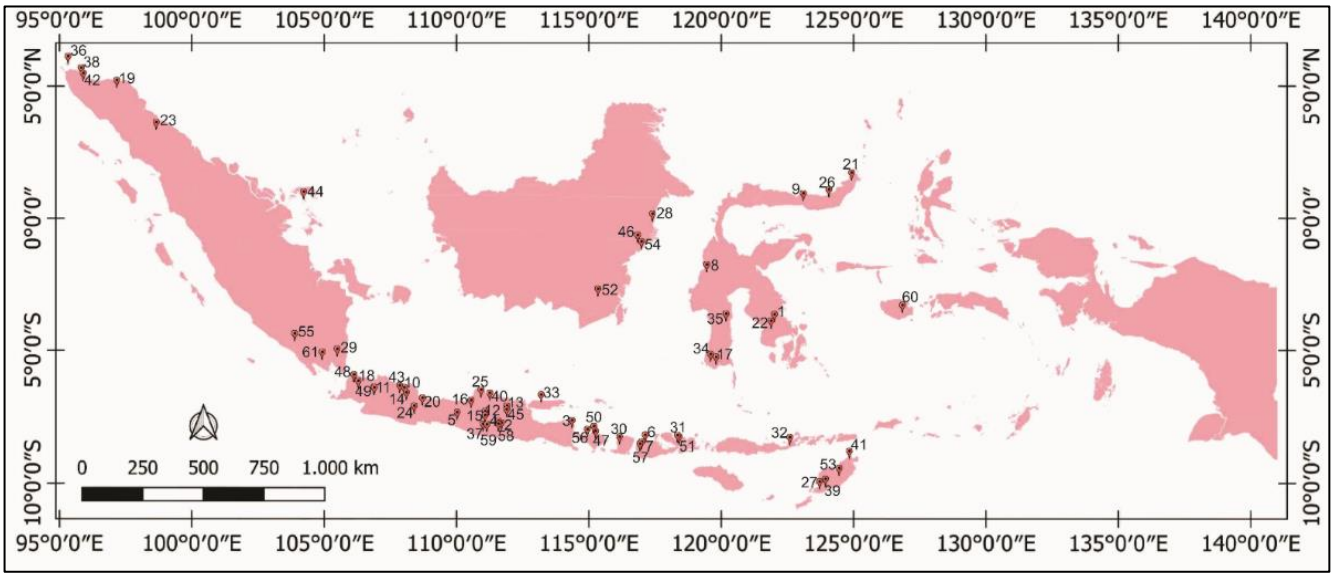
Dam is a barrier construction to hold back water and raise its level, forming a reservoir used to generate electricity, water supply, flood control natural resource conservation or tourism. Sometime the implementation of construction or maintenance of the dam appears constrained due to geological issues that cannot be avoided.

## 1.2 OBJECTIVES

The report aims to provide another perspective on dam analysis and information to be another view (opinion) for the advisor in making the final project report.

## 1.3 LOCATION OF TARGET DAM

The subject of dams is sixty one (61) dams spread throughout Indonesia (Figure 0 1), include under construction dam and impounding permit or operation permit dam.




| | | | | | |
|---|---|---|---|---|---|
| z | 11. Ciawi | 21. Kuwil Kawangkoan | 31. Mila | 41. Rotiklot | 51. Tanju |
| 2. Bagong | 12. Gondang | 22. Ladongi | 32. Napun Gete | 42. Rukoh | 52. Tapin |
| 3. Bajulmati | 13. Gongseng | 23. Lausimeme | 33. Nipah | 43. Sadawarna | 53. Temef |
| 4. Bendo | 14. Jatigede | 24. Leuwikeris | 34. Pamukkulu | 44. Sei Gong | 54. Teritip |
| 5. Bener | 15. Jlantah | 25. Logung | 35. Paselloreng | 45. Semantok | 55. Tiga Dihaji |
| 6. Beringin Sila | 16. Jragung | 26. Lolak | 36. Paya Seunara | 46. Sepaku | 56. Titab |
| 7. Bintang Bano | 17. Karalloe | 27. Manikin | 37. Pidekso | 47. Sidan | 57. Tiu Suntuk |
| 8. Budongbudong | 18. Karian | 28. Marangkayu | 38. Rajui | 48. Sindang | 58. Tugu |
| 9. Bulango Ulu | 19. Keureuto | 29. Margatiga | 39. Raknamo | 49. Sukamahi | 59. Tukul |
| 10. Cipanas | 20. Kuningan | 30. Meninting | 40. Randugunting | 50. Tamblang | 60. Way Apu |
| | | | | | 61. Way Sekampung |

**Figure 1-1 Location of 61 Dam of Indonesia**

## 1.4 DATA COLLECTION AND ORGANIZATION

The data collected included design reports, meeting minutes, exposures and as-build / design drawings. However, not all dams had complete data, so some dams were missing some data.

The collected data has been organized and is shown in Appendix-2. In addition, the site inspection reports is shown in Appendix-3, and the minutes of the technical meetings attended during the project are shown in Appendix-4.

# 2. BASIC CONCEPTS OF DAM GEOLOGY

## 2.1 TOPOGRAPHY AND MORPHOLOGY SURVEY

Topography is the study of the forms and features of land surfaces. The topography of an area may refer to the landforms and features themselves, or a description or depiction in maps.

Morphology in earth science (geomorphology) related to shape of the earth's surface or landscape. Knowing the morphology of certain area can help to understand landform and terrain history and dynamics and to predict changes through a combination of field observations, physical experiments and numerical modeling.

The geology of a place is closely related to or often reflected in its morphology. Recognizing (identify) hills and valleys, the shape of rivers and hillsides, canyons and plains, etc. However, to interpret the relationship between these features and the underlying geology requires considerable expertise and experience. The interpretation is based on several things, such as shape and orientation of the hills, the pattern, shape and density of rivers, lineaments, escarpments, and so on.

At present, aerial photo interpretation is often used to help interpret a study location. Aerial photograph interpretation is a method of extrapolating geological details of the ground surface from aerial images. It allows geologists to analyze the distinguishing geological structures (fault and fold), plant cover, past history of the site, soil properties, and topography of the study area. It is crucial in the early stage of a geological mapping as it is less time-consuming and offers important data at a minimal price.

Aerial photograph interpretation is also useful to assess the risk of landslides and other dangers in the natural environment in the geotechnical industry. As proper interpretation of aerial photos can reveal historical changes of the topography and the details of previous landslides, it can be help determine whether an area is stable or not. Geologists can further utilize the interpretations to design the most favorable locations for field studies and the acquisition of data.

## 2.2 REGIONAL GEOLOGICAL SURVEY

Regional geological information of certain area need to be identified first before starting to construct the dam. Regional geology information here means of kind rock, volcanism, active fault location, and seismic historical and groundwater basin.

### 2.2.1 Rock Type

Rock is a general term for all solid materials that make up the earth's crust, especially based on its genes, namely igneous rocks, sedimentary rocks, and metamorphic rocks. The initial description of the rock type of a location is very important to determine the possibility of geology conditions that exist at the location such as unconformity, weathering, swelling potential, foundation strength estimation and others.

Rocks with different genesis will have different engineering properties, so the handling related to the slope of the excavation slope or foundation strength will also be different. Regional geological maps of Indonesia have been widely published. One of the reference geological maps that are often used in Indonesia is the regional geological map published by the geological research and development center.

### 2.2.2 Active Volcano

An active volcano is defined as a volcano that has erupted in the last ten thousand years and that shows active fumaroles activities. Volcanic eruption causes lava flows, pyroclastic flows and debris flows. As a result, a deposit of soft volcano clastic materials is formed in a wide area at the foot of a volcano, which acts as a source of debris. Therefore, if there is an active volcano in or near a watershed of a dam, there is a possibility that a large quantity of debris may flow into the dam reservoir from the deposit of volcano clastic materials.

### 2.2.3 Active Fault Location

A fault is a fracture or zone of fractures between two blocks of rock. Faults allow the blocks to move relative to each other. This movement may occur rapidly, in the form of an earthquake or may occur slowly, in the form of creep. Faults may range in length from a few millimeters to thousands of kilometers. Most faults produce repeated displacements over geologic time. During an earthquake, the rock on one side of the fault suddenly slips with respect to the other. The fault surface can be horizontal or vertical or some arbitrary angle in between.

An active fault is a fault that is likely to have another earthquake sometime in the future. Faults are commonly considered to be active if there has been movement observed or evidence of seismic activity during the last 10,000 years.

### 2.2.4 Historical Seismics

Seismic hazard studies are conducted to determine the maximum value of peak ground acceleration (PGA) and spectral acceleration in certain areas to minimize the impact of earthquake damage. PGA and spectral acceleration play an important role in earthquake design settings.

Seismic hazard analysis is often used to determine the level of loading that is likely to occur at a site. There are two calculation methods that are commonly used. They are Deterministic Seismic Hazard Analysis (DSHA) and Probabilistic Seismic Hazard Analysis (PSHA).

In Indonesia, the calculation of peak acceleration and response spectrum in bedrock at Operating Basis Earthquake (OBE) and Safety Evaluation Earthquake (SEE) levels for dams must meet the safe limit values as suggested by ICOLD.

### 2.2.5 Landslide Potential

Locations that have experienced landslides or have the potential to experience landslides are not good alternatives for dam sites. In locations where landslides have occurred, the material resulting from the landslide (colluvium) is a type of weak and unstable material. If a dam site is built at that location, all colluvial material should be excavated.

A good analysis of landslide countermeasures, at a minimum, requires the determination of the landslide plane, the parameters of the soil or rock experiencing the landslide and its surroundings (unstable and stable parts), geohydrological conditions and appropriate geotechnical cross-sections that truly represent the conditions in the field. Therefore, the determination of the maximum depth of the landslide plane is absolutely necessary as a

guide to determine the drilling depth as input in determining the cause and countermeasures of landslides.

If a large-scale landslide happens due to storing water in the dam reservoir, hydraulic bore may occur, causing the failure of the dam body and flooding of the downstream area. Landslides in the dam reservoir, even if they were active in the past, may happen due to the influence of storing water in the dam reservoir. As such, it is important to conduct survey of the landslide topography and check it at the site by surface geology reconnaissance.

## 2.3 GEOLOGICAL SURVEY FOR DAM SITE

Detailed geological conditions of an area are one of the initial information used by dam engineers in designing a dam. Surface geological investigations are carried out as a field introduction, observation of outcrops and making geological maps by analogy to subsurface conditions.

Data that need to be studied include topography, stratigraphy, geological structure, rock properties, depositional materials, hydrogeology and historical of geology. The distribution and thickness of surface deposits, type and nature of materials, degree of weathering, pattern and distribution of discontinuity planes are studied through observation of existing outcrops with the help of topographic maps. The thickness, degree of weathering and nature of the overburden are observed by making trenches and test pit.

The data obtained from this investigation should be able to provide information on: stratigraphy, geological structure, orientation of discontinuity planes such as fault structures, strike, dips, rock types and properties, hydrogeology, landslide areas. The results of this investigation, together with the results of other investigation activities, are then outlined in a detailed scale geological map that must be able to clearly depict the results of surface geological investigations, and be made based on geological classification in accordance with the purpose of the investigation.

Based on "Panduan Perencanaan Bendungan Urug: Volume 1 (Survei dan Investigasi), 1999" the mapping area should cover certain area. The mapping area of the prospective dam, the survey should be carried out covering the area bounded by lines as follows. on the left and right abutment hills by a line perpendicular to the dam 2H away (H = Dam height) outside the of intersection between the dam crest of the left and right abutment hills. Upstream and downstream of the dam, each by a line 4 H away from and parallel to the dam axis.

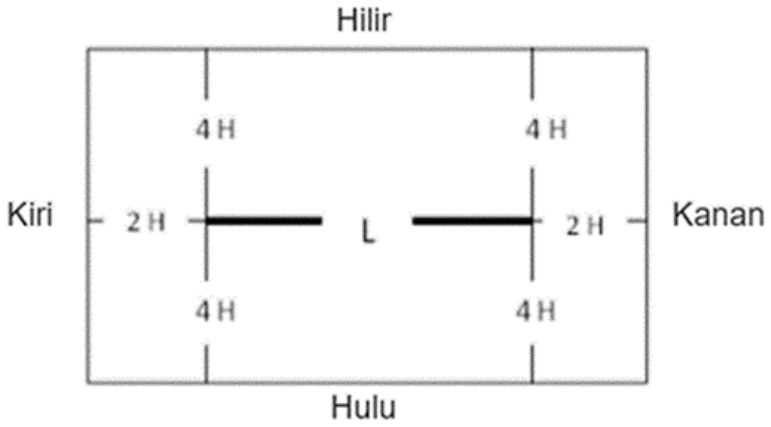



**Figure 2-1 Minimum area geological and geotechnical investigation (Minute of meeting, Mbay Dam, 26 April 2024)**

In addition to surface investigations, subsurface Investigations must also be carried out to classify foundation rocks based on their technical properties, which include geological conditions that include the type and nature of rocks both physical, mechanical, and hydraulic properties, and collect complete data to determine the type of dam, excavation limits and foundation repairs. The above conditions can be known from the results of core drilling. In addition to core drilling, other methods commonly used are geo-physical assessment by seismic surveys, and test tunnels (Adit). In general, the location and quantity of these investigations are determined by considering the type and size of the dam, as well as local geological conditions.

## 2.4 MATERIAL SURVEY FOR FILL DAM

Material investigation is carried out to identify and determine several parameter related to material for dam building. General purpose of material investigation are:

- ✧ The quality of the materials, including technical classification, physical and mechanical properties, while establishing which materials meet the design and construction requirements.
- ✧ Availability of eligible material reserves.
- ✧ Conditions related to excavation, source location including access roads, distance, status, need for conservation, etc.

Investigation activities that need to be carried out: surface geological investigation, subsurface geological investigation to obtain data on: quality, quantity, distribution, thickness of deposits, type of properties, weathering degree, patterns and areas of discontinuity. Available material reserves should be 2 to 3 times larger than the actual volume required for construction.

# 3. GEOLOGY OF INDONESIA

## 3.1 GEOGRAPHY

Indonesia is an archipelago spanning between 6° northern and 11° southern latitude, and between 95° and 140° eastern longitude. Sumatra, Java, Kalimantan, Sulawesi and Papua are the five largest islands in Indonesia.

Physically, Sumatra, Java and Kalimantan are located on the Sunda Shelf which is part of Eurasia Continent. In this area the water depth does not reach 200m. To the east, there are Papua and Aru Islands which are located on the Sahul Shelf which is part of the Australian Continent. Between the two shelves are the Nusa Tenggara, Sulawesi, Maluku and Halmahera island groups. The islands are surrounded by a deep sea that reaches 5000m in depth.

The shape of Indonesia's land surface is strongly influenced by tectonic and denudation processes, including mountain, mount, highland, hills, lowlands, coastal plains and swamp plain. Generally, the geography of Indonesia can be divided into four main areas (geological research and development center, 2010). The areas are Low Plain Area, High Plain Area, Hilly Area and Mountains Area which each unit can be divided again to several units base on endogenic factor (tectonic, magmatism etc.) exogenic factor (denudation/erosion. Sedimentation etc.).

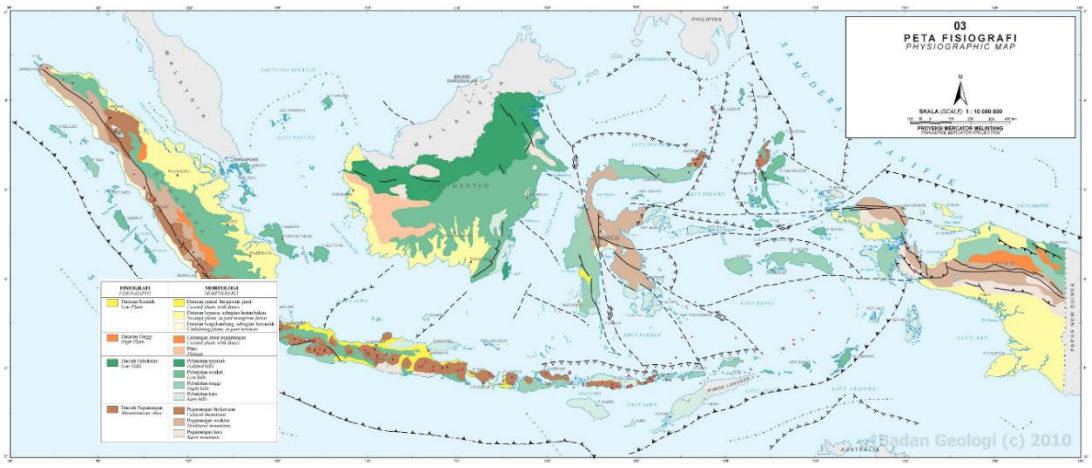



**Figure 3-1 Physiography map of Indonesia (geological research and development center, 2010)**

## 3.2 STRATIGRAPHY

The Indonesian archipelago is broadly formed by two continental masses each corresponds to the amalgamated Eurasian plate in the west and Australian plate in the east, respectively and the intervening Tertiary collision zone in the middle. Three major types of orogenies in Indonesia may be recognized.

- The Sunda type, representing the narrow and well defined Late Mesozoic Cordilleran type Meratus-Karangsambung orogen along the rim of the southeastern Sundaland and the Neogene orogeny stretching across Sumatra, Java and Nusatenggara. Suspected collision of microcontinent occurred in the Meratus-Karangsambung orogen.

- The Makassar type, which spatially outboards the Meratus-Karangsambung orogen, constitutes Oligocene and Miocene orogenies as a result of consecutive subduction abduction events of the East Arm of Sulawesi and the docking of Australian-derived microcontinents onto Sulawesi
- The Banda type, which is characterized by repeated pre-collisional obductions of short-lived spreading ridges in front of the Australian passive margins, took place in Oligocene and Miocene, respectively.

Parts of Southeast Asia show evidence of having Paleozoic or older continental crust. These include small fragments in the Philip¬pine and Indonesian archipelagoes, and (the main area) a large mass consisting of nearly all of mainland Southeast Asia most of Sumatra, southwestern Kalimantan, and parts of the border¬ing and intervening seas.

The Permian limestones and basalts of the Maubisse formation in Timor Island reflect sedimentation during rift formation of the Pa¬leo-Tethys Sea. Stratigraphic contacts with coeval Early Permian Atahoc and Late Per¬mian Cribas formation are rare but exist.

In Papua, the Paleozoic Kariem and Awitagoh formations are considered to belong to the oldest rock in the island. The Kariem formation consists of a monotonous alternation of gray to black slaty shales and siltstones with lighter pyrilllitic slates and bands of fine-grained quartzites. The whole formation is silicified while disseminated pyrite is common throughout.

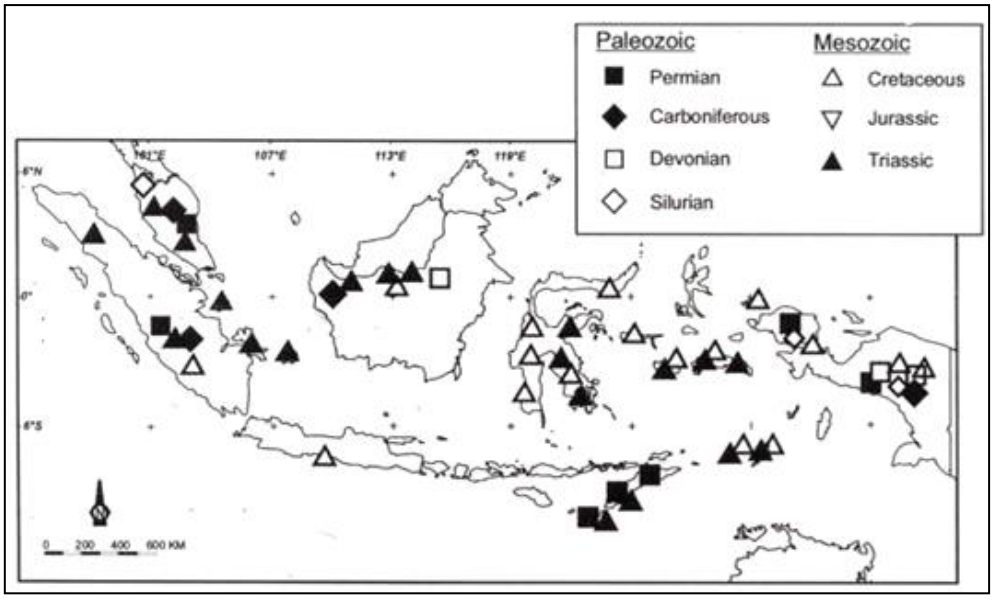



**Figure 3-2 Distribution of Paleozoic and Mesozoic outcrops in Indonesia (based on Sartono, 1974)**

Tertiary sedimentary strata in Indonesia mainly rest unconformably on a pre-Tertiary crystalline base¬ment. Tertiary sedimentary sections vary in thickness not only between basins but often within the basins.

The Sunda Shelf areas stabilized toward the end of Mesozoic time. The shelf edges appear to have been broken up by basement block faulting. Fault movements seem to have been continuous from the beginning of basin subsidence, and to have controlled sedimentation. Less differential movement took place in late Tertiary time, and although sedimentary strata of this age are generally not dissected, folding was apparently localized and influenced by the fault trends.

In the western Indonesian back-arc basins, rapid sedimentation occurred during the Tertiary in what may best be described as partially closed marine environments. These sediments were then subjected to the moderate to intense folding which followed at the end of the Tertiary.

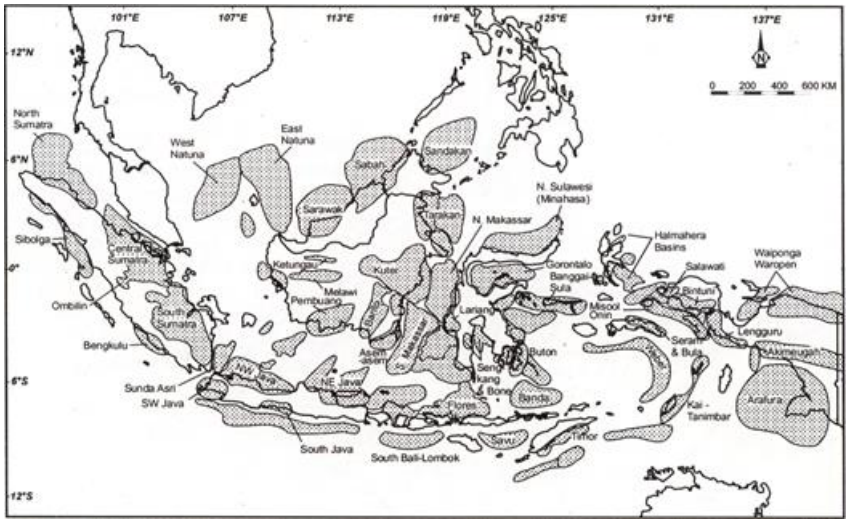



**Figure 3-3 Tertiary basins of Indonesia, based on a variety of publications (Indonesian association of geologist, 2000).**

## 3.3 TECTONIC SETTING

When the new concepts of global plate tectonics were introduced in 1967, western Indonesia (i.e. Sumatra and its surrounding regions) became a major focus of attention for further investigation. This region, with its deep sea trenches, volcanic chains, sedimentary basins and cratonic continental areas, is situated at the convergence of a northward moving Indian Ocean plate subducting beneath the Eurasian continental plate.

Studies were made by Hatherton and Dickinson (1969), Fitch (1970), Hamilton (1970, 1979) and Katili (1971) but it was not until 1973 that the first plate tectonic model of western Indonesia was published by Katili. In this model, the following structural zones are listed along transverse sections of Sumatra & Java:

1. The active subduction zone
2. The magmatic or volcanic arcs
3. The foreland (back-arc) basins

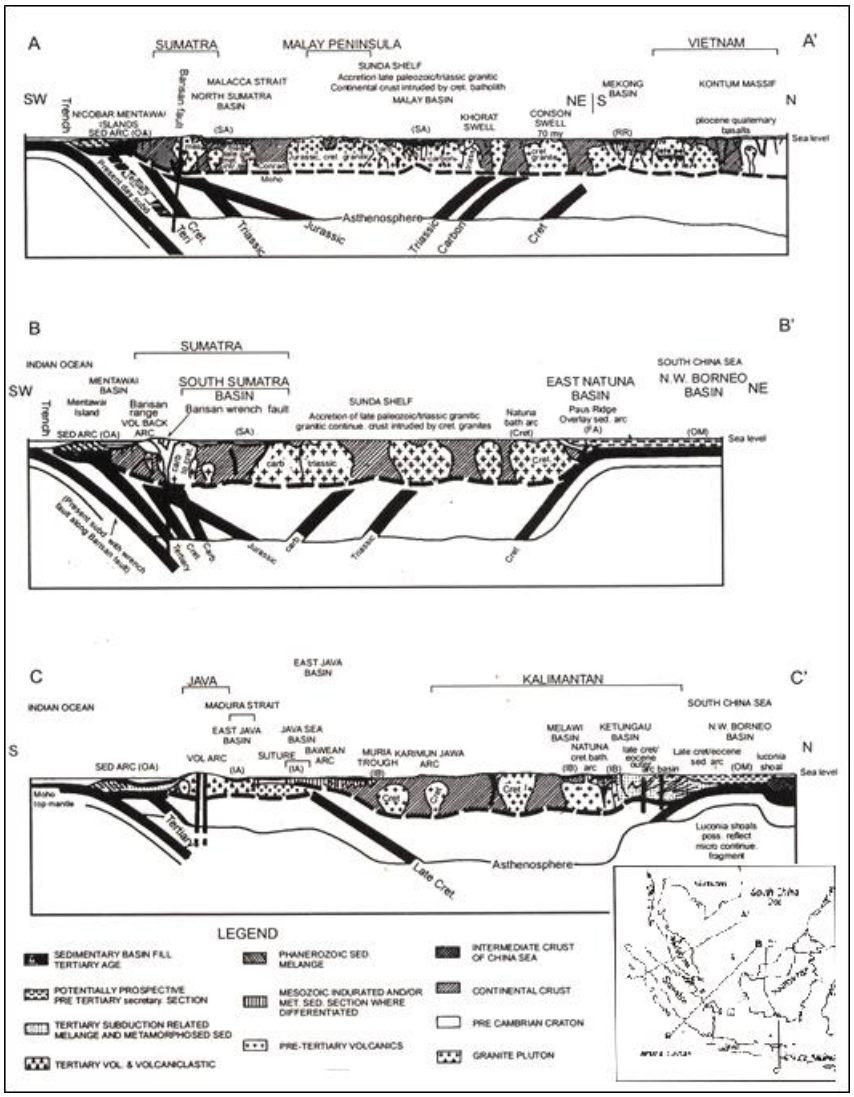



**Figure 3-4 Sections across Western Indonesia (Katili, 1981)**

The subduction zones have systematically moved farther away from the continent towards the Indian Ocean. The magmatic zones also show a zonal arrangement but the ages of the volcanics and granitic zones do not necessarily become younger towards the ocean. This posed problems to earlier investigators postulating the theory of a concentric arrangement of orogens but is explained by the supposition that the dips of the Benioff zones varied with time (Katili, 1980). Lithospheric descent in western Indonesia (i.e. Sumatra) also appears to have occurred during Permian, Jurassic, Cretaceous, Miocene and Pliocene times and continues today.

The Sulawesi-Banda sea region in eastern Indonesia is apparently a focal point of convergence between three plates: the westbound Pacific oceanic plate; the northbound Australian continental plate; and the Eurasian continental plate in the north and west.

The resulting complicated geologic setting certainly needs further research, particularly with regard to tectonic development and hydrocarbon maturation and migration history within the various basins. However, within the U-shaped Banda are region the following features are presently be recognized:

1. An inner ridge, comprising the volcanic islands of Bali, Sumbawa, Flores, Wetar, Damar and Banda Api.
2. An outer ridge, comprising the islands of Sawn, Roti, Timor, Leti, Babar, Tanimbar, Kai, Watubela, Seram and Burn which consist mainly of subduction melanges and imbricate complexes of Tertiary age.
3. Outer-arc basins, which include the Lombok basin, the Sawn basin and further east, the Weber Basin.
4. The trench, over 6,000 m depth south of Bali and Sumbawa and over 5,000 m depth north of Buru, elsewhere averages 2,000 m in depth (Hamilton, 1979).

The next generation of prospect areas is likely to focus on some of these outer-arc basins together with the shelf basins within the Arafura shelf region. This is in addition the onshore and offshore extensions of the known Salawati, Bintuni, Akimeugah, Merauke and Waropen basins in Papua, the Seram basin of the island of Seram and the offshore basins in the Sulawesi region.

In contrast to the western part of Indonesia, wrench faults with a wide variety of orientations are far more common in eastern Indonesia. A different style of basin development results from the complex faulting and requires different exploration concepts and strategies.

## 3.4 STRUCTURAL GEOLOGY

Tectonic processes in Indonesia form the main structures in Indonesia. The most prominent fault in western Indonesia is the Semangko Fault or Greater Sumatra Fault, which is a dextral strike-slip fault along the island of Sumatra (about 1900 km). The formation of this fault zone is related to the subduction zone in western Sumatra.

The Palu-koro fault is another major structure in central Indonesia. It runs along the central part of Sulawesi Island and extends offshore to the west through the Makassar Strait and ends at the Mangkalihat Peninsula in Kalimantan. The fault is named after the capital city of Central Sulawesi, Palu, on the west coast of Sulawesi and also the Koro River, which is formed by the fault zone.

The Sorong Fault is a major dextral horizontal fault in eastern Indonesia, named after the city of Sorong. The fault has an east-west orientation and extends north from Irian Jaya to East Sulawesi for about 2000 km.

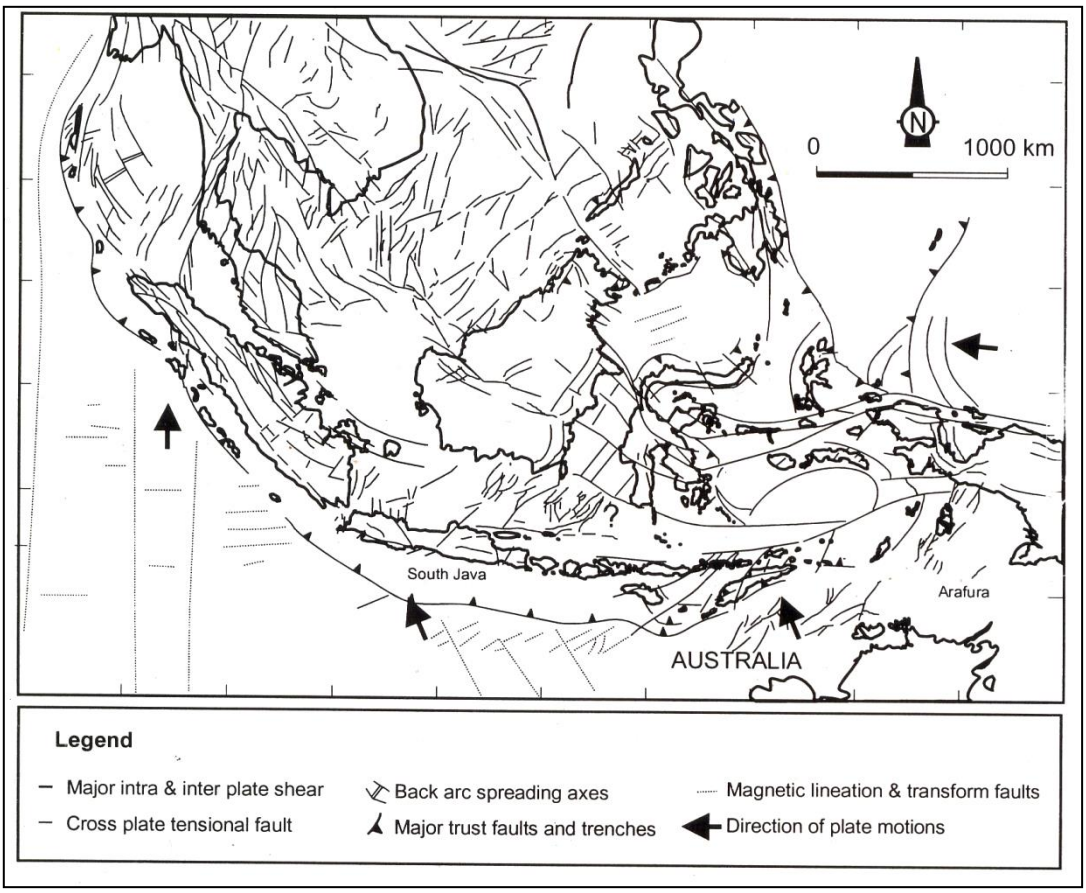



**Figure 3-5 Fault system of Indonesia illustrating sequential Cainozoic deformation (modified from Wood, 1985 in Hutchison, 1989)**

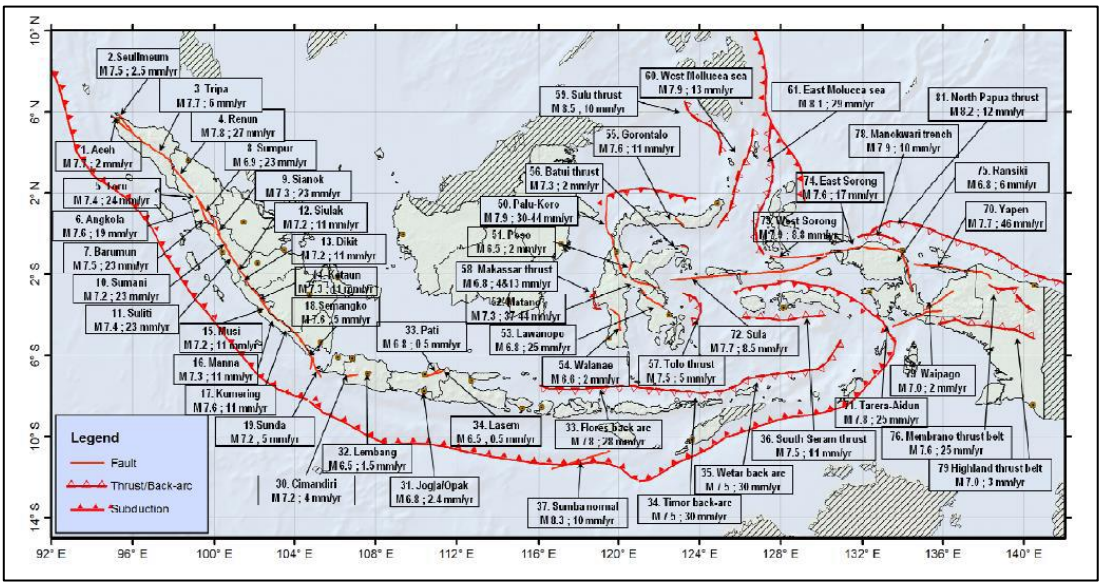



**Figure 3-6 Indonesia earthquake source map (PUSGEN, 2017)**

# 4. OVERVIEW OF 61 DAM SITES

## 4.1 GENERAL

61 reviewed dam spread throughout Indonesia, most dam located in Jawa Island. The overview of the Dam is just based on 3 regional geological condition, they are:

- ✧ Active fault location
- ✧ Seismicity Condition
- ✧ Lithology of the dam

In general, many active onshore faults are located on the islands of Java, Sumatra and Sulawesi where many dams are located on these islands, especially Java. This condition needs to be watched out considering that active faults are one of the sources of earthquakes and sometimes become a trigger (reactivation) of other faults.

Indonesia is one of the locations of areas that have a high seismic level, considering that Indonesia is the meeting area of the world's three major active tectonic plates, namely the Eurasian Plate, the Pacific Plate, and the Indo-Australian Plate. In addition, Indonesia is also a ring of fire line where volcanic activity is very intensive. This is a factor in the high seismicity in Indonesia.

The rock lithology conditions in Indonesia consist of various types of rocks including igneous / volcanic rocks, sedimentary rocks and few dams that are in metamorphic rocks. Most dams have sedimentary and volcanic rock lithology.

## 4.2 DATA AND THEORETICAL BASIS

The data used for the location of active faults in Indonesia refers to **"Peta Sumber dan Bahaya Gempa Bumi Indonesia (2017)"** published by Pusat Studi Gempa Indonesia (PUSGEN), as well as for the probabilistic seismic hazard analysis, peak ground acceleration (PGA) map for Operating Basis Earthquake (OBE).

Deterministic seismic hazard analysis is conducted using USGS (United States Geological Survey) with earthquake parameter is from 1900 to 2023 and magnitude more than 5 M.

The analysis was conducted using a peak ground acceleration calculation approach based on the empirical equation of Boore 1997 (from Douglas, 2001) obtained based on attenuation research in subduction regions. The 1997 Boore equation is as follows:

$$\log Y = b_1 + b_2(M-6) + b_3(M-6)^2 + b_4 r + b_5 \log r + bv(\log Vs_{30} -$$

*Where* : $r$ $= \sqrt{d2+h2}$ *d is epicenter distance,*
$M$ *= earthquake magnitude*
$Vs30$ *= S wave velocity at 30 m depth*
$Y$ *= horizontal ground movement in units of g*

There are also constants used are b1=-0.105, b2=0.229, b3=0, b4= 0, b5=-0.778, h= 5.57, bv=-0.371 and VA=1400, with the assumption that the earthquake wave that are taken into account are the horizontal component (Douglas, 2001).

The use of this equation requires site classification data based on the seismic shear wave velocity for the top 30 m of soil (Vs30). The value of Vs30 is estimated from NEHRP Site Classification (BSSC, 2003) based on lithology of the dam site.

Table 0 1 NEHRP Site Classification (BSSC, 2003)

**Table 4-1 NEHRP Site Classification (BSSC, 2003)**

| Site Class | $V_{S30}$ (m/s) | $N_{30}$ | General Description |
|---|---|---|---|
| $S_A$ | > 1500 | N.A. | Hard rock |
| $S_B$ | 760–1500 | N.A. | Rock with moderate weathering |
| $S_C$ | 360–760 | < 50 | Very dense soil and soft rock |
| $S_D$ | 180–360 | 15–50 | Stiff soil |
| $S_E$ | < 180 | < 15 | Soft clay soil |
| $S_F$ | N.A. | N.A. | Soils requiring site-specific evaluations |

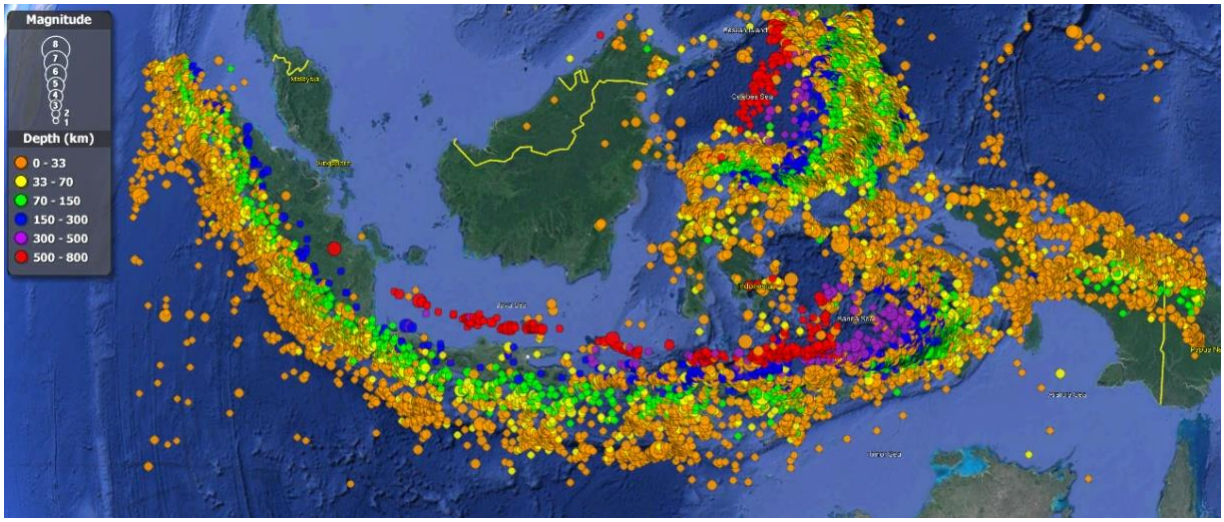



**Figure 4-1 Earthquake epicenter of Indonesia from 1900-2023 with magnitude more than 5.**

## 4.3 GEOLOGY OF 61 DAM SITES

Based on the sub-chapter 4.2 previously, the general overview of 61 dams is summarized on the Table 0 2.

**Table 4-2 Overview of 61 Dams of Indonesia**

| NO | NAME OF DAM | NEAREST ACTIVE FAULT | EARTHQUAKE HAZARD | | ROCK FOUNDATION |
|---|---|---|---|---|---|
| | | | PSHA OBE (g) (PUSGEN, 2017) | DSHA (g) ESTIMATION | |
| 1 | Ameroro | 40 | 0.1 - 0.15 | 0.04 | phyllite, slate, gneiss |
| 2 | Bagong | 75 | 0.15 - 0.2 | 0.14 | Colluvium, limestone, sandstone, volcanic breccia |
| 3 | Bajulmati | 3 | 0.1 - 0.15 | 0.06 | Tuff lapilli, lahar, river deposit |
| 4 | Bendo | 70 | 0.15 - 0.2 | 0.09 | Volcanic breccia, tuffaceous sandstone, andesite |
| 5 | Bener | 50 | 0.1 - 0.15 | 0.08 | Andesitic breccia, tuff breccia, tuff, andesite lava |
| 6 | Beringin Sila | 35 | 0.2 - 0.25 | 0.08 | Volcanic breccia, lahar, tuff, lava, volcanic ash |
| 7 | Bintang Bano | 25 | 0.2 - 0.25 | 0.16 | Tuff breccia, limestone and andesite intrusion |
| 8 | Budongbudong | 80 | 0.1 - 0.15 | 0.10 | Alluvium, breccia |

| NO | NAME OF DAM | NEAREST ACTIVE FAULT | EARTHQUAKE HAZARD | | ROCK FOUNDATION |
|---|---|---|---|---|---|
| | | | PSHA OBE (g) (PUSGEN, 2017) | DSHA (g) ESTIMATION | |
| 9 | Bulango Ulu | 15 | 0.3 - 0.4 | 0.14 | - |
| 10 | Cipanas | 15 | 0.1 - 0.15 | 0.06 | Conglomerate, breccia, sandstone |
| 11 | Ciawi | 35 | 0.2 - 0.25 | 0.18 | Tuff-lapilli, breccia, breccia sandstone-intercalated |
| 12 | Gondang | 45 | 0.1 - 0.15 | 0.07 | Terrace, colluvium, tuff-lapilli, volcanic breccia |
| 13 | Gongseng | 4 | 0.1 - 0.15 | 0.08 | Calcarenite, marl |
| 14 | Jatigede | 18 | 0.15 - 0.2 | 0.17 | Breccia, claystone |
| 15 | Jlantah | 60 | 0.15 - 0.2 | 0.08 | Andesite, basalt, breccia, lahar |
| 16 | Jragung | 7 | 0.1 - 0.15 | 0.04 | Claystone, siltstone, sandstone |
| 17 | Karalloe | 60 | 0 - 0.05 | 0.05 | Volcanic breccia, andesitic lava, tuff breccia |
| 18 | Karian | 70 | 0.2 - 0.25 | 0.09 | Tuff, lapilli, sandstone, breccia |
| 19 | Keureuto | 10 | 0.1 - 0.15 | 0.09 | Mudstone |
| 20 | Kuningan | 20 | 0.15 - 0.2 | 0.10 | Claystone, claystone-sandstone alternation, breccia |
| 21 | Kuwil Kawangkoang | 15 | 0.2 - 0.25 | 0.08 | Sandy Tuff, tuff lapilli, clayey tuff |
| 22 | Ladongi | 64 | 0.05 - 0.1 | 0.06 | Alluvium, schist mica |
| 23 | Lausimeme | 70 | 0.1 - 0.15 | 0.09 | Pumiceous Pyroclastic |
| 24 | Leuwikeris | 47 | 0.15 - 0.2 | 0.10 | Volcanic breccia, sandstone, claystone, tuff, conglomerate |
| 25 | Logung | 9 | 0.05 - 0.1 | 0.04 | Tuff, Lapilli-tuff, conglomerate, tuffaceous sandstone |
| 26 | Lolak | 88 | 0.25 - 0.3 | 0.11 | Lava, tuffaceous sandstone, shale-sandstone |
| 27 | Manikin | 70 | 0.2 - 0.25 | 0.18 | Scaly Claystone, Exotic block |
| 28 | Marangkayu | 100 | 0 - 0.05 | 0.04 | Alluvium, sandy silty clay |
| 29 | Margatiga | 100 | 0.1 - 0.15 | 0.07 | Basalt, tuff, tuffeceous sandstone |
| 30 | Meninting | 40 | 0.2 - 0.25 | 0.09 | Breccia, andesite lava |
| 31 | Mila | 67 | 0.2 - 0.25 | 0.11 | Andesite (dyke), andesite (lava), lapilli-tuff, breccia-tuff |
| 32 | Napun Gete | 80 | 0.2 - 0.25 | 0.09 | Tuffaceous sandstone, andesitic breccia, volcanic breccia |
| 33 | Nipah | 70 | 0.05 - 0.1 | 0.05 | Sandstone and claystone |
| 34 | Pamukkulu | 70 | 0 - 0.05 | 0.04 | Breccia, basalt-andesite lava |
| 35 | Paselloreng | 40 | 0.05 - 0.1 | 0.12 | conglomerate, sandstone, claystone |
| 36 | Paya Seunara | 2 | 0.3 - 0.4 | 0.38 | - |
| 37 | Pidekso | 65 | 0.15 - 0.2 | 0.05 | Tuff, pumiceous breccia, tuffaceos sandstone, dasitic lava, dasitic tuff |
| 38 | Rajui | 15 | 0.2 - 0.25 | 0.13 | Sandstone, silty sandston, claystone, clay |
| 39 | Raknamo | 70 | 0.2 - 0.25 | 0.15 | Claystone. Siltstone, claystone-siltstone alternation, siltstone-intercalation claystone |
| 40 | Randugunting | 10 | 0.05 - 0.1 | 0.05 | Siltstone, sandstone |
| 41 | Rotiklot | 60 | 0.2 - 0.25 | 0.15 | Claystone |
| 42 | Rukoh | 4 | 0.4 - 0.5 | 0.45 | Silty sandtone, claystone |
| 43 | Sadawarna | 2 | 0.1 - 0.15 | 0.08 | Claystone, sandstone, Breccia |
| 44 | Sei Gong | 400 | 0 - 0.05 | 0.03 | Quartz sandstone, claystone, sandy claystone, sandy tuff |
| 45 | Semantok | 19 | 0.1 - 0.15 | 0.06 | Sandstone, claystone |
| 46 | Sepaku Semoi | 100 | 0 - 0.05 | 0.03 | Quartz sandstone intercalated claystone, limestone, siltstone |
| 47 | Sidan | 70 | 0.2 - 0.25 | 0.13 | Andesitic breccia, volcanic breccia, sandy tuff |
| 48 | Sindang Heula | 120 | 0.2 - 0.25 | 0.09 | Pumiceous tuff, welded tuff (ignimbrite ) |
| 49 | Sukamahi | 35 | 0.2 - 0.25 | 0.17 | Breccia |
| 50 | Tamblang | 80 | 0.15 - 0.2 | 0.11 | Andesite lava, volcanic breccia, tuff |

| NO | NAME OF DAM | NEAREST ACTIVE FAULT | EARTHQUAKE HAZARD | | ROCK FOUNDATION |
|---|---|---|---|---|---|
| | | | PSHA OBE (g) (PUSGEN, 2017) | DSHA (g) ESTIMATION | |
| 51 | Tanju | 75 | 0.2 - 0.25 | 0.14 | Andesite e, breccia |
| 52 | Tapin | 100 | 0 - 0.05 | 0.02 | Andesite , basalt |
| 53 | Temef | 80 | 0.2 - 0.25 | 0.11 | Sandstone, claystone, limestone |
| 54 | Teritip | 160 | 0 - 0.05 | 0.04 | Clay, quartz sand |
| 55 | Tiga Dihaji | 13 | 0.25 - 0.3 | 0.11 | Sand, tuff, sandston-claystone alternation |
| 56 | Titab | 80 | 0.15 - 0.2 | 0.20 | Andesitic breccia, tuffaceous sandstone tuffaceous mudstone |
| 57 | Tiu Suntuk | 30 | 0.2 - 0.25 | 0.09 | Andesite |
| 58 | Tugu | 85 | 0.15 - 0.2 | 0.08 | Breccia, lava, tuff, sandstone -siltstone intercalation |
| 59 | Tukul | 90 | 0.15 - 0.2 | 0.06 | Andesite, tuff. sandstone, breccia, claystone-siltstone |
| 60 | Way Apu | 55 | 0.15 - 0.2 | 0.13 | Alluvial, terrace, Metamorphic rock unit |
| 61 | Way Sekampung | 30 | 0.15 - 0.2 | 0.15 | Sandstone, conglomerate and schist |

## 4.4 ISSUES IN ONGOING DAM PROJECTS

In general there are several issues related to the dam construction in Indonesia. The most issue is retaliated to slope stability, structure foundation, dam material, tunnel collapse or leakage. General issue of dam in Indonesia is provided on the Table 0 3.

Table 4-3 General issue of dam in Indonesia

| Dam Name | Issues Arose at Site |
|---|---|
| **1 Landslide/Slope Stability** | |
| 1 Bendo | Intake slope stability is doubtful |
| | Reservoir landslide potential |
| 2 Budong Budong | Reservoir landslide potential |
| | Sliding potential of spillway |
| 3 Ciawi | Landslide on left slope of stilling basin |
| | Sliding potential at reservoir |
| 4 Cipanas | Landslide during excavation at spillway |
| 5 Gongseng | landslide potential at reservoir area |
| 6 Jatigede | Slope Stability of Reservoir |
| 7 Jragung | many landslide of access road |
| 8 Keureuto | landslide potential around the Apron spillway |
| 9 Kuningan | landslide at surrounding dam body and reservoir |
| 10 Ladongi | Landslide at left side of spillway |
| 11 Lausimeme | Spillway landslide potential |
| | Landslide potential of reservoir |
| 12 Logung | Reservoir landslide potential |
| 13 Manikin | Exotic block sliding |
| 14 Meninting | Sliding potential at left abutment |
| | Landslide at reservoir/quarry |
| 15 Napun Gete | landslide monitoring above spillway |
| 16 Nipah | Sliding at reservoir |
| 17 Pamukkulu | sliding around the spillway cut slope |
| 18 Randu Gunting | landslide potential around facility building |
| 19 Rotiklot | Landslide ever occurred on the downstream slope to the left of the dam. |

| | Dam Name | Issues Arose at Site |
|---|---|---|
| 20 | Sadawarna | Landslide potential near to diversion slope |
| | | Landslide around stilling basin |
| | | Reservoir sliding |
| 21 | Sei Gong | Landslide on left bank of spillway |
| 22 | Sindang Heula | Landslide potential |
| 23 | Sukamahi | Reservoir landslide potential |
| 24 | Temef | landslide of spillway bank |
| 25 | Teritip | Sliding at right abutment hills during impounding |
| 26 | Tiga Dihaji | Landslide potential on conglomerate |
| 27 | Tiu Suntuk | Reservoir landslide potential |
| 28 | Tugu | Landslide at the right slope of spillway |
| 29 | Way Sekampung | Sliding at outlet tunnel |
| **2** | **Dam Material** | |
| 1 | Ameroro | slurry clay for contact clay (no standard) |
| 2 | Bagong | secant pile material should meet requirement |
| 3 | Bendo | density value of zone 3a & 3b (rock, is too high |
| 4 | Bener | Material gradation and Specification of Toe Slab |
| 5 | Beringin Sila | some concrete strengh test result doesn't meet requirement |
| 6 | Bintang Bano | some riprap is no interlocked |
| 7 | Budong Budong | insufficient potential of core material |
| | | Using breccia for rock fill |
| 8 | Cipanas | Random material for spillway bacfill gradation |
| 9 | Jlantah | Parameter of material |
| 10 | Jragung | insufficient random material (resident rejection) |
| 11 | Karian | Wet core material (7-12% above OMC) |
| 12 | Kuwil | high ranged data of rock zone material |
| 13 | Lausimeme | Core material does not meet requirement |
| 14 | Leuwikeris | High OMC (47%) of core material/ difficulity of compaction |
| 15 | Manikin | alluvium for fly ash |
| 16 | Meninting | Quantity of core material |
| | | Fine grained of random |
| | | Soil random |
| | | Core quality |
| 17 | Marangkayu | Dam embankment material (no impounding from completing construction) |
| | | Filter sample |
| | | Counter weight condition |
| 18 | Margatiga | Core material does not meet requirement |
| 19 | Pamukkulu | Termal craking posibility of concrete |
| | | Changing specification of zone 2B material |
| 20 | Sadawarna | Dam material parameter |
| 21 | Semantok | Embankment doesn't meet requirement |
| | | Different value of permeability of main cofferdam and dam embankment |
| 22 | Sepaku Semoi | Difference modulus of dental concrete and rock foundation |
| | | high pore water pressure at dam embankment |
| 23 | Sidan | Material of asphalt concrete |
| | | Filter density |
| | | Random zone material (dam shoulder) |
| 24 | Sindang Heula | Weathering Riprap |
| 25 | Sukamahi | Piping potential at core material (high pore pressure) |
| 26 | Tamblang | Quality of central concrete as base asphalt concrete (no reinforcement) |
| | | Settlement of asphalt concrete |
| | | high stress potential at contact of dental and asphalt concrete |
| | | Piezometer reading of embankment |
| 27 | Tanju | Weathered riprap |

| Dam Name | | Issues Arose at Site |
|---|---|---|
| 28 | Tapin | Current piezometer readings, pore water has yet to reach a steady state |
| 29 | Tiga Dihaji | Rock fill material criteria |
| | | Material changing for the dam |
| | | Thick overburden of dam material & Dam design change |
| 30 | Tukul | high pore water pressure at dam embankment |
| | | there has been a sattlement of >1% (compaction was not carried out properly) |
| 31 | Way Apu | Difference modulus of groutcap and rock foundation |
| | | Contact clay material |
| **3** | **Dam Stability** | |
| 1 | Bajulmati | Cross and long crack and settlement at Dam Crest |
| 2 | Bintang Bano | Craking on dam crest |
| 3 | Budong Budong | high density parameter of design |
| 4 | Gondang | conterweight additional |
| | | Difirence specification of counterwright material |
| 5 | Karian | High settlement potential |
| 6 | Keureuto | Settlement of core embankment |
| 7 | Kuningan | Bulging at dam surface |
| | | high settlement from instrument reading |
| 8 | Ladongi | Crack on construction joint of dam |
| | | Crack on aspalt at dam crest |
| 9 | Lausimeme | Sudden settlement of core embankment |
| 10 | Marangkayu | Dam body inspection (deformation) |
| 11 | Meninting | Rapid drowdown |
| 12 | Napun Gete | landslide of dam slope stability mostly passes through zone 4 |
| | | Sudden settlement |
| 13 | Paselloreng | settlement in the riprap (near the right abutment of upstream) |
| 14 | Pidekso | Uplift potential |
| | | Crack along dam foundation |
| 15 | Raknamo | wavy asphalt on dam crest and crack |
| 16 | Randu Gunting | Vertical and horizontal movement of dam (high differrence) |
| 17 | Rukoh | Broken Piezometer of embankman and dam foundation |
| 18 | Sei Gong | Surface erosional on dam body |
| 19 | Semantok | Uplift potential |
| 20 | Sepaku Semoi | Slidding during construction at dam embankment |
| 21 | Sidan | Depth of D-Wall and Uplift potential |
| | | Dam deformation |
| 22 | Sindang Heula | Settlement on the dam crest |
| 23 | Sukamahi | High settlement reading |
| 24 | Tamblang | Safety factor of MDE analysis doesn't meet requirement |
| | | Craking on dam crest (aspalt road) |
| | | Dam Deformation |
| 25 | Teritip | Instrument settlement reading |
| | | X-Y movement direction |
| 26 | Tukul | Immediate settlement |
| **4** | **Water Seepage / Spring on the Dam** | |
| 1 | Ameroro | Water sepage on dam foundation |
| 2 | Bendo | Seepage around the v notch |
| 3 | Bener | Akuifer influence |
| 4 | Cipanas | V-notch seepage before imponding (2 liter/second) |
| 5 | Gongseng | seepage from lithology boundary (limestone and marl) |
| 6 | Karalloe | Spring on the dam body |
| 7 | Keureuto | Seepage at the chute floor of spillway |
| 8 | Leuwikeris | Seepage from left and right abutment |
| 9 | Logung | Seepage at left dam abutment |

| | Dam Name | Issues Arose at Site |
|---|---|---|
| 10 | Napun Gete | Seepage at the downstream of dam |
| | | High discharge |
| 11 | Nipah | Water pressure on OW has higher elevation than ground surface |
| 12 | Paselloreng | Scouring and seepage at spillway |
| 13 | Pidekso | difference seepage from v-notch reading |
| 14 | Raknamo | Seepage on the abutment and toe drain |
| 15 | Randu Gunting | Seepage on the slope near to valve house |
| 16 | Semantok | Reservoir leakage posibility |
| | | Seepage at the dam toe |
| 17 | Tamblang | Water leakage through dam body ( can reach 1 m?/s) |
| | | Dam body seepage |
| 18 | Titab | Spring at the downstream of Dam |
| | | Seepage at dam toe |
| 19 | Tugu | seepage at foot of downstream slope |
| 20 | Way Sekampung | Spring/seepage at right abutment |
| **5** | **Grouting** | |
| 1 | Ameroro | Very deep grouting at abutment |
| 2 | Bener | no foundation grouting in places |
| 3 | Cipanas | possibility of seepage between spillway and abutment |
| 4 | Gongseng | Ineffectiveness grouting indication from instrument |
| 5 | Jlantah | Replaced grouting by cut-off wall |
| | | additional monitoring for grouting and D wall connection |
| 6 | Keureuto | Lugeon Value of Grouting |
| 7 | Kuningan | Ineffectiveness grouting indication from instrument |
| 8 | Lausimeme | Insufficient grouting at the dam |
| | | Rim grouting |
| 9 | Leuwikeris | The grouting carried out does not reach the appropriate depth in the body |
| | | Foundation seepage of grouting and D-wall connection |
| 10 | Meninting | Rim grouting |
| 11 | Rukoh | Grouting for Spillway |
| 12 | Sidan | Consolidation grouting for tunnel floor |
| 13 | Tamblang | no grouting at river bed of dam foundation |
| 14 | Tiu suntuk | only blanket grouting on riverbed (no curtain grouting) |
| | | ineffective curtain grouting from piezometer reading |
| 15 | Way Apu | Insufficient depth of grouting at the dam |
| **6** | **Dam Foundation** | |
| 1 | Ameroro | Step excavation of foundation |
| 2 | Bagong | Colluvium foundation at right and left abutment |
| | | Using coarse colluvial for dam foundation at left abutment |
| | | Left abutment foundation |
| 3 | Bener | possibility of concrete slab crack at foundation & insufficient of concrete slab width |
| | | insufficient of concrete slab width |
| 4 | Budong Budong | Colluvium foundation at left abutment |
| | | Alluvium at dam shoulder & Dam toe |
| | | Alluvium foundation |
| 5 | Cipanas | Thrush fault on dam Foundation |
| 6 | Gongseng | possibility difference modulus value of foundation and dental concrete |
| 7 | Jlantah | Permeable zone of dam foundation |
| | | Difference modulus test result (from 2 tests) |
| | | Overlapping diaphragm and grouting |
| 8 | Jragung | Colluvium deposit at dam foundation |
| 9 | Lausimeme | Water pressure and Foundation piezometer |
| 10 | Manikin | Swelling pressure related to asphalt core |

| Dam Name | | Issues Arose at Site |
|---|---|---|
| | | Foundation based on MASW |
| 11 | Marangkayu | Dam foundation (effectiveness of vertical drain) |
| 12 | Meninting | Unconformity of foundation |
| 13 | Paselloreng | Erosion at right abutment |
| 14 | Randu Gunting | Swelling potential |
| 15 | Tiga Dihaji | Distribution of loose sand as foundation |
| | | Loose zone at core |
| **7** | **Spillway Design / Condition** | |
| 1 | Ameroro | ineffective stilling basin to reduce water velocity |
| 2 | Bagong | Changing spillway design due to colluvium |
| 3 | Manikin | leakage potential of Morning glory elbow connection |
| | | purpose spillway channel to be open channel from conduit |
| | | Effectiveness of auxiliary spillway |
| | | Consider changing auxiliary spillway elevation |
| 5 | Rukoh | design of slab drainage of spillway (insufficient drainage to downstream) |
| | | Spillway backfill material for drainage is not free drain material |
| | | Spillway capacity |
| 6 | Sidan | Changing stilling to sky jump type |
| | | Sub Dam additional at downstream of spillway |
| 7 | Tanju | Crack at the spillway |
| 8 | Tapin | Crack at the top of spillway |
| | | Many crack at threshold (mercu) |
| 9 | Tiga Dihaji | Changing stilling design |
| 10 | Tugu | deformation on spillway between some blocks |
| **8** | **Diversion leakage** | |
| 1 | Bendo | Seepage around the tunnel |
| 2 | Beringin Sila | Leakage water on diversion gate during dry test |
| 3 | Karalloe | Seepage in the tunnel |
| 4 | Keureuto | Water leakage of Tunnel |
| | | Leakage at tunnel |
| 5 | Kuwil | Leakage water in the tunnel |
| 6 | Logung | Several seepage on conduit wall |
| 7 | Marangkayu | Leakage water at conduit |
| 8 | Napun Gete | Leakage in the wall of conduit |
| 9 | Nipah | Seepage on the tunnel |
| 10 | Paselloreng | Leakage on tunnel wall |
| 11 | Rukoh | Crack and stalactization in tunnel |
| 12 | Semantok | D-wall and conduit connection |
| 13 | Tapin | Water leakage at the downstream of tunnel |
| | | Calcite at the tunnel |
| **9** | **Spillway Foundation** | |
| 1 | Bagong | Colluvium foundation |
| | | Using bore pile for spillway |
| 2 | Bajulmati | Settlement around spillway |
| 3 | Cipanas | there a unconformity under stilling basin |
| 4 | Jragung | Colluvium foundation & landslide |
| 5 | Keureuto | leakage at spillway |
| 6 | Ladongi | Improvement of spillway foundation (residual soil foundation) |
| 7 | Meninting | Foundation weak zone / laharic breccia |
| 8 | Sepaku Semoi | alluvium deposit ot confluence of spillway and conduit |
| 9 | Sidan | Foundation of spillway weir |
| 10 | Temef | Swelling pressure of spillway floor |
| 11 | Way Apu | Dispersive material spillway slope |
| **10** | **Fault Zone / Seismicity** | |

| | Dam Name | Issues Arose at Site |
|---|---|---|
| 1 | Gongseng | Influence Kendeng Fault to Gongseng dam |
| 2 | Jatigede | Seismicity consideration in PLTS Installation |
| 3 | Keureuto | Active fault |
| 4 | Kuwil | Influence Airmadidi Fault to Kuwil dam |
| 5 | Lausimeme | Weak zone monitoring by Instrument installation |
| | | Seismic conductivity potential |
| 6 | Margatiga | Possibility of Reservoir Induced Seismicity |
| 7 | Meninting | Dynamic analysis for active fault |
| 8 | Randu Gunting | Near to earthquake source (fault) |
| 9 | Sadawarna | there is a part of the Baribis fault structure indication |
| 10 | Tapin | Influence Meratus Fault to Tapin dam |
| 11 | Tukul | Instrument installation at fault zone & Monitoring |
| **11** | **Dam Design** | |
| 1 | Ameroro | Very slim core zone shape |
| 2 | Budong Budong | Dam zonal of rock fill |
| 3 | Jlantah | Dam design changing |
| 4 | Keureuto | Changing Rap-rap Thickness |
| | | Horizontal Drain Function at Middle of Dam Body |
| 5 | Leuwikeris | Design changing from rock filled to zoning |
| 6 | Marangkayu | Mapping of functioning Instrumentation |
| 7 | Rukoh | changing dam slope (become steeper) |
| 8 | Tamblang | dimension of asphalt concrete (too thin) |
| 9 | Tiga Dihaji | Cutting excavation |
| **12** | **Tunnel Collapse** | |
| 1 | Bagong | Tunnel collapse at lithology boundary |
| 2 | Bener | weak zone claystone layer |
| 3 | Jragung | Deformation on inlet and outlet of tunnel |
| 4 | Manikin | swelling material on tunnel (tunnel damage) |
| 5 | Tiga Dihaji | Diversion tunnel through loose material |
| 6 | Way Apu | Tunnel collapse due to poor rock mass |
| **13** | **Sedimentation** | |
| 1 | Ciawi | rubbish accumulation on the trash rack |
| 2 | Logung | water hyacinths on reservoir |
| 3 | Randu Gunting | high sedimentation |
| 4 | Sukamahi | Clogging on the trash rack & Clogging on the trash rack |
| | | Trash and sediment problem |
| 5 | Tugu | sedimentation reducing (sabo dam construction) |
| 6 | Tukul | high sedimentation potential |
| **14** | **Flooding** | |
| 1 | Bener | There is no analysis about flood control (one of Bener dam benefit) |
| 2 | Beringin Sila | Flash flooding potential |
| 3 | Jlantah | Large flooding historical |
| 4 | Lolak | Flash flooding potential |
| 5 | Meninting | Flooding exceeds design plan for cofferdam |
| 6 | Tugu | Flooding brings sediment quickly |
| **15** | **V-notch** | |
| 1 | Keureuto | V-notch Elevation is lower elevation than the river elevation |
| 2 | Leukeris | The V-Notch position is lower elevation than the river elevation |
| 3 | Logung | water seepage and foundation seepage in one v-notch |
| 4 | Napun gete | Disturbed due to backwater from the outlet building. |
| 5 | Rukoh | The V-Notch position is lower elevation than the river elevation |
| **16** | **Reservoir** | |
| 1 | Luewikeris | Water quality |

| Dam Name | | Issues Arose at Site |
|---|---|---|
| 2 | Logung | Environment regulation recommendation to be applied |
| 3 | Jatigede | Location of Panel Installation in reservoir |
| 4 | Marangkayu | Reservoir water level impounds gas wells |
| 5 | Napun Gete | Rapid water rise of reservoir |
| **17** | **Hydromechanical** | |
| 1 | Rukoh | not be equipped with a bottom outlet. |
| 2 | Keureuto | Displacement of Sluice Gate |
| | | Raw Water Pipe Installation |
| | | Installation of Bottom Outlet |
| 3 | Temef | Early release pipe are too sharp and twisty. |
| **18** | **Intake design/foundation** | |
| 1 | Jragung | changing incline intake to tower intake |
| 2 | Leuwikeris | there is unstable potential of intake foundation |
| 3 | Marangkayu | Foundation of additional release channel |
| 4 | Rukoh | instrumentation for sliding monitoring at around intake |
| 5 | Temef | There was a shifting slope of pillar at bridge of spillway wall to intake tower |
| **19** | **Drilling on Dam Body** | |
| 1 | Bendo | drilling on dam body to install piezometer |
| 3 | Raknamo | drilling on dam body to install inclinometer |
| 2 | Rotiklot | drilling on dam body to install inclinometer |
| | | drilling on dam body to install piezometer |
| **20** | **Penstock Pipe** | |
| 1 | Karian | Difficulty of maintenance after impounding |
| 2 | Keureuto | Shifting penstock location |
| **21** | **Liquefaction** | |
| 1 | Kuwil | Liquefaction potential |
| 2 | Tiga Dihaji | Liquefaction potential |
| **22** | **Plugging of diversion** | |
| 1 | Lolak | detail plugging implementation is required |
| 2 | Manikin | Plugging and cooling method |
| **23** | **Cut-off wall / secant pile** | |
| 1 | Bagong | possibility of insufficient length of spillway side |
| **24** | **Dam Impounding** | |
| 1 | Lolak | staging impounding to monitor dam behavior |
| **25** | **Anchoring Panel** | |
| 1 | Jatigede | base anchor on soil |
| **26** | **Galery Inspection** | |
| 1 | Tiga Dihaji | Gallery recommendation |
| **27** | **Water Treatment plant** | |
| 1 | Sepaku Semoi | Water treatment location |
| | | WPT location at left abutment |
| | | Slope excavation at left abutment for WTP |
| | | Determination of WTP location at Dam downstream |

# 5. ENGINEERING CONSIDERATIONS

## 5.1 FAULT ZONE / SEISMICITY

Active fault zone effect to the dam become main issue related to seismicity. One of the parameters in dam site selection is the seismicity of the location. Parameter selection can be done deterministically or probabilistically for a catastrophic earthquake or a combination of both. For example, the relationship between earthquake acceleration and return period to determine the MDE, and with the OBE consists of the maximum ground acceleration (PGA) and the shape of the earthquake response (spectrum). (Peak ground acceleration, PGA) and the specific shape of the earthquake response (spectrum).

Earthquake parameters that reflect the magnitude of MDE, OBE or RIE are often used as input data for numerical analysis in as input data for numerical analysis of dams. The results of the numerical analysis are used for the evaluation of dam behavior and dam safety, resulting in a resulting in the magnitude of shaking.

Based on Pd T-14-2004-A (Analisis stabilitas bendungan tipe urugan akibat beban gempa, PUPR 2004), damage classification according to earthquake magnitude is classified to 4 group that provide on the Table 0 1. 10 km is the distance considered safe for a dam site from an active fault. If it is less than 10 km, a special earthquake hazard study must be carried out on the site of a dam.

**Table 5-1 Damage level according to the magnitude of the maximum earthquake acceleration at MDE (Pd T-14-2004-A, PUPR)**

| Maximum earthquake acceleration (PGA=ad) | Classification of damage level |
|---|---|
| *PGA* < 0.1 g | I (Low) |
| 0.10 ≤ *PGA* < 0.25g | II ( Medium) |
| *PGA* ≥ 0.25g No active faults within 10km of the site | III ( High) |
| *PGA* ≥ 0.25g active fault closer than 10 km from the location | IV (extreme) |

Ameroro Dam, Jatigede Dam, Kuwil Dam, Lausimeme Dam, Margatiga Dam, Randu Gunting Dam, Sadawarna Dam, Tapin Dam, Tukul Dam are dam name with seismicity issue, but only Randu Gungting Dam and Sadawarna Dam which located less than 10 km from active fault. According to PSHA and DSHA (see Table 0 2), the Peak ground acceleration is less than 0.25 that still can be classified low to medium.

Some dam has Possibility of Reservoir Induced Seismicity (RIS). RIS is the incidence of earthquake triggered due to impoundment of water behind a dam. Many people believe that reservoirs trigger earth tremors due to load of water. However, a reservoir, at worst, can only advance an earthquake which would have occurred otherwise too. The magnitude of forces associated with an earthquake is several orders bigger compared to the additional load of water in the reservoir. The change in stresses due to water load is too small to cause fracture in the earth's crust (Srivastava, 1993).

## 5.2 LANDSLIDE/SLOPE STABILITY

Cruden and Vernes (1996) mentioned that the factors that cause landslides are divided into 2 groups, first is causal factors and second is triggering factors. Causal factors include

slope, rock and soil types. Heavy rain (water), seismic activity such as volcanic eruptions and earthquakes are included in the triggering factors.

According to Goenadi et al (2003), landslide triggering factors are grouped into two, static triggering factors and dynamic triggering factors. These dynamic triggering factors have a considerable influence because landslides are often triggered by changes in force or energy due to changes in dynamic factors. Included in the category of dynamic triggering factors are rainfall and land use. In the group of dynamic factors there is actually seismic factor. Furthermore, the static triggering factors of landslides are divided into 2 groups, namely rock (type of constituent lithology and geological structure), and soil physical properties.

**Table 5-2 Factors that trigger landslides (Goenadi et al, 2003)**

| NO | CAUSAL FACTOR | PARAMETER |
|---|---|---|
| 1 | Dynamic triggering factors | Land slope |
| | | Rainfall |
| | | Land use |
| 2 | Static triggering factors | Rock Type & Geological structure |
| | | Soil Condition |
| | | Soil/rock permeability |
| | | Soil texture |

Based on this explanation, it can be concluded that there are conditions that cause and trigger landslides, among others: (a) Slope, (b) Technical properties of rock/soil, (c) geology condition, (d) water condition / soil saturation and (e) soil/rock permeability. Some of these parameter can be control or reinforcement by engineering. It mean to avoid landslide knowing on rock/soil and controlling of these parameter is needed.

Most of the dam in Indonesia has slope stability problem especially at 3 location. Generally the treatment all of these locations is almost same. Important this is how to control condition or strengthening of slope. The locations that landslide often occur in Indonesia dam are (1) around spillway building, (2) outlet and inlet tunnel and, (3) sliding / potential at reservoir

Regarding for geologist, there are 3 conditions have to be understood well to identify the landslide. First is rock/soil material, second is geological condition including strike/dip, discontinuity and unconformity and last is groundwater condition.

*Rock/Soil Material*

On slopes cutting associated with soils or rocks with a fine material composition often become landslide sliding planes and become weak zones because they are easily destroyed when in direct contact with air resulting in loss or increase of water content (swelling/slaking).

*Geological Condition*

The stability of rock slopes is often significantly influenced by the structural geology of the rock in which the slope is excavated. Structural geology refers to naturally occurring breaks in the rock such as bedding planes, joints, foliation and faults, which are generally termed discontinuities. The properties of discontinuities relative to stability include orientation, persistence, roughness and infilling. The significance of discontinuities is that they are planes of weakness in the much stronger, intact rock so failure tends to occur preferentially along these surfaces. The discontinuities may directly influence stability.

*Groundwater*

The presence of ground water in a rock slope can have a detrimental effect upon stability for the following reasons:

- ✧ Water pressure reduces the stability of the slopes by diminishing the shear strength of potential failure surfaces
- ✧ Changes in moisture content of some rock, particularly shale, can cause accelerated weathering and a decrease in shear strength.
- ✧ Freezing of ground water can cause wedging in water-filled fissures due to temperature
- ✧ Erosion of weathered rock by surface water, and of low strength infillings by ground water can result in local instability where the toe of a slope is undermined, or a block of rock is loosened.
- ✧ Excavation costs can be increased when working below the water table. For example, wet blast holes require the use of water-resistant explosives that are more expensive than non-water-resistant.

Bendo Dam, Budong Budong Dam, Ciawi Dam, Cipanas Dam, Gongseng Dam, Jatigede Dam, Jragung Dam, Keureuto Dam, Kuningan Dam, Ladongi Dam, Lausimeme Dam, Logung Dam, Manikin Dam, Meninting Dam, Napun Gete Dam, Nipah Dam, Pamukkulu Dam, Randu Gunting Dam, Rotiklot Dam, Sadawarna Dam, Sei Gong Dam, Sindang Heula Dam, Sukamahi Dam, Temef Dam, Teritip Dam, Tiga Dihaji Dam, Tiu Suntuk Dam, Tugu Dam, and Way Sekampung Dam, have some issues related to slope stability.

### 5.2.1 Landslide of Spillway on Fine Grained Material or Colluvium

Spillways may be classified according to their function. Several spillways are designed for frequent use in conveying both normal and flood releases from a reservoir to the watercourse downstream from a dam, because of spillway should reach certain elevation to control water level and water flow condition, some spillway has depth excavation.

At least there are 26 dams that has issues about slope stability. Most landslide occur at volcanic and sedimentary lithology that associated with fine grained material like clay, claystone, marl and tuff. Rocks that have a material composition with fine grains tend to have a small internal friction angle value besides having some typical clay properties such as swelling and slaking.

Fine grained material has high porosity and low permeability. This condition makes fine-grained materials tend to hold that it will be an additional burden on a slope. Slopes with the presence of fine materials should be added subsurface drainage to control the water conditions on the slope.

Subsurface drainage should be installed deeper than the critical landslide boundary with a certain distance. Perforated pipes can be used as drainage and filled with gravel and sand (permeable material). Filling with gravel and sand is intended so that the hole does not become a nest for animals that are feared to interfere the drainage function.

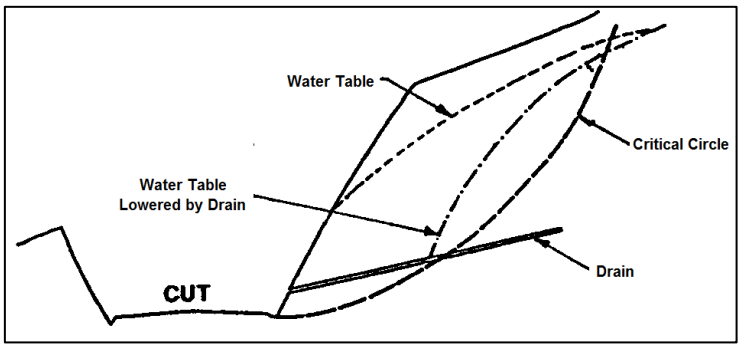



**Figure 5-1 Horizontal drain to lowered water level especially at fine-grained material**

Colluvium or high weathered rock was observed in some slopes cutting, colluvium usually is unstable and unconsolidated deposit that may be become another landslide. Slope with observed colluvium should be excavated/removed or re-embankment with compaction if there are any building on. Subsurface drainage is also should be installed to control water level.

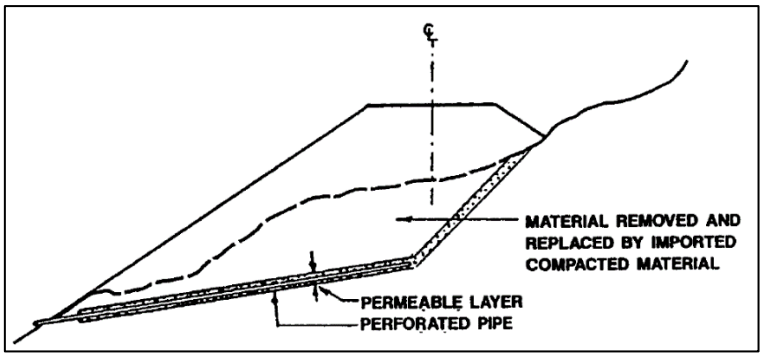



**Figure 5-2 drain blanket underneath embankments subsequent to removal of poor material (Rodrigues et al, 1988)**

### 5.2.2 Slope Stability of Tunnel Portal

In case of spillway and tunnel portal, mostly has high cutting slope. Higher cutting slope has high risk of landslide / slope failure.

The portal area is the area at the entrance and exit of the tunnel, where the overburden is 1 to 2 times the excavation diameter and the rock arc effect is not formed easily, as shown in Figure 0 3. These conditions mean that tunnel portals often have fairly steep cut slopes.

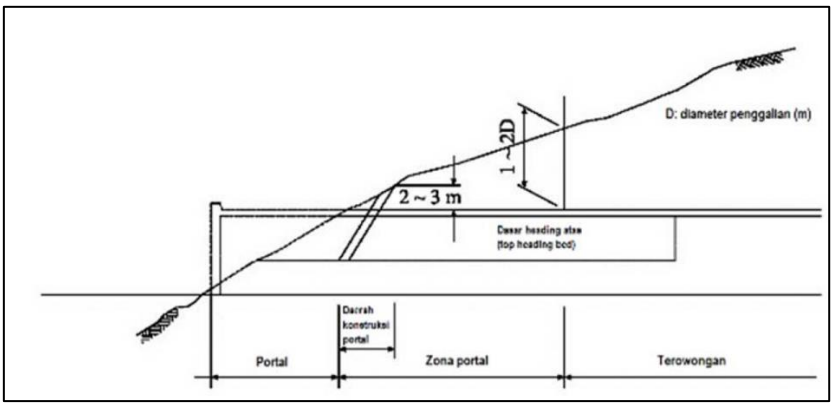



**Figure 5-3 Typical tunnel portal area (JSCE, 2007 in SNI 8460:2017)**

The tunnel portal is one of the weak zones in the tunnel structure. This is because at this location residual soil or weathered rock becomes overburden at the top. It is better to locate the portals deeper into the ground or hill where rock cover of at least equal to width of tunnel is available. The slope of the portal should be stable. Otherwise the same should be reinforced properly with the rock anchors. Alternatively a thick wall (1 m) of concrete should be constructed to ensure stability of portals (Singh & Goel, 2002). In case of unstable portals, horizontal anchors of equal length should be provided inside the cut slope, so that it acts as a reinforced rock wall.

one of the tunnel support methods that is often used in Indonesia is the tunnel support method of Bieniawski (1984) which is determined from the results of the RMR value. The tunnel support table of Bieniawski's method is presented in the Table 0 6.

### 5.2.3 Landslide or Potential Landslide around Reservoir

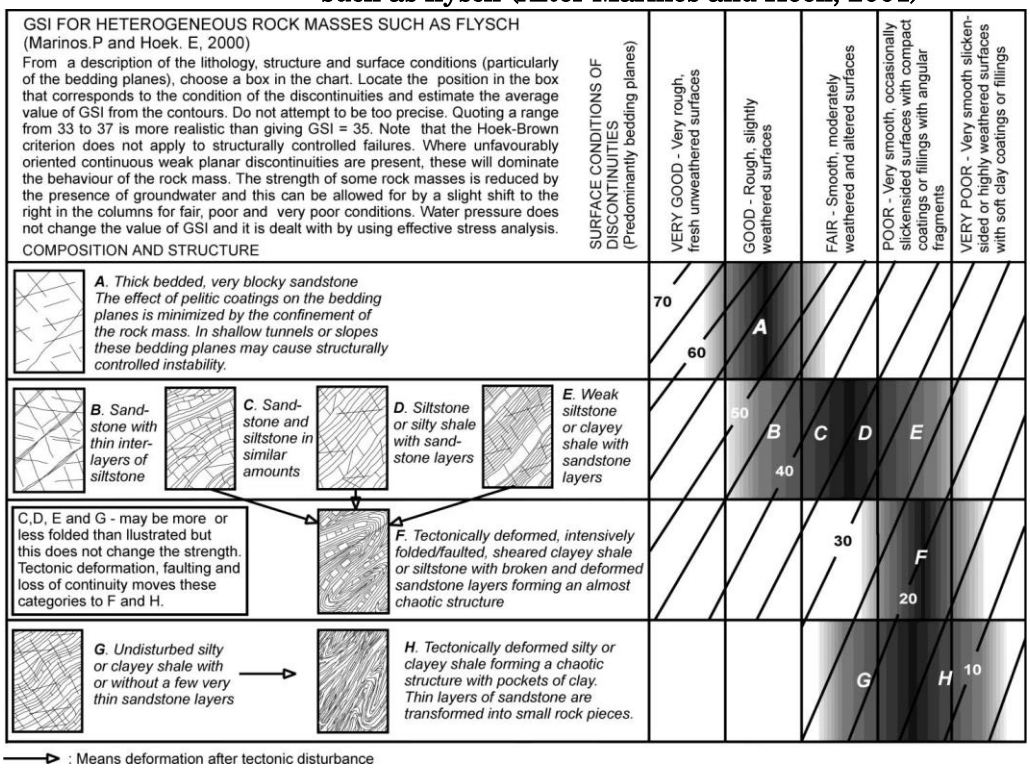
The most critical slope stability at the dam reservoir is during impounding. The cliffs/walls around the reservoir must be stable under all operating conditions (severe operation), so there must be no instability in the thin walls around the reservoir. This can result in large landslides entering the reservoir during impounding, triggering large waves that can cause reservoir overflow.

After impounding, the area around the reservoir water fluctuation is a zone that is prone to landslides. During fluctuations, erosion of the slope surface occurs and in the long term can lead to landslides, besides that the zone often occurs water saturation which increases the load on the slope.

Planting plants in the fluctuation zone can be a viable alternative to prevent landslides in the reservoir. A selection of tap rooted perennial trees can be used as reinforcement and grasses can be planted as protection, considering that reservoir areas are usually dominated by soil.

Although the reservoir area is usually dominated by soil material, rocks are also sometimes found. The landslide analysis material of some dam only considers the values of unit weight, cohesion and internal friction angle, it should also take into a consideration of rock parameters such as GSI (geological strength index) and RMR (rock mass rating).

**Table 5-3 Estimate of Geological Strength Index GSI for heterogeneous rock masses such as flysch (After Marinos and Hoek, 2001)**




One of calculation method in slope stability is Hoek-Brown that suitable for rock mass stability. In Hoek-Brown method GSI is very influence to the rock mass strength parameter, the parameter that should is:

- ✧ UCS of intake rock
- ✧ Constant of rock type (mi)
- ✧ reduced value of the material constant mi for intact rock (mb)
- ✧ constants for the rock mass (s and a)

Bieniawski (1976) published a rock mass classification called geomechanical classification or better known as Rock mass Rating (RMR). This rock mass classification has undergone adjustments due to the addition of input data so that Bieniawski made changes to the rating values on the parameters used for the assessment of the rock mass classification. In this research, the rock mass classification used is the Bieniewski 1989 classification. The 5 main parameters and 1 condition parameter used in the RMR classification are;

1. Uniacial compressive strength of whole rock
2. Rock Quality designation (RQD)
3. Discontinuous plane spacing
4. Discontinue plane condition
5. Groundwater condition
6. Orientation/direction of discontinuous plane

Romana (1985) introduced an adjustment to the RMR concept specifically for slopes known as slope mass rating (SMR) which is obtained from the RMR dilai corrected by an

adjustment factor that depends on the relative direction of the crack or dip direction and the slope direction.

### 5.2.4 Case of Tugu Dam cutting slope

Administratively Tugu Dam located Pucanganak Village, Tugu District, Trenggalek Regency, Jawa Timur Province and geographic coordinates on 111° 34' - 111° 37' E and 8° 1' - 8° 3' S. Initial impounding of Tugu Dam was carried out in September 2021.

Landslides ever occur on the slope on the right side of the spillway during construction of Tugu Dam.

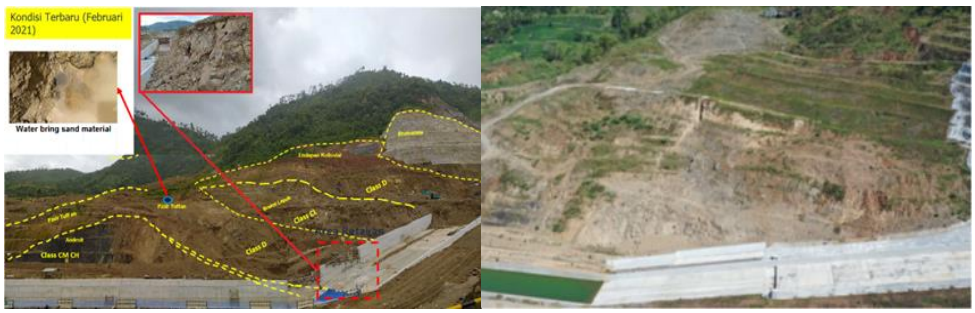



**Photo 5-1 Sliding at right spillway during construction (left) and current condition (right)**

The soil layer of the excavation slope of the chute channel between Sta.0+300 to Sta.0+500 is in the form of colluvium layer which is quite thick and water level was observed too. Much of the excavation surface is eroded by surface water flow. There are deflection cracks and landslides, so that the shape of the slope and the excavation are irregular. Subsurface (Figure 0 1) and surface drain should be conducted at the location and also slope protection for erosion.

On the right abutment of the dam, there is a steep cliff with a fairly intensive joint that has the potential to cause landslide with type rock fall or wedge (Figure 0 2). It was also reported that there was a rock fall around the site during the post impounding evaluation. At the location, it is necessary to strengthen the cliff and analyze rock fall as a anticipatory step so that it can find out what structures/instruments are affected if it occurs.

**Photo 5-2 Slope condition of right abutment of Tugu Dam**

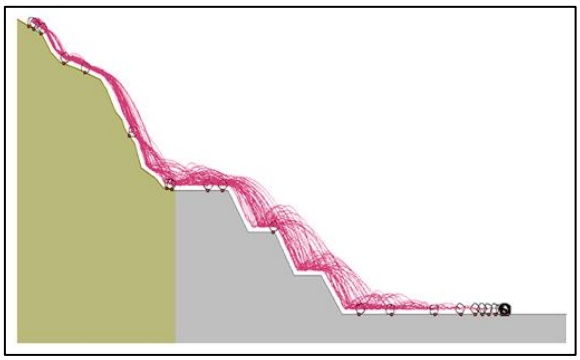


Figure 5-4 Sample of rock fall simulation

### 5.2.5 Case of Access Road of Jragung Dam

Jragung Dam is a dam that is still under construction. Administratively located Kedungglatik Village, Pringapus District, Semarang Regency, Jawa Tengah Province. One of the problems is many landslide were observed at access road where the lithology is dominated by claystone. In this case, water is the main triggering factor of landslides. So that the control of the water content is needed. It is necessary to add drainage and compaction for filling location. Because of access road will be frequently traveled vehicles, reinforcement of compacted fill is also required. At the location where the landslide had occurred subsurface drained and berm/ gabion should be installed in this case as shown on the Figure 0 5.

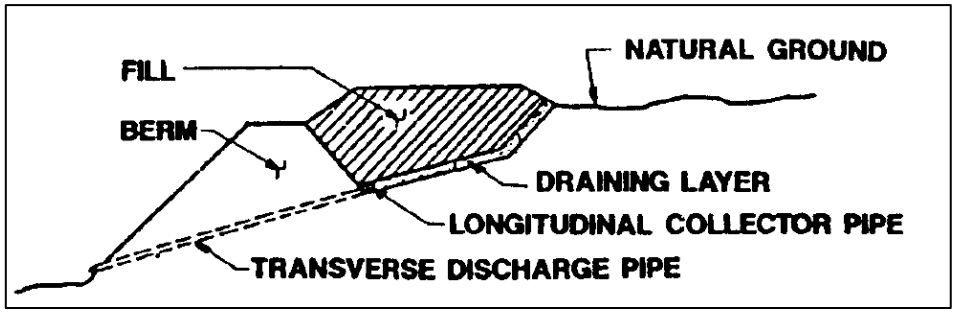



Figure 5-5 Lateral berm and transfer discharge pipe (Rodrigues et al, 1988)

### 5.2.6 Case of Potential Landslide around Reservoir

Ciawi Dam, Randu Gunting Dam, Tiu Suntuk Dam and Logung Dam was identified had landslide potential around reservoir during construction or after impounding. As explained before (chapter 5.1) Causal factors of landslide include slope, rock and soil types then to identify the landslide potential at reservoir area, morphometric and rock/soil type should be mapped. by looking at the morphometry around the dam, the location of potential landslide sites can be easily recognized by looking at the type of soil/rock and its patemeter around the reservoir inundation area.

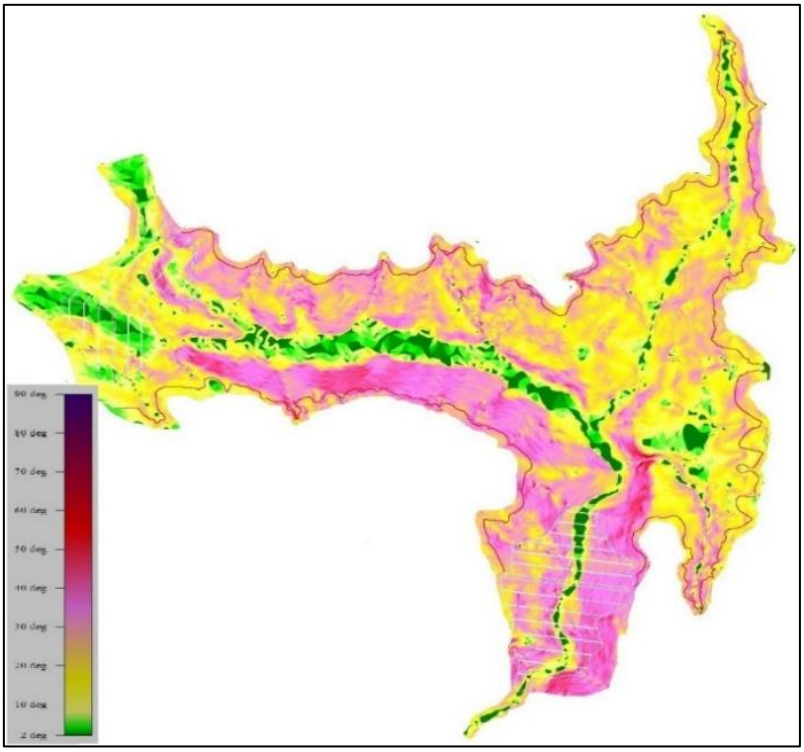


**Figure 5-6 Sample of morphometric map at reservoir area**

At Randu Gunting Dam there is a potential landslide located in the reservoir area. The distance of the potential landslide from the dam axis is about 300 m. Landslide dimensions with a length of about 30 m and a height difference of 3 m. the landslide body hits the reservoir water level. Landslide location near the right abutment hill with material in the form of compacted embankment soil during construction. Material in the form of gravelly clay. The current condition has been sloping the slope, but the open slope still allows landslides due to fluctuations in reservoir water.

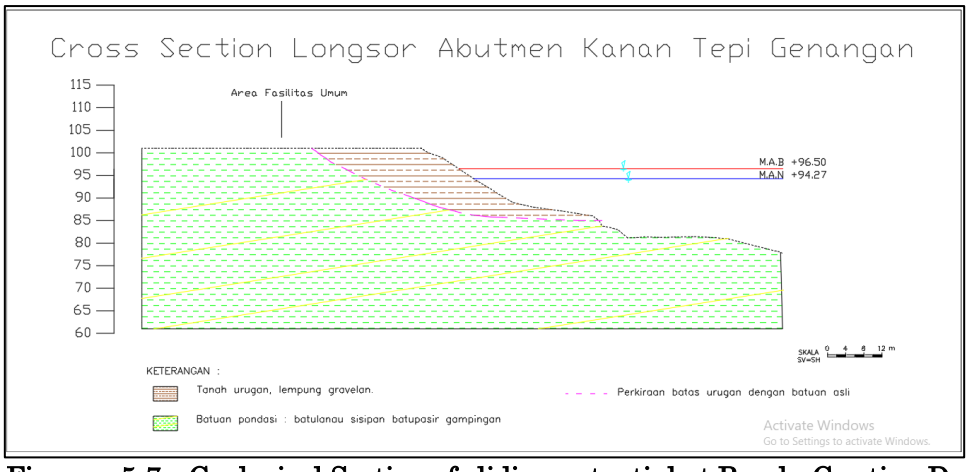



**Figure 5-7 Geological Section of sliding potential at Randu Gunting Dam**

**Photo 5-3 Condition of potential landslide around reservoir at Randu Gunting Dam**

At this location, slope protection is required as well as reinforcement with concrete retaining walls and slope sloping and re-vegetation. Anchor and framework method can be conducted but should be noticed that the depth of anchor is reaching the depth of rock (do not finish at the embankment zone).

In embankment type dams, material is often taken from the dam reservoir site for efficiency during the construction process, be it soil, sand or rock. After taking the material, there is often no action to protect the former excavation when inundation will be carried out. At the Logung Dam, one of the locations for taking material is at the inundation site which leaves a former excavation where the distance of the potential landslide (former quarry) location is about 600 m from the main dam.

**Photo 5-4 Former Quarry Slope at The Logung Dam**

The photo 5-4 show condition of former quarry at logging dam with the steep slope where the lower part (influence of water fluctuation) look like soft rock that can easily eroded. This condition can be toe erosion that trigger large landslide. The slopping and protection for soft rock should be conducted to minimize landslide potential.

## 5.3 DAM FOUNDATION

Dam foundation rock in principle must be able to support stably against all loading conditions and be safe against seepage. The geological conditions of the dam foundation greatly affect the choice of dam type, therefore geological research and investigation must be carried out with sufficient quality and quantity. The factors that must be considered include:

- ✧ the shear strength of the foundation rock can support the loading and operation of the dam

- ✧ stability of the dam foundation
- ✧ Prevention of seepage in the rock

Issue about dam foundation mostly related to (1) unstable foundation such colluvium and alluvium, (2) Permeable weak zone and (3) swelling / slaking. From the records and observations of Gruner (1962), the dam failure/collapse events that have occurred so far are due to the following factors:

- ✧ Foundation rock collapse/damage 40%
- ✧ Inadequate spillway 23%
- ✧ Construction quality 12%
- ✧ Uneven subsidence 10%
- ✧ Excessive pore water pressure 5%
- ✧ Avalanche 2%
- ✧ Material quality 2%
- ✧ Operational error 2%
- ✧ Other, including war and earthquake 4%

Therefore, engineering geology is an important factor that is very influential and needs to be considered in every stage of dam development and construction, especially in choosing foundation, because in a dam failure 40% is caused by foundation problems as mentioned by Gruner.

Dam selection is conducted at the feasibility study, one aspect of consideration is geological conditions. Surface geological conditions are carried out geological mapping and subsurface geological conditions can be carried out by drilling and geophysical surveys. Based on the Panduan Perencanaan Bendugan Vol.1 (1999), at the feasibility study stage, 2-3 drilling points are carried out in the river trough and the abutment of the dam. In the detailed design study, there are no exact provisions for the distance and number of drilling points (depend on site) but at least follow the provisions:

- ✧ Along the dam axial on the left and right abutment slopes, the borehole distance is between 20-30 m.
- ✧ In river valleys, drillings with a distance of 20-30 m as well as one or two pairs of incline drillings towards the river, if the river valley is narrow or traversed by a fault structure.

Seismic surveys are one of the scopes and procedures in geological surveys carried out on 7 lines. 1 line at the dam shaft, 2 lines upstream and downstream parallel to the dam shaft, 3 lines across the dam axial at the abutment and river valley and 1 line at the spillway building axial.

Detailed investigation at design stage is very important to choose the right location with all consideration. Although sites with poor geology may be chosen, at construction phase as any adverse possibilities have been anticipated.

### 5.3.1 Colluvium and Alluvium Foundation

Colluvium (also called colluvial material) is a deposit of rock or weathered rock in the foothills as a result of a fall or avalanche (transported by gravity) that is loose and unconsolidated. Alluvial is material transported by running water and deposited along rivers streams. Both of this kind of deposit has poor condition for foundation because mostly unstable and permeable.

With the characteristic of loose and unconsolidated (unstable), colluvium deposit should be remove for dam foundation. Creep phenomenon can occur when structures are placed on colluvium deposits. It is known that some long-term translation or movement of materials can occur, especially within the near-surface.

The bearing capacity of colluvium foundations should be determined based on plate bearing tests in the field, but must be aware that the risk of using colluvium as foundation is very high, especially for dam.

In alluvium the stability of the foundation is indicated by a standard penetration test (SPT) number >50. If the SPT number is <50 and the hard rock is far below the surface, within certain limits a dam can be built with piles, In additional of controlling permeability which may be conducted with secant pile of cut-off wall (diaphragm wall). However, if the piles are too deep and expensive, a change of location should be considered.

### 5.3.2 Permeable Dam Foundation

The Foundation lithology of Jlantah dam is Quaternary volcanic rock. Quaternary volcanic rocks in Indonesia are found in forms that have not completely lithified and are sometimes weathered. Foundation was originally designed using curtain grouting, but from the results of the grouting test in the riverbed section could not reach the required water impermeable value (Lugeon).

The permeable zone of Jlantah Dam foundation is breccia. Due to breccia consist of matric and fragment, the bigger fragment is more difficult to be excavated during making the pit. Considering the depth of pit is 35 m it will difficult to dig a narrow pit and drilling maybe is needed. Instead of drilling only for excavation, perhaps secant pile installation will be faster and more efficient as a barrier wall (cut-off wall). As explained at chapter 5.5, a guidelines that can be used in the use of cut off walls on embankment dams is "Pedoman pembuatan dinding halang (cut off wall) pada bendungan urugan, PU 2005".

### 5.3.3 Swelling Potential

Randugunting Dam foundation located on Ledok Formation. Ledok Formation (Tml) consist of grey claystone, marl, and bedded calcarenite, occasionally contains glauconitic sandstone interbeds. Based on construction data, the site lithology is siltstone with calcareous sandstone intercalation is spread over most of the Randugunting Dam area and becomes the foundation of the main dam and other supporting buildings. The siltstone has characteristics of light gray color, dark brown for weathered color, hard, laminated structure, in places consist of shells of marine organisms. Because of the foundation consist of fine grain material of Ledok Formation, it afraid has swelling potential of the foundation.

XRD studies have been conducted on Ledok Formation rocks which show that smectite minerals are present in clay/shale rocks. The results of the XRD test data show that smectite group minerals are found in all depth intervals analyzed in Well W-1 (490 ftMD - 8643 ftMD) with a distribution that decreases with increasing drilling depth. In the Wonocolo Formation, a transition zone began to occur where the dominance of the Smectite group was replaced by Kaolin (thesis Pranata Afdi, Deny (2014)).

Smectite group of clay mineral has characterized for high expand (swelling). Due to Randugunting located at Ledok Formation that has potential of smectite clay contain, the XRD test and swelling pressure is recommended to be conducted to ensure the

characterized clay material of Randugunting dam foundation then the analytic of result should be correlated to the dam safety.

### 5.3.4 Rock Classification

To display subsurface geological conditions, Geology engineering divides rock classes based on the CRIEPI (Central Research Institute of Electric Power Industry) classification (mostly used in Indonesia). In the CRIEPI classification, rock classes are more intended for visual field observations, while in the design of dams the numerical parameters are easier to understand. Preferably, in addition to using the CRIPIE classification, number-based classifications can be combined such as the ISRM rock strength class and the RQD by Deere (1967). Combining these classes is intended to make it easier to understand the rock conditions that will be used as a dam foundation.

In case of Sadawarna Dam, the classification of rock classes is quite confusing. In the rock classification there is a CL-CM class. These rock classes have a range between qu 0.8-46.2 kg/cm2. The qu value of 0.8 is generally owned by soils that tend to be soft-firm. Soils with this class still have the potential to experience settlement/ consolidation. This means that in locations with the CL-CM class at Sadawarna Dam there is a mixture of rock and soil that have dam foundation settlement potential.

### 5.3.5 Case of Bagong Dam Foundation

The foundation of Bagong Dam is colluvium of limestone. The characteristics of limestone itself is easily dissolved by water. The plan is to add secant piles to reduce permeability and still be in colluvium deposits. From the results of the permeability test that has been carried out on the colluvium deposits, it has a high permeability / lugeon value (Lu>60) even in the grouting test Lu is more than 100.

The consultant plans to use a secant pile on the left side, with class D soil characteristics and as colluvium that has the potential for settlement to occur. The presence of a secant pile will cause differential settlement between the foundation and the secant pile.

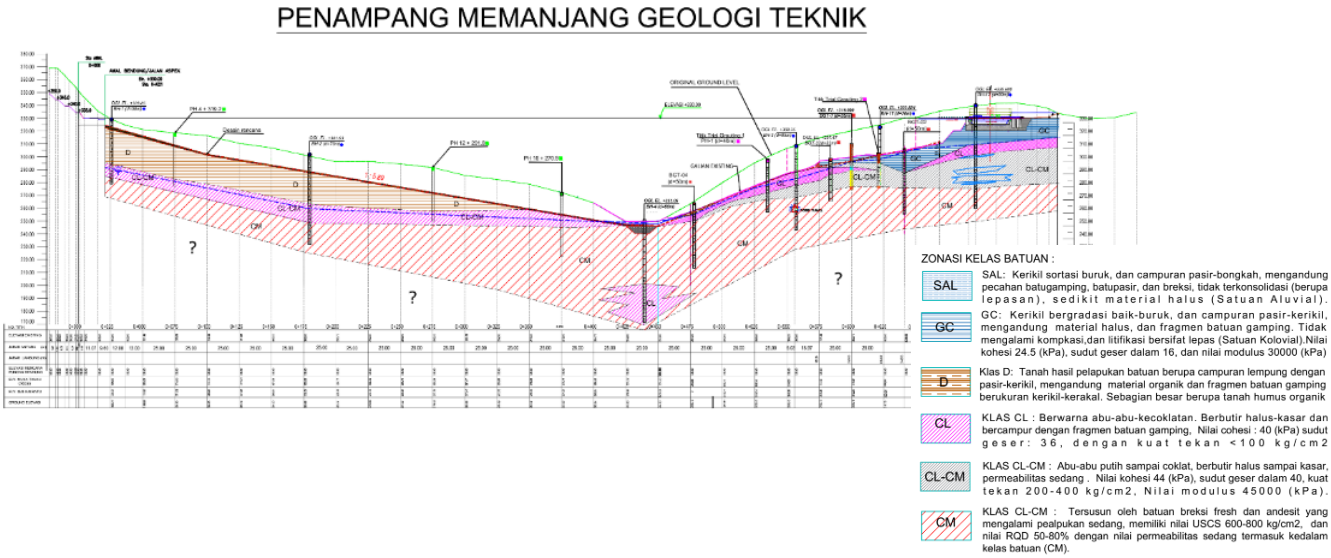



**Figure 5-8 Engineering geology profile at the main dam of Bagong Dam**

The foundation will rest on class D that characterized by a mixture of clay with sand-gravel, containing organic material and limestone fragments in the size of gravel-cobble. An organic humus soil dominant. Such as described before clays with organic material tend to have a low bearing capacity and a large shrinkage.

With the almost complete distribution of colluvium deposits on the abutment hill, there is a possibility that there will be seepage from storage resulting in dissolution and erosion of the foundation material. In addition, colluvium is an unstable material and can still have the potential for landslides.

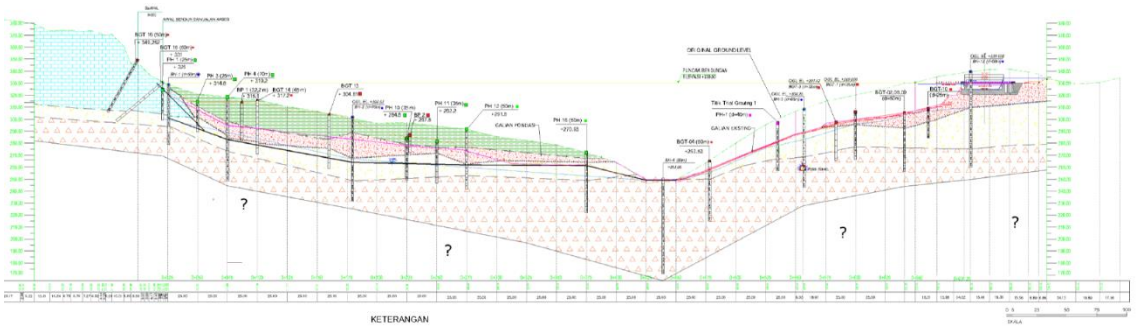


**Figure 5-9 Geological profile of Bagong Dam Axial shows steep cliff at left abutment with limestone lithology (exposure of technical meeting of Bagong Dam, 10 September 2024)**

At the end of left abutment there is a steep cliff that may not colluvium layer. Drilling needs to be conducted to confirm the lithology of the cliff. If the cliff is not colluvium it can be consideration to abutment and removing all the D class.

## 5.4 DAM MATERIAL

Rocks and soil are the main materials or elements for the construction of dams, especially earth filled dams. Therefore, engineering geology is an important factor that is very influential and needs to be considered in every stage of the project, especially in the construction of dams. Not only does it determine the character and nature of the foundation rock, geological conditions also imply the availability of construction materials in terms of quality and quantity.

SNI 8062:2015 explain some criteria for soil, sand/gravel and rock that can be used for dam embankment as described below.

***Soil Material***

If the fine-grained soil available at the compaction site has a compaction moisture content ranging from an optimum moisture content of less than 1% (OMC-1%) to an optimum moisture content of plus 3% (OMC+3%), it can be used as embankment material. In tropical regions such as Indonesia, clay soils generally have an original moisture content that exceeds a few percent (>5%) of their optimum moisture content, so compaction cannot always be carried out following standard procedures (OMC-1% < Wfield < OMC+3%).

Compaction of these soils can be carried out in the wet state at OMC+3%. However, under load, the pore water pressure easily increases. Drying the soil is usually difficult because after it is compacted, the moisture content of the soil returns to its original moisture content before drying. Soil types whose moisture content is less than OMC-1% need to be moistened before compaction. Compaction should achieve a degree of density D □ 92%. It is also required that the impermeable material has a permeability coefficient of k □ 10-5 cm/s.

***Sand / Gravel Material***

Gravel-sand backfill should be compact with high shear strength and permeability coefficient and low compressibility. In general the shear strength will be high when the compacted backfill material contains variable grains and a high dry volume weight. Permeability depends on the fine grain content. Compressibility will be low when the dry volume weight is high and the density of the backfill is determined by its relative density.

The shear strength of gravel sand embankments is determined by the inner shear angle. For gravel sand fill that contains fine grains (grain size < 0.074 mm), the effect of shear strength on changes in pore water pressure during construction should be assessed, because an increase in pore water pressure will reduce the shear strength.

Gravel-sand embankment is usually used as a filter material, which is placed between low-permeability backfill materials and high-water pass materials, and serves to prevent reed erosion.

***Rock Material***

Fresh rock or massive weathered rock that has a high enough strength can be used as compacted stone of embankment material. Rocks that are crushed into fine grains during excavation, transportation or compaction cannot be used as rock fill material. The availability of rock fill material should be checked by conducting a study of the technical properties of the material with compressive strength tests, absorption tests, and tests for the durability of the stone. Some important requirements that must be met are as follows:

a) The permeability coefficient of the ideal stone should be greater than or equal to 10-3 cm/s.

b) The ideal stone size must meet the following requirements:

   1) Average diameter of 45 to 60 cm with a minimum weight of 250 to 500 kg or more and the shape of the stone is not flat.

   2) The number of stones less than 10 cm in diameter should not be more than 5%.

   3) Stone material is not easily broken, both in transportation and when pouring from transportation equipment.

c) The compressive strength for low dams 200-280 kg / cm2 medium dam 280-350 kg / cm2 and high dams 350-450 kg / cm2.

d) Durability properties (durability) against water and weather changes are carried out by a durability test using sodium sulfate with a weight change value of less than 15% is considered good. Absorption test should be less than 3% and specific gravity value of at least 2.5.

e) Rock fill material should not contain chemicals that have a pH that is too low (<5) or too high (>9).

The problems that often occur related to materials are (1) material does not meet the requirements, (2) insufficiency of materials, (3) using wet core of the dam and (4) rip-rap condition.

### 5.4.1 Material Does Not Meet The Requirements

The determination of material requirements is based on the results of material availability on investigations had been conducted. At the investigation stage there can be less sampling so that it does not represent the overall condition of the material in the field.

Based on Indonesia guideline of dam (pedoman kriteria umum desain bendungan, published by PUPR 2003), some of the things that need to be done during the investigation are as follows:

***Impermeable material / clay soil***

a. borrow site at selection stage
   - 1 test pit every 150-200 m grid interval
   - physical test 1 sample every 25,000 m3 of material
   - dynamic test 1 sample every 50,000 m3 of material

b. detailed design stage
   - 1 test pit or auger drilling every 50-100 m grid interval
   - physical test 1 sample every 10,000-25,000 m3 of material
   - dynamic test 1 sample every 10,000-25,000 m3 of material

***Semi-permeable material / sand***

a. borrow location selection stage
   - physical test 1-2 samples
   - dynamic test 1-2 samples

b. detailed design stage
   - physical test 1-2 samples, depending on material gradation

***Permeable material /rock***

a. quarry location selection stage
   - Drilling is done if necessary
   - rock test 10 samples of each type
   - gradation test for river sediment material

b. detailed design stage
   - detailed design stage
   - drilling to confirm quality and quantity, 1 borehole every 200,000 m3
   - rock test 5 samples of each type
   - shear test 5 samples of each type

By making detailed investments according to the guidelines, the possibility of mismatches can be avoided to a minimum. Data mismatches sometimes occur due to lack of investigation at design stage so that when construction the materials available do not match the requirements.

### 5.4.2 Insufficiency of Materials

As explained in the previous subchapter, detailed material investigation is important for dam design. Insufficient of material occurs due to the lack of investigation conducted at the design stage. For example, the Budong-Budong dam has been carried out detailed design in 2017 which stated that the available core material is 2,409,900 m3 from 4 borrow areas, confirmed by 4 test pit points. Referring to the guidelines at detail design, the volume of material should be confirmed with at least 24 test pit or hand auger points. Budong-Budong Dam and Meninting is currently one of the dams that has problems due to the insufficiency of dam core material. In Meninting dam, the insufficiency of core material is recognized during embankment, before embankment is conducted is better to confirm availability of all dam material at least 2 time larger than required.

However, sometimes materials cannot be taken due to landowner's restrictions, such conditions require finding new materials that match the design criteria which will certainly increase costs or utilizing existing ones with the consequence of changing the design of the dam which will increase the implementation time. For the reason the detailed investigation should be done appropriately to anticipate data shortages that hinder the construction process.

### 5.4.3 Riprap Condition

The primary purpose of riprap or other slope protection elements on the upstream slope of an embankment dam is to prevent erosion and damage to the embankment from wave action. Because slope protection can represent a significant cost, the design requires a proper balance between the initial cost for construction and future maintenance costs, while ensuring safety of the structure.

Good riprap is based on rocks that have high compressive strength values, good abrasion resistance and chemical weathering. One type of rock that has these criteria is a type of igneous rock that is widely found in Indonesia from the activity of magmatic and volcanic.

In case of Sindang Heula Dam, volcanic breccia was used to be riprap material. In geology, breccia is a term generally used for an enigmatic rock group that consists of a variety of individual mineral grains or broken fragments of rocks, often very angular and cemented together by a fine grain matrix, and sometimes glassy matrix which may or may not be similar to the composition of rock fragments. From the definition Breccia consist of two component called fragment and matric. Sindang Heula dam located at quaternary volcanic rock, lithification of volcanic quaternary breccia in Indonesia is usually not perfect so that the breccia matrix will be easily destroyed and tends to be brittle and has high abrasion. In contrast to fragment which is an igneous rock. So that the amount of weathering that occurs in the Sindang Heula Dam may come from mixing matrices and fragments as riprap, riprap should only be used from fragment of breccia. With good material, riprap should be installed properly and interlocked each other.

### 5.4.4 Using Wet Core of The Dam

Some criteria for soil material as impermeable core zone has well-graded, in the gradation zone according to the provisions in the USBR and the material is classified as : GC,GM,SC,SM,CL,ML,CH,SM (USBR), plasticity index, $20 \leq PI \leq 40$ and liquid limit, $LL \leq 70\%$.

As described before, moisture content compaction ranges from optimum moisture content less than 1% (OMC-1%) to optimum moisture content plus 3% (OMC+3%), but in tropical region like Indonesia, Natural water content of soil is more than 3% of OMC. Because of this condition, drying clay should be conducted and soils with a high degree of shrinkage should be covered with plastic to prevent evaporation. Clay should not be used as a backfill material in conjunction with concrete or masonry construction, except in the impermeable layer of a backfill type dam. Well-compacted soil backfill with high volume weight has high shear strength and low compressibility.

### 5.4.5 Material of Dam Shell

One of the functions of the shell on the dam body is to support / strengthen the dam core material. With a good shell, it reduces the deformation that occurs in the dam core. Meninting and Sidan Dam have a type of shell material that is not good so that it needs monitoring during the impounding later.

At the upstream of Meninting dam contain 2 type shell at the upstream of dam body, namely random rock and random soil, the gradation of random soil contain fine grained material up to 35% and random rock only less 5% for fine material. During impounding there possibility of soil random leaching (fine material) due to water fluctuation of reservoir area. For long term it can endanger for dam stability.

**Photo 5-5 Contraction of Meninting Dam during dam embankment, Photo shows condition at the upstream of dam body (Dam Inspection on February 2024)**

The shell material of Sidan dam is sand dominant material (SM class based on USCS). SM class mean that the material is sand dominant with some percentage of silt material.

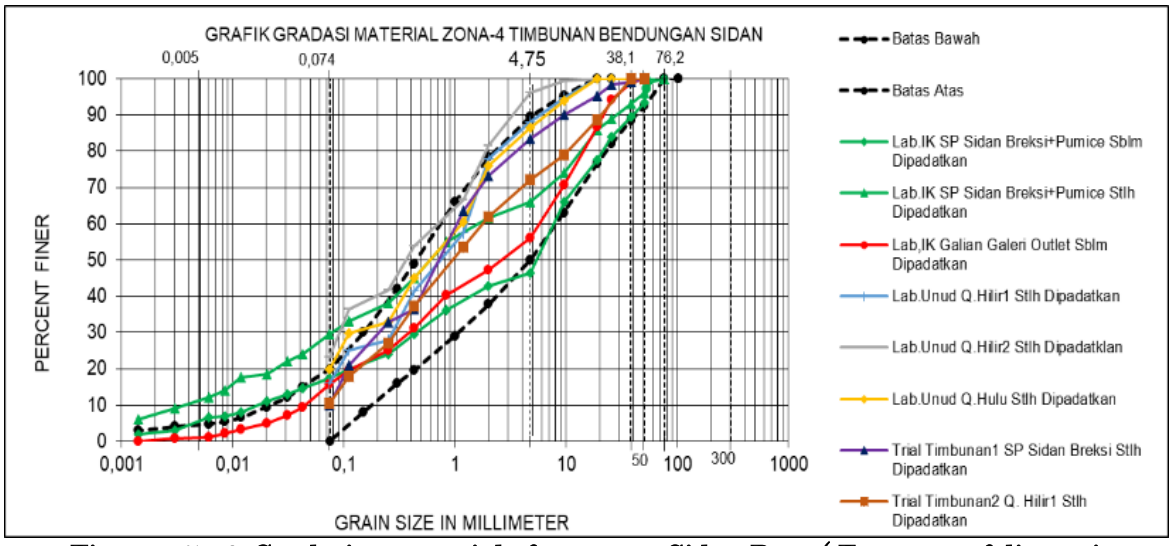



**Figure 5-10 Gradation material of zone 4 at Sidan Dam ( Exposure of discussion material, October 2024)**

The results of triaxial testing on zone 4 material have a value between 27-35 degrees (exposure Sidan dam, October 2024), there is some correlation between the NSPT value and the internal friction angle, with the internal friction angle still having the potential for liquefaction so it is necessary to study the potential for liquefaction on the dam body. Keep in mind that at the time of inundation, the upstream slope of the dam will become a water-saturated zone.

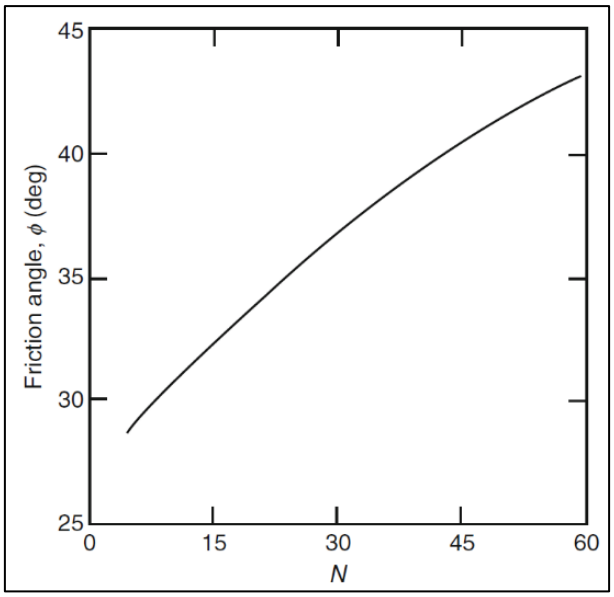



**Figure 5-11 correlation of N value (SPT) and Friction angle (Braja, 2016)**

## 5.5 DAM DESAIGN

The determination of the width of the crest of the dam is considered from several factors including the minimum distance of water seepage through the dam under normal reservoir elevation conditions, traffic needs above the dam, ease of construction and special considerations for dam in earthquake areas. In the core zone the largest settlement occurs in the middle. The wider the crest of the dam, the smaller the arching effect will be.

The influence of steep arching can trigger cracks in the core material that result in water leakage.

Fell et al. (2004) found that dams that have a ratio between the height of the rockfill dam (H) and the width of the base of the dam core (W) greater than two, H/W>2, are much more likely to experience hydraulic fracturing, while dams with a ratio of 1<H/W<2 are more likely to experience hydraulic fracturing.

The width of the dam core affects the stability of the slope and is usually chosen according to the ratio between price and materials available in the field. In general, the width of the core or the width of the seepage barrier trench at the base of the foundation can be taken as equal to or greater than one quarter of the difference in "head" height (the difference between the maximum water level of the reservoir and the water level downstream of the dam). The width of the crest of the dam core can be taken as a minimum of 3.0 m, while the maximum width depends on the stability of the urugan material used (see RSNI M-03-2002, Method of static slope stability analysis of urugan type dams).

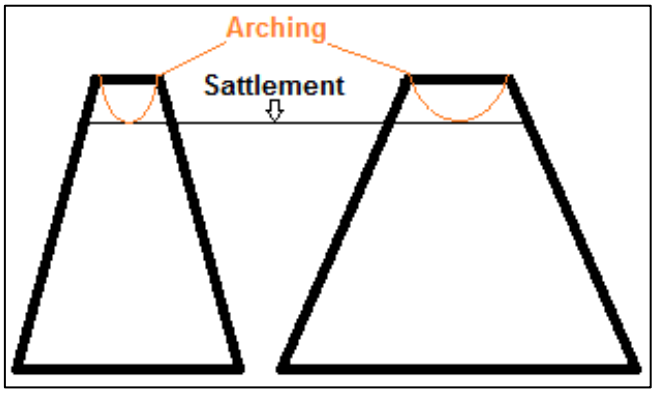



**Figure 5-12 arching effect at the core zone of dam**

### 5.5.1 Case of Leuwikeris Dam Design

Leuwikeris dam is designed for rock-filled dam, because of material insufficient, the consultant plan to change material using alluvium material. Changing the type of material in the dam will affect the change in the shape of the dam as well. Using alluvial material will increase the volume to be used because the alluvial tend has a smaller Phi and cohesion value smaller than the rock fill material. Alluvial deposits tend to product in rounded material conditions. Angular and rough shape has phi and cohesion value greater than the rounded one. For alternative to minimize the volume of material, crushing the alluvium deposit is alternative solution to increase value of phi and cohesion.

### 5.5.2 Case of Rukoh Dam Design

There have been two major earthquakes around the Rukoh Dam with a radius of less than 10 km from the dam. Both earthquakes occurred in 1945 and 1975 with magnitudes of 6.7 and 6.2 (https://earthquake.usgs.gov).

**Figure 5-13 Epicenter of earthquake around Rukoh Dam in 1945 and 1975 (https://earthquake.usgs.gov).**

Rukoh Dam was originally designed with a slope of 1:3.5 on the upstream slope of the dam, after the review there was a change to 1:2.75. Considering the high earthquake factor may be a safety reason to make a gentle slope the dam at the design stage.

Based on the seismic hazard analysis, the calculation of the magnitude of the earthquake uses the probability method and gets an earthquake acceleration value of 0.32 for OBE. Areas with locations close to the source of the earthquake should also be analyzed for earthquake acceleration using the DSHA method because it could be that the calculated value of the earthquake velocity is much higher than the PSHA value (see Table 0 2). Judging from the historical earthquakes that have occurred, the distance of the earthquakes that have been observed is very close to the location of the Rukoh Dam.

## 5.6 DAM STABILITY

### 5.6.1 Crack on Dam Crest

Cracks in the dam crest can occur transversely or longitudinally. Longitudinal cracks have the potential to cause landslides on the dam slope. If this occurs, the freeboard will be reduced, which has the potential to cause the reservoir water to flood through the dam crest (overtopping). Transverse cracks in the dam will be very dangerous because they will become a path for reservoir water to escape which can erode around the path and trigger landslides.

Cracks in the dam core material can occur due to Hydraulic fracture in the embankment dam due to reservoir water pressure, pore water pressure can reduce the effective stress so that the hydraulic pressure of reservoir water can create tensile cracks and if the crack is abandon it will cause piping which has the potential for dam failure. In addition, cracks in the dam core can also occur due to differential settlement of the core material which is usually influenced by the steepness of the dam foundation slope, the density of the core material and the characteristics of the material used as the dam core material.

To confirm the crack condition at the crest of the dam, a test pit should be carried out, the crack at the crest of the dam can still be tolerated if the depth of the crack does not reach the phreatic line in the dam core. After the test pit is still found cracks, a more detailed investigation needs to be carried out such as conducting a geophysical survey. In this case a Ground Penetrating Radar (GPR) geophysical survey can be carried out because it has a fairly detailed subsurface picture for the shallow depth.

Treatment of cracks can be carried out by Excavate the crest along the crack to a point below the bottom of the crack. Backfill the excavation using suitable material and correct construction techniques. This seals the cracks at the crest surface to prevent surface water infiltration. Monitor the crest routinely for evidence of future cracking.

### 5.6.2 Settlement of Dam

Settlement that occurs in clay soil occurs due to the process of soil consolidation. Consolidation is the process of volume reduction or reduction of pore voids of low permeability saturated soil due to loading. Settlement occurs in the core material of an embankment type dam. Settlement of the dam results in deformation or crack of the dam body which can have an impact on the stability of the dam (dam safety)

Settlement is related to the condition of the embankment material and compaction during construction. Karian and Sindang Heula dams have materials that are not good to be used as dam core material. It can be seen from several tests that they have high LL values dominated by fine-grained materials (clay - silt). This type of material tends to have high shrinkage so that the settlement that occurs will be relatively large. In Indonesia, The allowable settlement is 2% when the height of the dam body is >30 meters (Panduan Perencanaan Bend Urugan Vol III).

### 5.6.3 Movement of Dam (Deformation)

Several dams in Indonesia have problems related to dam movement. These dams include Kuningan Dam, Marangkayu Dam, Napun Gete Dam, Randu Gunting Dam, Sei Gong Dam, Sepaku Semoi Dam and Teritip Dam.

Several dams that have experienced movement problems, most of them is a homogeneous dam (Marangkayu, Sei Gong, Sepaku Semoi and Teritip Dam). Homogenous dam has high potential to experience deformation off all body because of all dam body consist of soil material (vertical or horizontal deformation). The deformation that occurs in a homogeneous dam body is normal as long as it does not cause cracks in the dam body itself. Surface protection of dam slope should be monitored well, if there is an unprotected surface (broken protection) it can cause erosion which can trigger landslides.

Kuningan dam and Randu Gunting Dam are random filled. The random material has fine material more than 20% and has cohesion. It indicate containing high fine material. Fine material has high potential deformation for embankment so periodic monitoring should be conducted. The movement of the dam is monitored by instrument of surface monument installed on the body of the dam. In addition, it can also be seen from the visual appearance of the dam, either from bulging or fractures around the dam body.

### 5.6.4 Data Parameter of Dam

The Parameter design of Budong Budong dam is considered strange. Based on technical discussion of Budong Budong Dam design on 24 Juli 2019 there are some recommendations related to the parameter:

a. parameter density of material core zone □=18.4 kN/m3 is considered too high and will be difficult to achieve in the field, should be corrected, for example to 17 kN/m3

b. Parameter internal friction angle of filter zone material and transition is used same value of 35°, while random rock used a lower value of phi = 28°, the same as core zone phi = 28°.

   - ✓ The phi (□) value of random rock is the same as the □ value of the core, this is unnatural, the parameters should be re-examined and corrected.
   - ✓ Cohesion (c) and effective internal friction angle (□') in the core material are quite high. The effective inner shear angle value in this material can reach 28° but usually the cohesion value is close to zero. Recheck these values and attach the laboratory test results of soil shear strength.

c. The design parameters internal friction angle of filter and transition zone materials are determined based on assumptions. Laboratory tests should be conducted to ensure that the values of internal friction angle and other parameters that match the conditions of field and after compacting.

d. Design parameters used in the analysis of slope stability, will be used as technical specifications in the implementation of backfilling and compaction in the field, the value should not be taken too large so that it is difficult to achieve when implementation of compaction in the field.

e. Based on SNI 8064: 2016 static slope stability analysis method of embankment type dam, loading conditions that should reviewed on the analysis are:

   - ✓ Construction period condition
   - ✓ Lasting flow condition
   - ✓ Operational condition
   - ✓ Emergency condition

f. Calculation of pore pressure should refer to SNI8064: 2016 static slope stability analysis method of embankment type dam p.13-14.

g. Slope stability analysis of Budong Budong dam there are MDE conditions that majority of the results are still below the required safety value, should be carried out a fixed switch analysis with the requirement that the decline does not exceed 50% of the height of the guard.

## 5.7 WATER SEEPAGE / SPRING ON THE DAM

Ameroro Dam, Bendo Dam, Cipanas Dam, Gongseng Dam, Karalloe Dam, Keureuto Dam, Leuwikeris Dam, Logung Dam, Napun Gete Dam, Nipah Dam, Paselloreng Dam, Pidekso Dam, Raknamo Dam, Randu Gunting Dam, Semantok Dam, Tamblang Dam, Titab Dam, Tugu Dam, and Way Sekampung dam are the dams with seepage or spring issue.

Seepage / spring problems that occur in several dams in Indonesia mostly occur at the dam abutment and foundation, but there are several dams that experience seepage in the dam body as well. 19 dams with seepage problems 11 dam of them have a lithology of volcanic rocks, 8 dams of sedimentary rock (claystone/sandstone) and one dam of metamorphic rock. Indonesia is located in the ring of fire, so it is natural that many volcanoes are found. Therefore the groundwater system in Indonesia is found in many volcanic areas, especially on the islands of Java, Sumatra and Sulawesi and the northern part of Papua. Groundwater flow in Quaternary volcanic rocks can pass through intergranular spaces and fractures.

In general, groundwater conditions around a dam will change before and after impounding. Changes in groundwater conditions affecting the springs around the dam, previously no springs may appear after impounding or an increase in discharge. The type and genesis of a spring that comes out of a dam must be studied in advance that modeled in geological profile then appropriate treatment can be carried out.

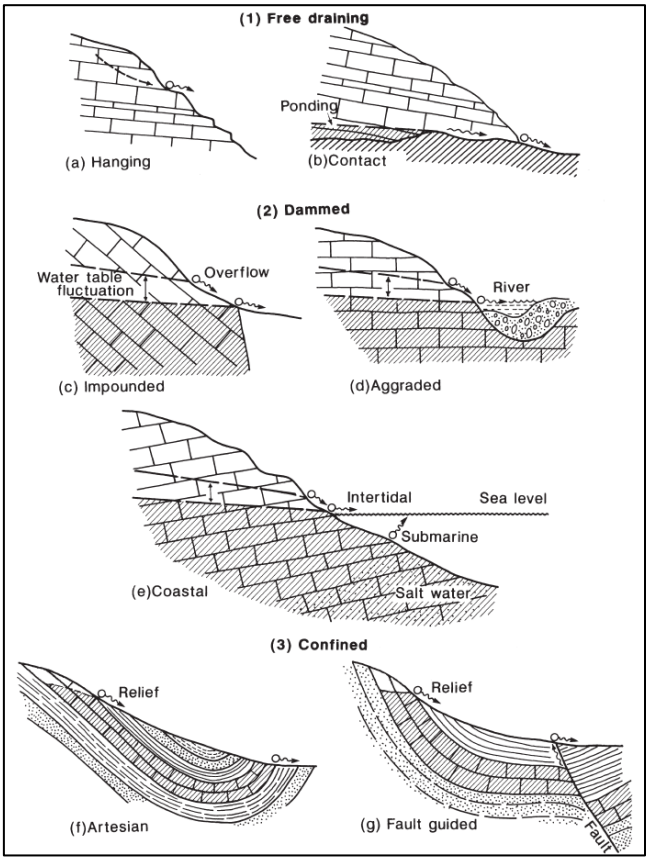



**Figure 5-14 Types of springs. After Ford and Williams (1989).**

In additional, installation of monitoring well needs to be conducted to determine groundwater fluctuations in relation to the reservoir water level. If there is seepage with a large enough discharge, flow control needs to be added (surface drain) so that the outgoing flow does not cause damage.

### 5.7.1 Water Control during Construction

Some springs that come out at the dam foundation become trouble, especially at core zone foundation. Clay material cannot be compacted optimally if there are additional water from the dam foundation, this case happened in Leuwikeris Dam. Dewatering is necessary to lower the water level for core material construction.

One of method can be applied is using dewatering well. The construction of dewatering well should be placed near to core material foundation zone. At least 2 dewatering wells (or more) are needed, which are then pumped that the water table can be lowered and water does not come out of the dam foundation. It is important to note that the dewatering well placement should be as close as possible to the location to be dewatered, but not interfere with the construction process, this is because the further away the drawdown effect will be smaller.

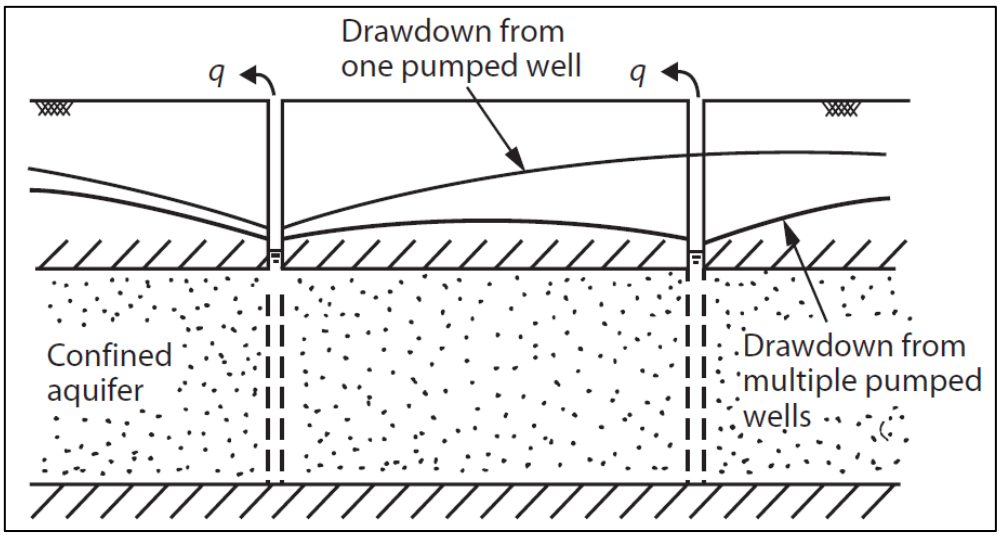



**Figure 5-15 Superposition of drawdown from multiple wells.**

### 5.7.2 Case of Tamblang Dam Seepage on Dam Body

In Tamblang Dam, water leakage occurred on dam body at elevation 168 to 170 m and also on the dam toe. Discharge monitoring results at the toe of the dam once reached 1 m3/sec.

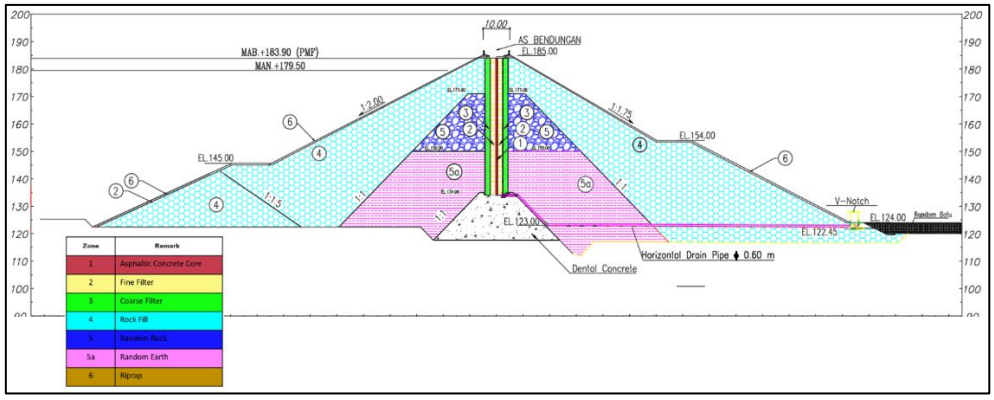



**Figure 5-16 Typical profile of Tamblang Dam with Concrete Asphalt for Dam's Core**

Seepage coming out of the dam body shows that the core function of the dam is not functioning properly. Tamblang dam design there is random material up to 171 m elevation and seepage coming out at elevation 168 to 170 m. this happens because the random material is semi-permeable (can lowered the seepage) and the rock fill is free drain so that in the zone above the random material, water will easily come out then accumulated at the dam toe. Seepage water conditions in the dam body need to be studied further, one method that can be carried out to observe seepage in dam body is by conducting geophysical studies.

**Photo 5-6 Water leakage location at Tamblang Dam (right) and leakage condition at the Dam Toe (left)**

## 5.8 GROUTING

One of the purpose of grouting in dam is to improve the foundation in minimizing the permeability value of the foundation. Impermeable curtain can hold back large seepage by extending filtration, thereby also reducing uplift and the possibility of piping. Regarding grouting issues, some dams had problem such as (1) grouting depth, (2) no grouting location, (3) ineffective grouting indication, (4) very permeable condition that cannot be grouted and (5) changing foundation treatment method without grouting

Based on grouting guideline by PUPR (Pedoman Grouting untuk Bendungan, 2005), some equation (Table 0 5) can be used to determinate the depth of the grouting. As a general guide for preliminary planning, the grouting depth can be taken as 2/3 of the reservoir water pressure height difference so the grouting depth will be shallower in the abutment area. The permeability of rock foundations usually decreases with increasing depth.

**Table 5-4 Equations of grouting depth for dam (PUPR, 2005)**

| Equation | Grouting Hole Depth (m) | Distance between holes (m) | Remark |
|---|---|---|---|
| I | 1/3H + 10 ~ 20 | 3 or less | calculated from the riverbed |
| II | 1/2 H | 1.5 | _ |
| III | 0.7H ~ 0.8H | varied | depending on the joint of rock |

Grouting at the river bed is not conducted at several dam, one of the reason is some of them has good permeability condition (impermeable foundation). River bed is the location that get most of water pressure of dam after impounding. The permeability condition of rock foundation must be highly considered to anticipate uplift in the dam that could potentially cause dam failure.

Even if a dam foundation is in such good condition that no grouting is required, some measures should be taken to strengthen it. Not grouting is usually done because the pilot hole of the grouting plan is already in an impermeable condition, so grouting is deemed unnecessary. The impermeable condition of the pilot hole should be confirmed by additional inclined drilling because the pilot hole is a vertical drilling that cannot detect vertical joints. In additional geophysical survey can be conducted to strengthen the foundation condition.

Sometimes grouting cannot be carried out on foundations that have very high permeability values such as on fault lines or rocks that have very intensive crack. In such cases foundation improvement can be carried out using other methods such as cut off walls or secant piles. For fault zones whose extent can be estimated, the secant pile method can be

more easily implemented by installing in the foundation area of the fault zone only and grouting can be done for around area.

In general, the replacement of foundation improvement on dams can be done not only by grouting methods, cut off walls or secant piles can also be applied. A guidelines that can be used in the use of cut off walls on embankment dams is "Pedoman pembuatan dinding halang (cut off wall) pada bendungan urugan, PU 2005".

### 5.8.1 No Grout Foundation

Grouting is a type of subsurface foundation improvement that is often performed on rock foundations. The objectives of foundation repair with grouting are -Reduce leakage from the reservoir through fractures in the foundation rock, -Reduce the lifting force at the base of the dam, -Increase the bearing capacity of the foundation rock.

In determining whether or not grouting is necessary, the subsurface condition of the rock that will be the dam foundation that can be identified from drilling, water pressure tests and geophysical testing. Based on grouting guideline by PUPR (Pedoman Grouting untuk Bendungan, 2005) related of lugeon value and grouting necessity, only foundation with lugeon 1 or less that no need for grouting. For lugeon 3 or less grouting is necessary for concrete dam.

**Table 5-5 Relationship of lugeon value and grouting requirement (Pedoman Grouting untuk Bendungan, 2005)**

| Lugeon Value | Description |
|---|---|
| 1 | degree of permeability in tight foundations and almost no need for grouting |
| 3 | foundation needs a little grouting, if occupied by a concrete dam or reservoir water is very valuable, tends to piping so need to stop seepage |
| 5 | need to be secured by extensive grouting for concrete dams or regional grouting for earth or rockfill dams |
| 10 | need to be secured by grouting for all types of dams |
| 20 | highly fractured foundation with relatively small apertures |
| 100 | highly fractured foundation with relatively coarse apertures and can also be on foundations with tight fractures but wide apertures |

### 5.8.2 Case of Grouting in Tamblang Dam

The results of the grouting cross-section of the dam show ineffective grouting in several places in the main dam body foundation, so that these locations become a weak path for water to flow. In some locations the LU value is even >5 and some are >10.

From the geological engineering cross section of the main dam, there are lenses of rock class D between the CL rock classes. Where the characteristics of class D at the tamblang dam site are dominated by sand material which tends to have a high permeability value.

This type of lithology is a volcanic product which is the type of lithology that has the most groundwater aquifers in Indonesia. The tamblang dam location is also included in the Tejakula groundwater basin. To optimize the grouting activities, the reservoir water level should be lowered to reduce water pressure. It is also possible that there is considerable groundwater flow/pressure around the dam.

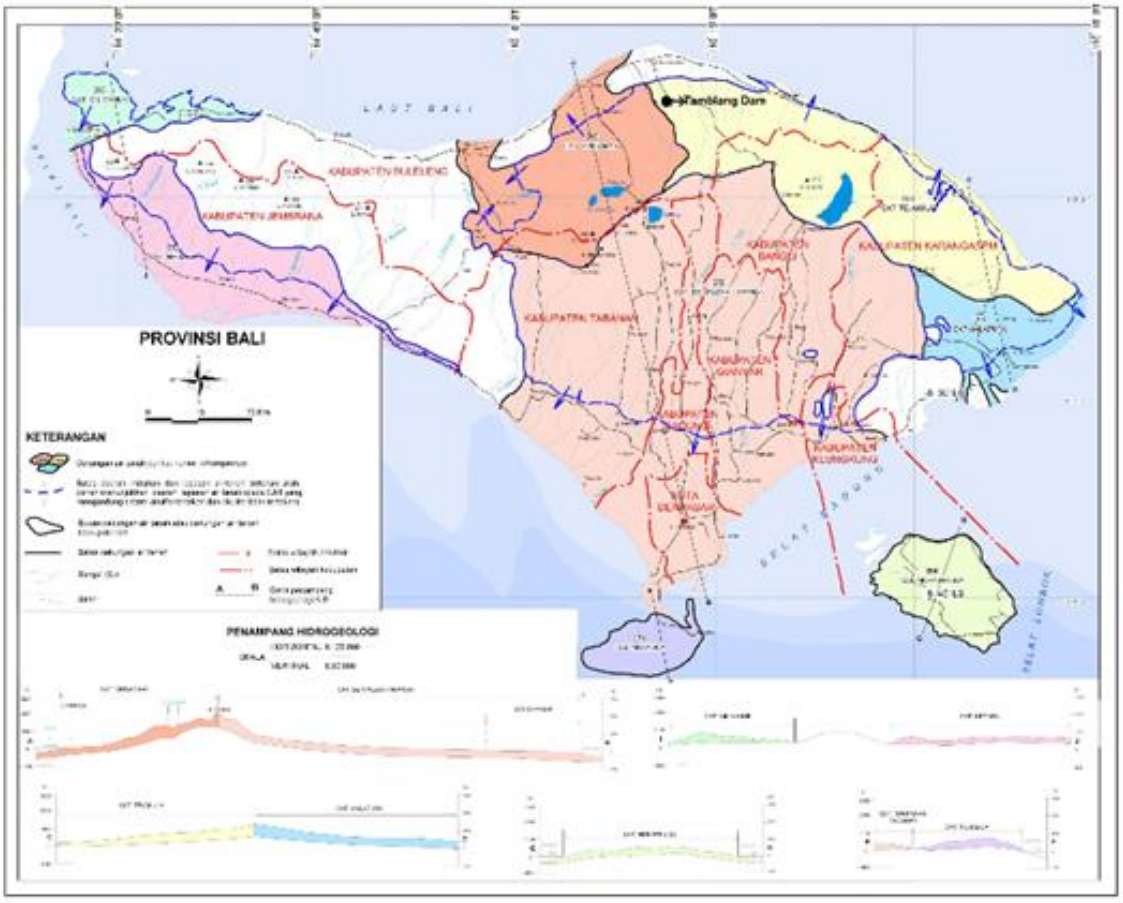



**Figure 5-17 Groundwater basin Map of Bali Island (pamsimas.pu.go.id)**

The increase in the reservoir water level affects the groundwater conditions around the reservoir which in turn raises the groundwater level. The higher the groundwater level with a high lugeon value in the rock, it is possible that there is flow in the foundation. This flow condition will affect the grouting which could be the grouting material carried away by the flow which makes the grouting ineffective.

## 5.9 SPILLWAY FOUNDATION

In some dams there are foundation problems in the spillway section of the dam which are known after the construction of the dam. The problems found in dam spillway foundations include:

- ✧ Colluvium foundation: Bagong, Jragung
- ✧ Settlement: Bajulmati
- ✧ Foundation strength: Cipanas, Ladongi, Sepaku Semoi, Sidan
- ✧ Swelling: Temef

### 5.9.1 Colluvium foundation

The criteria when choosing good foundation is strong against the load above it and the foundation is stable. Colluvium deposit is not good foundation even though it is strong enough against the load, because colluvium is unstable deposit that be able to experience movement or settlement. In case of colluvium foundation of Jragung Dam the colluvium

is found spotted at certain area that can be removed and filled by dental concrete that has modulus is same as the rock foundation. At the Bagong Dam the condition is difference that colluvium was observed very thick which excavation is difficult.

Colluvium is an avalanche sediment that has a plane of movement may become a weak zone. The consultant decide to use bore pile for reinforcement of spillway as show in the Figure 0 18.

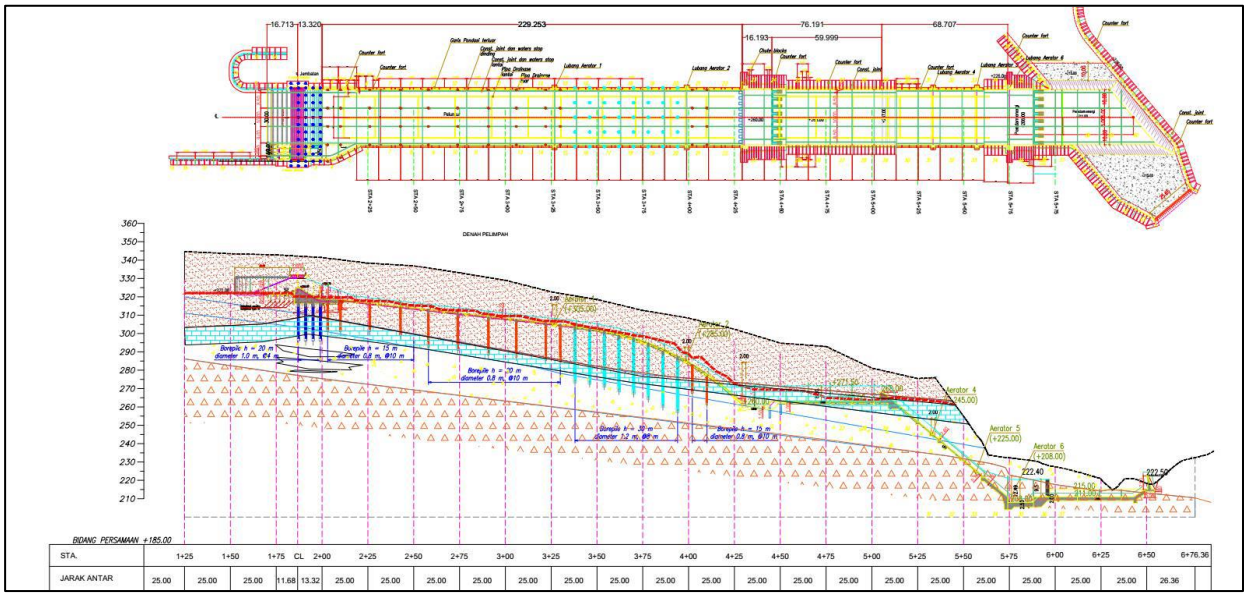


**Figure 5-18 Reinforcement of foundation with bore pile of Bagong Dam (source: exposure of technical discussion of bagong dam spillway, September 2023)**

Using bore pile for spillway foundation can cause a gap between colluvium and spillway floor (by settlement or colluvium movement). Water can flow easily at the gap. Based on the reinforcement design of bore pile, at upper part of spillway (red pile on the Figure 0 18) the pile need to be penetrated deeper to ensure the strength of the pile.

### 5.9.2 Settlement at Spillway Backfill

Settlement occurred at the backfill location of the spillway slope abutment of Bajulmati Dam. This may be caused by soil compaction during construction is not good, based on the OP operator during the construction period the settlement location is filled area. The location need to be re-backfilled and compacted.

### 5.9.3 Foundation strength

Cipanas Dam, Ladongi Dam, Sepaku Semoi Dam and Sidan Dam has issue related the condition /strength of the spillway foundation. The strength of the foundation in the dam structure is very important because most of dam failures are caused by foundation problems including spillway foundations.

Problems in Cipanas dams is stilling basin lies on unconformity zone of volcanic rock and for Sepaku Semoi dam is spillway and conduit confluence is lied on alluvium deposit. In rocks with unconformity, rock movement can occur which may damage the spillway structure. Strengthening that can be done at Cipanas dam is by adding rock anchors to the left and right of the spillway surrounding the unconformity zone. The alluvium

foundation at Sepaku Semoi dam is better to be removed or reinforcement using concrete mixing if non-cohesive alluvium is dominant.

Ladongi dan Sidan dam has issue relate to foundation strength. Dams with rock foundations that are considered less strong need foundation reinforcement. One method of reinforcement that can be performed on soil and rock is grouting. But trial grouting should be conducted first to ensure the rock condition after grouting.

### 5.9.4 Swelling Pressure of Spillway floor at Temef Dam

Swelling in clay occurs due to the addition of water molecules to the clay material. These water molecules will fill between the clay sheets, increasing the volume of the clay material.

If the clay material has a dip, the direction of greatest swelling will be perpendicular to the dip of the particles. Clay particles have a flat shape so that they tend to be deposited horizontally, so the direction of the slope in the rock layer also reflects the tendency of the direction of clay particles to be deposited. Knowing the orientation of the clay material layers, we also know the potential direction of the greatest development of clay expansion.

In the case of Temef Dam, there is a layer of swelling clay (bobonaro clay) on the spillway floor, if the direction of the layer of bobonaro clay is found, the most effective resistance response can be done by providing resistance perpendicular to the direction of the layer.

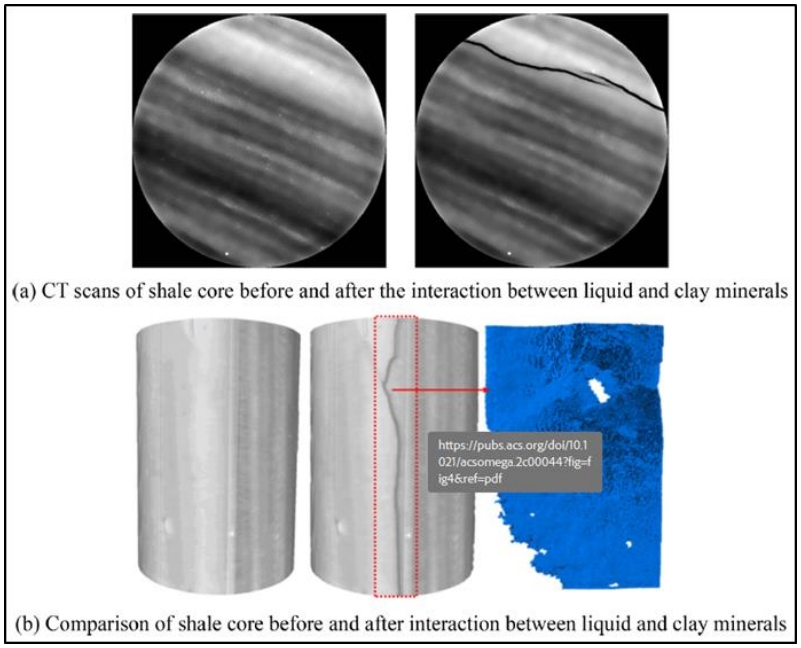



**Figure 5-19 The greatest swelling occurs perpendicular to the direction of layering (ACS Omega 2022, 7, 9796−9807)**

Rockbolt can be used to countermeasure the swelling pressure that occurs on the spillway floor. If rockbolt will be used alternatively to countermeasure swelling, the rockbolt should be installed perpendicular to the direction of the rock layers.

### 5.9.5 Secant Pile

At Bagong Dam, the right side of the spillway is planned to be installed secant pile along 20 meters. Considering the layer of colluvium has a wide distribution, it is necessary to confirm the drill at the end of the secant pile by conducting a permeability test to determine the condition of the possibility of seepage.

If the site is still characterized by large lugeon conditions, it is necessary to extend the secant pile until good geology is found. The geology map MASW study shows the presence of breccia lithology in the right back of the dam. It is necessary to confirm the existence of the breccia by conducting more detailed mapping. The breccia can be the edge of the secant pile laying.

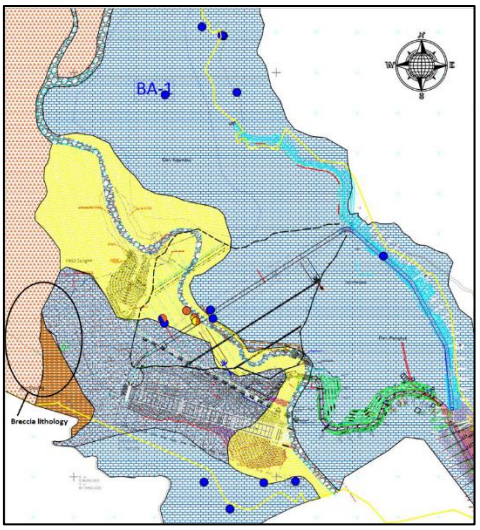



**Figure 5-20 Breccia observed at the right abutment (Laporan Progress Pengeboran hasil MASW, Rayaconsult KSO)**

## 5.10 SPILLWAY DESIGN

Spillways are provided for storage and detention dams to release surplus water or floodwater that cannot be contained in the allotted storage space, and for diversion dams to bypass flows exceeding those turned into the diversion system. Ordinarily, the excess is drawn from the top of the reservoir and conveyed through a constructed waterway back to the river or to some natural drainage channel. Mostly of design changing of spillway related to hydrology of hydraulic. Only Bagong dam and Manikin Dam that the design changed for geological condition reason.

### 5.10.1 Case of Spillway Design of Bagong Dam

Bagong dam is one of dam that design of spillway will be changed due to geological condition. Limestone and claystone colluvium was observed at spillway foundation. The types of limestone in Bagong Dam are clastic limestone (calcarenite and calcilutite) and non-clastic limestone (coralline and crystalline). Non-clastic limestone is more brittle so that when exposed to stress (fault), they will break more easily and many joints/cracks will be found. In addition, non-clastic limestone is easier to dissolve by water than clastic limestone.

The jointed limestone will be eroded and dissolved by water gradually and sometimes water carries soil material and fills the voids between cracks. Indonesia has high rainfall intensity that make water can penetrated deeply into limestone. The soil/joins will be weak zone and some clasts will release step by step that make unstable condition at slope.

The foundation of the Bagong Dam spillway on the right abutment is not contain of pure colluvium deposit but a mixture of the results of weathering limestone and landslide material from the limestone itself because of the layer still have its original sediment structure. Landslides will occur as long as the limestone is dissolving and weathering.

At the site location also found a layer of black clay that is prone to slaking. Slaking occurs to form a long plane that will fall off and be eroded to form a weak plane. The black color of the clay may come from organic matter. Clays with organic material tend to have a low bearing capacity and a large shrinkage.

**Photo 5-7 Shrinkage on the dark claystone which form weak zone at the slope (field inspection of Bagong Dam, 2023)**

With all this condition the consultant plan to add pile foundation for reinforcement. As mentioned in previous chapter colluvium is unstable deposit which landslide can occur again. The landslide can be debris flow under spillway (at the pile) and may damage to the pile. Making morning glory spillway is better solution that using pile for reinforcement. The tunnel work that is being carried out shows that the rock in the tunnel is dominated by fresh rock so that a change to a morning glory spillway is possible.

### 5.10.2 Case of Spillway Channel of Manikin Dam

Based on the design, some of the additional spillway channels are in the form of conduits or box culverts. The consultant proposes to change the channel type to open channel and the channel is designed to be longer.

Considering that most of the rocks in the manikin dam are Bobonaro mudstones which have easy slaking and swelling properties, maintaining the moisture of the rocks around the building is very necessary. By using conduit channels, the moisture of the rocks around the channel will be more preserved so that they are not prone to swelling and slaking. If this channel will be made open channel, the anticipation is much more because in addition to protecting the surface, the channel reinforcement is also necessary because the swelling pressure from the Bobonaro Formation is also quite large. For the reason, using of conduit is an appropriate design for the condition of the manikin dam.

## 5.11 TUNNEL COLLAPSE

Tunnel collapse issues at several dams in Indonesia are closely related to the geology condition. The issues that occur in Indonesia dam are caused by tight cracks, weakening planes, weak layers such as claystone, swelling material and the presence of loose material through which the tunnel trace.

Tunnel collapse mostly related to geological condition of tunnel. Tunnel collapse due to weakening plane or weak layer such as Bener and Bogong dam is actually can be anticipated before collapse is really happened. A site geologist should be always monitor after tunnel is excavated. The lithology condition can be observed earlier from the tunnel wall (face and both side of right and left). When a weak plane is seen in the tunnel, reinforcement of the tunnel wall should be carried out immediately before collapse occurs. One of the reinforcements that can be done is with rock bolt. Rock bold is carried out starting from the beginning of the weak plane observed then do not trigger other collapses in the blasting process that will be carried out.

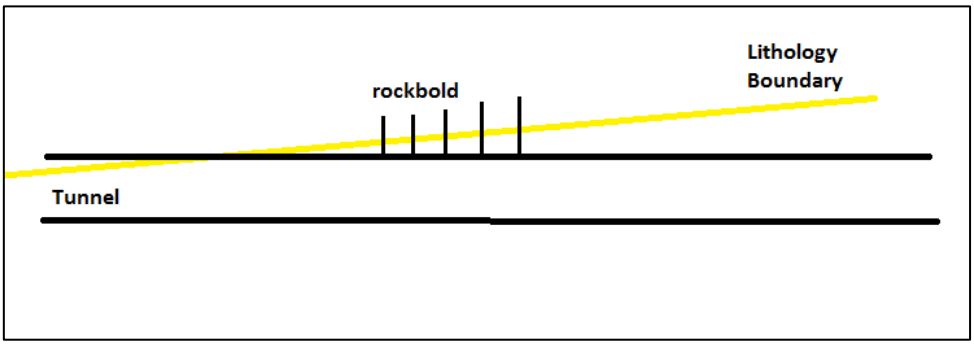



**Figure 5-21 Rock-bold illustration at beginning of lithology boundary**

The tunnel condition of Way Apu dam has very tight joint with the lithology of schist. Schist is metamorphic rock with foliation plane which can be weak zone. Based on engineering geological mapping was carried out during the tunnel work, the resulting RMR value of rock along the tunnel building is in the RMR range < 40 (poor rock according to the Bieniawski classification). Bieniawski make a guidelines for excavation and support of rock tunnels in accordance with the RMR system that provided in the Table 0 6.

**Table 5-6 Guidelines for excavation and support of rock tunnels in accordance with the RMR system (Bieniawski , 1989)**

| Rock Mass Class | Excavation | Support | | |
|---|---|---|---|---|
| | | Rock Bolts (20-mm Dia, Fully Grouted) | Shotcrete | Steel Sets |
| Very good rock<br>I<br>RMR:81–100 | Full face<br>3-m advance | Generally, no support required except for occasional spot bolting | | |
| Good rock<br>II<br>RMR:61–80 | Full face<br>1.0–1.5-m advance<br>Complete support 20 m from face | Locally, bolts in crown 3 m long, spaced 2.5 m, with occasional wire mesh | 50 mm in crown where required | None |
| Fair rock<br>III<br>RMR: 41–60 | Top heading and bench<br>1.5–3-m advance in top heading<br>Commence support after each blast<br>Complete support 10 m from face | Systematic bolts 4 m long, spaced 1.5–2 m in crown and walls with wire mesh in crown | 50–100 mm in crown and 30 mm in sides | None |
| Poor rock<br>IV<br>RMR: 21–40 | Top heading and bench<br>1.0–1.5-m advance in top heading. Install support concurrently with excavation 10 m from face | Systematic bolts 4–5 m long, spaced 1–1.5 m in crown and wall with wire mesh | 100–150 mm in crown and 100 mm in sides | Light to medium ribs spaced 1.5 m where required |
| Very poor rock<br>V<br>RMR: <20 | Multiple drifts<br>0.5–1.5-m advance in top heading. Install support concurrently with excavation. Shotcrete as soon as possible after blasting | Systematic bolts 5–6 m long, spaced 1–1.5 m in crown and walls with wire mesh. Bolt invert | 150–200 mm in crown, 150 mm in sides, and 50 mm on face | Medium to heavy ribs spaced 0.75 m with steel lagging and fore-poling if required. Close invert |

Shape: horseshoe; width: 10 m; vertical stress: <25 MPa; construction: drilling and blasting.

The design of the Manikin Dam diversion tunnel was originally circular (PT. Indra Karya, 2018). However, in the implementation of the work, the tunnel was changed to a semicircle. In the case of swelling rock, a circular tunnel shape is recommended and in extreme cases it is also recommended to use yielding support as stated by Terzaghi, 1946.

The Tiga Dihaji dam tunnel is passes through a location with geological conditions in the form of loose sand. When the tunnel is excavated, the top wall of tunnel was collapse and the collapse material is loose sand. The collapse made a cave that through surface of dam foundation (make sinkhole from tunnel to surface). The sinkhole treatment of Tiga Dihaji Dam was covered with concrete.

Loading plat test is conducted at foundation of Tiga Dihaji Dam to confirm the strength of foundation (Figure 0 22). Partially, there are several part that has poor bearing capacity (safety factor less than 3 / red color). The poor bearing capacity may relate to loose that form sinkhole in tunnel so further study should be conducted and the lugeon value should be confirmed.

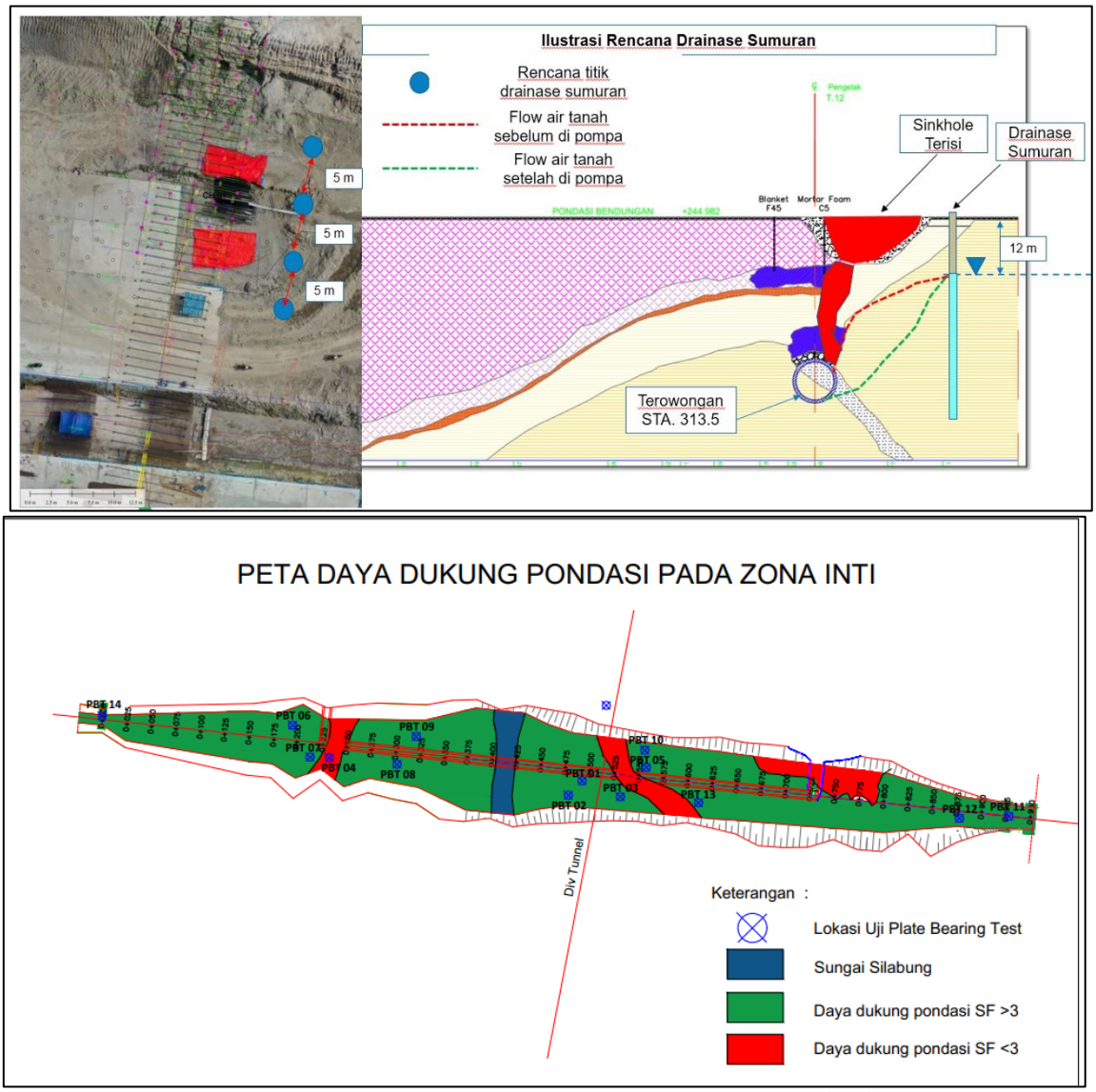



**Figure 5-22 Sinkhole at the top of tunnel due to tunnel collapse (top), and safety factor of foundation bearing capacity (bottom) ( Respond of Technical discussion of Tiga dihaji dam on 13-April-2022)**

## 5.12 DIVERSION LEAKAGE

Bendo Dam, Beringin Sila Dam, Karalloe Dam, Keureuto Dam, Kuwil Dam, Logung Dam, Marangkayu Dam, Napun Gete Dam, Nipah Dam, Paselloreng Dam, Rukoh Dam, Semantok Dam, Tapin Dam had issue related water come out from tunnel wall. Leaks that occur in the tunnel will be dangerous if the water comes from the reservoir and bring the dam material. even though the water that comes out of the tunnel may not come from reservoir water, it will still be disturbing during operation and maintenance because the water that comes out can erode the tunnel walls or pipelines thereby reducing the quality of the material, besides that the water that comes out will make the tunnel damp and then moss will easily grow.

Knowledge of the knowing the source / origin of the water coming out through the tunnel is required to ensure that the water is not coming out from reservoir. Several studies can

be conducted to identify in leaking water in tunnel. Things that need to be done to identify the condition of the tunnel include:

1. Sampling of water in the reservoir, water around the reservoir (groundwater) and water coming out of the tunnel needs to be conducted to determine water properties such as the Electrical Conductivity and Total Dissolved Solid (TDS). The comparison of water properties can be initial guide for water source.
2. Knowing the subsurface condition around the tunnel is important, Geophysical study can be conducted such rock resistivity test.
3. To ensure the source of water, testing of isotope deuterium and oksigen-18 can be conducted.
4. After knowing the source of water counter measurement method can be considered. Alternative treatments that can be considered include plugging the seepage cracks with crystal technology which has been applied to the Pandanduri Dam.

At Rukoh Dam and Tapin Dam, calcite formed at the wall of tunnel. The calcite formation indicates the dissolution of lime cement from the tunnel concrete structure. The effect of dissolution on the quality of tunnel structure concrete should be evaluated. Periodic measurements and monitoring of calcite volume or dimensions should be carried out. The results of measurements of the volume of calcite formed in the plugging should be separated from the results of measurements of the volume of calcite from the tunnel lining (plenary discussion of implementation of the initial impounding of the reservoir and readiness for operation of Tapin Dam. January 12th, 2023).

In dams with leakage problems that are conduit-type diversion channels, more attention is needed if there is a leak both inside and around the channel, because of the embankment is directly above the concrete channel so that the boundary between the concrete and the embankment is weak zone that becomes a waterway. If it becomes a waterway, it is likely that the embankment material can experience erosion which has an impact on the collapse of the dam. The dams with conduit channel and leakage diversion are Marangkayu Dam, Semantok Dam, Napun Gete Dam and Logung Dam

## 5.13 PLUGGING OF DIVERSION

Plugging is the work of blocking the diversion channel with reinforced concrete. The aim is to block the river flow so that the dam is filled with water. The method of implementation is casting from inside the conduit using a concrete pump and is carried out in stages. Diversion plugging is the initial stage of reservoir impounding that begins with the closure of the mouth of the diversion tunnel.

The minimum length of the main plug is half the diameter of the tunnel but for safety it can be more than half the tunnel diameter. To accelerate the plugging and still keep the quality of concrete, usually the plug is equipped with a water cooling system. With a water cooling system, the setting of concrete can be accelerated but the possibility of shrinkage due to cracks can be prevented.

At the Lolak dam, the number of grouting points to be carried out in the plan for implementing contact grouting on plugging concrete is become the issue. Based on discussion, it is recommended that plugging implementation plan should be accompanied by detailed planning design drawings, including the number and pattern of grouting points to be implemented.

## 5.14 HIDROMECHANICAL

Rukoh dams, Keureuto dams and Temef dam have hydromechanical issues, which are generally a matter of design or installation of equipment and installation of bottom outlets. Bottom outlet is an outlet building at the lowest elevation of the dam that can be used for various purposes, such as to control reservoir impounding, lower reservoir water levels, emergency outlets and sediment flushing. Seeing the function of the bottom outlet, the bottom outlet is very useful for dams such as extending the life of the dam by removing sediment in the reservoir. Besides that, if a maintenance or repair is required that needs to lower the reservoir water level to below the intake, it can be lowered through the bottom outlet.

## 5.15 INTAKE DESIGN/FOUNDATION

Jragung Dam, Leuwikeris Dam and Temef Dam had issues related to intake design or foundation. In general the changing location or type of intake is no problem as long as the foundation has enough bearing capacity (Jragung Dam and Leuwikeris Dam).

At Temef Dam there was a shifting slope of pillar at bridge of spillway wall to intake tower. There was a shifting slope of pillar 5 (4.8o) to pillar 6 with a base elevation of +354 meter of the bridge where there is movement of landslides of steep cliffs with fractures and cracks. Based on Minutes of Implementation Construction, 5 September 2022, counter weight is recommended to balance pillars 5 so that it can be repaired or replaced with a new one. The slopes should be stabilized first, then the pillar is constructed. It is recommended that the backfill is carried out immediately and pillar 5 can be excavated again under the foundation on the original soil.

## 5.16 PENSTOCK PIPE

Based on recommendation by discussing for Karian Dam, considering after plugging, the penstock pipe cannot be maintained and repaired if a leak occurs, the penstock pipe should be covered with concrete. Make sure the quality of the concrete used and the thickness of the concrete blanket is sufficient to prevent the penstock pipe from getting damp and rusting.

In Keureuto Dam, the penstock is shifted. Pipes that experience bends should be strengthened, for example, by adding anchors to the pipe mounts, tightening the pipe mounts, covering the pipes with concrete, etc (discussion recommendation). In Additional it should be check the water flow condition.

## 5.17 IMPOUNDING

Lolak Dam has issue related to impounding. The construction is completed and ready for initial impounding. After completing of construction, the initial impounding of the reservoir was planned for June 23th, 2022, but realized in august 18th, 2023. The implemented delayed because of some problems with the land acquisition of the reservoir.

Based on technical discussion related to readiness for initial impounding of Lolak Dam (August 11, 2023), total time needed to reach the normal water level (NWL) of 71 days (16 day to reach LWL / intake and 55 to reach NWL). The dam safety commission has recommendation regarding to the impounding of Lolak Dam.

1. In carrying out the initial impounding of the reservoir, it should wait to raise the reservoir water level to the normal water level. Still, there should be a time lag after reaching the intake elevation (elevation +99 m) to monitor the behavior of the dam body for around 2 - 3 months before continuing to fill the water level to

the MAN. This time lag determines the instrumentation response and tests the dam's hydromechanical equipment.

2. Hydrological modeling should be made from more than just the point where the dam is located. Hydrological modeling can be made up to the downstream of the dam, given the frequent occurrence of floods.
3. A control plan is needed as an anticipatory effort if things happen that are not planned during the initial filling of the reservoir, including the appointment of personnel responsible for the problem.

## 5.18 RESERVOIR USE

There are 4 dams that have issues related to reservoir conditions with different issues. The 4 Dam are:

1. Logung : Environment regulation recommendation
2. Jatigede : Panel Installation in reservoir
3. Marangkayu : Reservoir water level impounds gas wells
4. Napun Gete : Rapid water rise of reservoir

For Logung Dam Environment regulation about status of Lake Ecosystem quality by the Ministry of Environment and Forestry is recommended to be adopted/applied in Logung Dam. Because it was regulation that will be formalized, study and operation adaptation of the regulation better to be applied.

Jatigede Dam is planned to be installed solar panel at reservoir area. Jatigede Dam was ready operated in 2017. Based on historical of Jawa Island climate, in 2018-2019 Jatigede Dam ever lowered the water level reservoir up to 15 m.

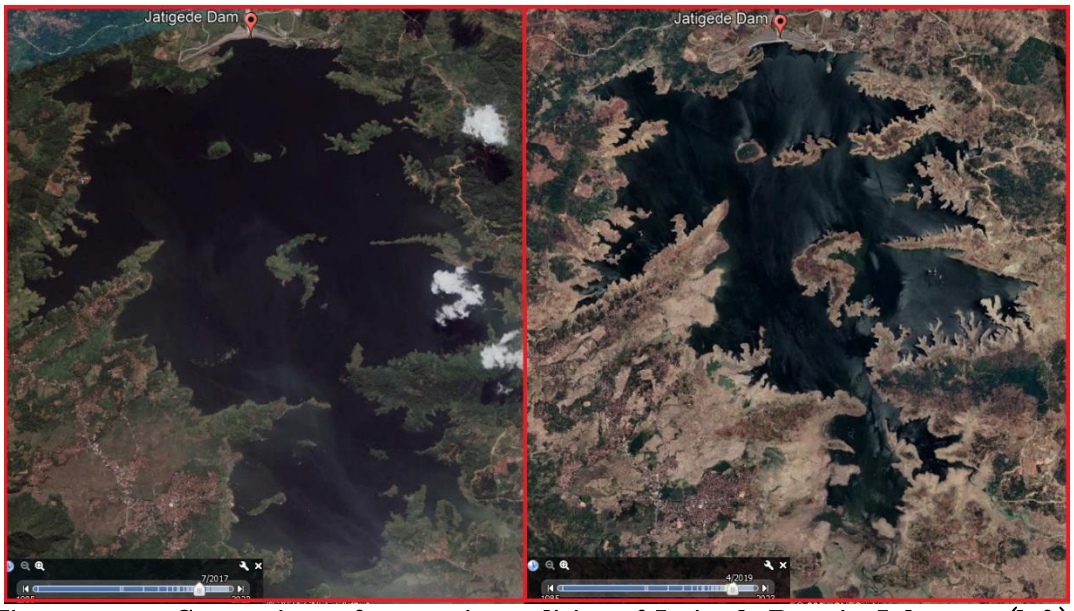



**Figure 5-23 Comparison of reservoir condition of Jatigede Dam in July 2017 (left) and April 2019 (right) (image by google earth**

The solar panel installation is planned to be located in left side of dam reservoir. Comparing the location to reservoir condition, the location is very effected to water

reservoir fluctuation. For the reason, the solar panel is better to be located above low water level (LWL) elevation at reservoir to avoid the solar damage due to lowered water level that can crash to the land.

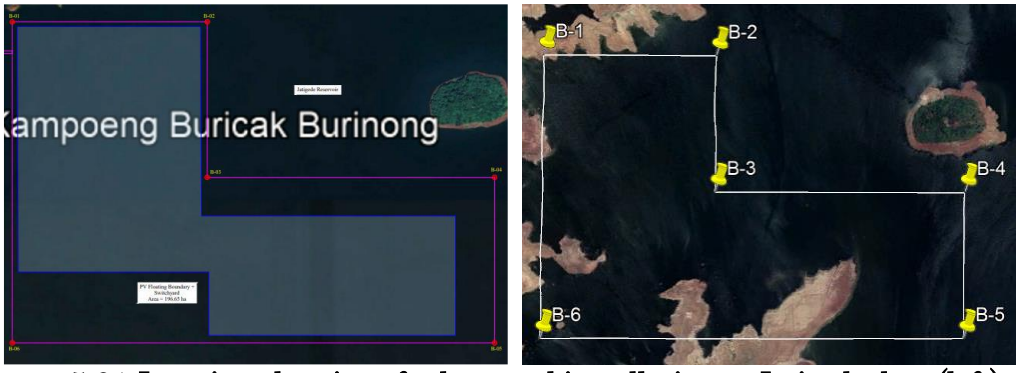



**Figure 5-24 Location planning of solar panel installation at Jatigede dam (left) and the location comparison at April 2019.**

There are several oil and gas wells in the reservoir of Marangkayu Dam. If the reservoir is impounded to normal water level of Marangkayu Dam, 4 wells will be drown. If the reservoir reach elevation of high water level (flooding 1000 return period), 7 wells will be drown. for the reason the initial impounding of Marangkayu dam has been conducted yet (2023) even the dam construction already finished in 2013.

There is a opinion that impounding target is elevation of +107.27 m which is not drowning any well and using emergency spillway for main spillway that only can handle flooding for Q5. Rebuilt the spillway that can handle up to flooding Q100 is better than taking high risk for impounding. Initial impounding is better to be suspended until the spillway is already build. The other option is studying for the function and mechanism of oil and gas well, where possible, protection and maintenance for it. This should be involved to the owner of the well too.

During initial impounding rapid water rising occured at Napun Gete Dam. The detail of rapid rising is not detailed due to the increasing of water level measurement was conducted once a week. The water level measurement should be carried out every day during initial impounding. It is also can be used for instrument calibration or instrument checking that was installed in dam body.

## 5.19 ANCHORING PANEL

As explained before, Jatigede Dam is planned to be installed solar panel at reservoir area. Peraturan Menteri PUPR RI NO.6 2020 allow to take advantageous from dam reservoir to be installed solar energy system (solar panel), but one of procedure to install the panel is All components should be located inside designated safety zones and do not interfere with critical function of the reservoir structures such as the intake and spillway structures. To keep the floater staying in place, anchoring with concrete block at the bottom of specific location at reservoir.

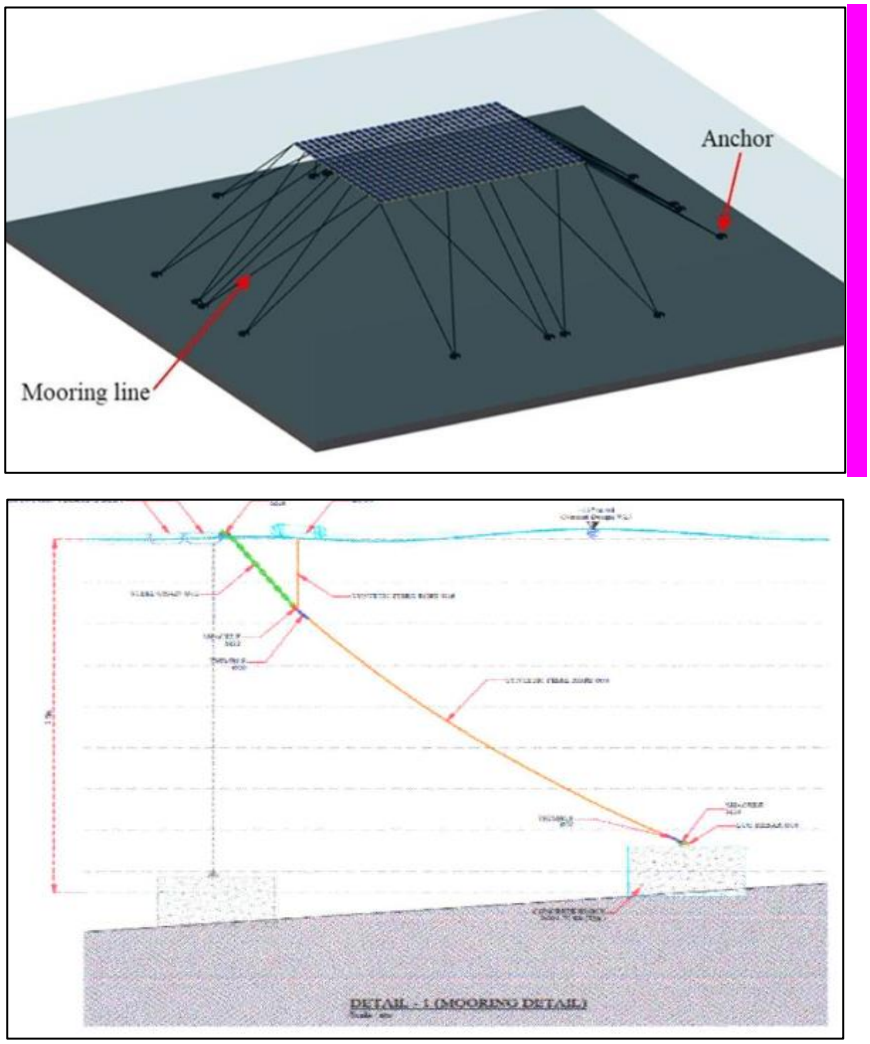



**Figure 5-25 Detail profile of anchor and mooring system**

Some dam of in Indonesia has anomaly phenomenon like small tornado (in Bahasa Indonesia called Puting Beliung) that occur in dam reservoir. This phenomenon ever happen in Gajah Mungkur dam (2020). The effect / risk of this phenomenon should be considered.

**Figure 5-26 Video screenshot of small tornado in Gajah Mungkur Dam**
(https://www.youtube.com/watch?v=-wEz0ojJXCg)

## 5.20 SEDIMENTATION AND RESERVOIR CONSERVATION

Ciawi Dam, Logung Dam, Randu Gunting Dam, Sukamahi Dam, Tugu Dam and Tukul Dam sedimentation from upstream and hyacinths and rubbish.

SNI 19-6459-2000 (Tata cara pengontrolan sedimentasi pada waduk) explain that Sediment that flows into a reservoir comes from upstream drainage areas and is transported into the reservoir through the river channel. Only a small amount comes from surface runoff around the reservoir. The amount of sediment from the entire drainage area depends on the erosion and sediment transport characteristics of the area and the characteristics of the river channel flowing into the reservoir.The main factors affecting sediment delivery from a drainage basin are:

1. intensity, and amount of rainfall;
2. soil type;
3. land cover (vegetation, litter, and rock debris);
4. land use (tillage for agriculture, pasture, construction activities, and conservation land);
5. topography;
6. erosion history (nature of the drainage network-density, slope, shape, size, and alignment of the channel);
7. “run-off” or water escape;
8. Sediment characteristics (grain size, mineralogy, etc.);
9. The hydraulic properties of the stream.

In evaluating sediment delivery from the conveyance area above a dam and reservoir, a field inspection by a sedimentation expert is required to determine the role of the above 9 factors in influencing sediment delivery.

There are five different approaches to estimating sediment delivery of a drainage basin, primarily for use in the planning and design of dams and reservoirs. Under some

conditions, one or more of these approaches may be used for older reservoirs where indirect measurements are not possible due to time or cost constraints. The five approaches for estimating sediment delivery are as follows:

a) evaluation of 9 (nine) factors affecting sediment delivery,

b) evaluation of the gross erosion rate equation,

c) application of the sediment transport equation,

d) empirical relationships from measurements,

e) mathematical model.

Sedimentation and rubbish entering the reservoir must come from the upstream area of the dam, therefore control of the sedimentation rate needs to be carried out in the upstream part of the reservoir. One way that can be done is to make a sabo dam on each river flow that enters the reservoir. The existence of this sabo dam can withstand sediment and rubbish that will enter the reservoir. So it is also necessary to remember to routinely take sediment in the sabo dam when it is full.

High sedimentation rates are also caused by damaged watersheds so that land use improvements also need to be considered, such as planting bare land. However, this cannot be done by the dam manager alone, it must be done together with related parties.

From the perspective of water quality conservation or improvement, water hyacinth in reservoirs has a positive value in reservoirs with a certain amount of inundation area. Water hyacinth can be used to purify dirty water, water that smells bad, so that water that was initially cloudy and smells bad can be used at least for washing. But water hyacinth can grow so fast that it blocks the flow of water and if it lives in an undesirable place it can damage or hinder the water's flow, and so on.

The presence of water hyacinth can be tolerated as long as it does not interfere with the dam function or safety as long as it is controlled, but if it is felt that it has grown too fast and is considered difficult to control, it is better to clean it completely.

## 5.21 FLASH FLOOD

Flood problems that occur in several dams are related to flash flood potential problems, some dams that have flash flood potential are Beringin sila, Lolak, Meninting and Tugu dams. In addition, there is also the Bener dam which was designed with the benefit of flood reduction but there has been no discussion of how much flood reduction from the dam. On June 17, 2022, a flood occurred upstream of the Meninting Dam which caused water to overflow through the temporary cofferdam and flow into the main cofferdam and main dam work areas.

Flash flood denotes an abrupt rise in the discharge of a river or stream, providing an event of short duration. Flash floods are strongly related to weather and rainfall, but Topographic Mountainous geomorphology has the potential for flash floods, especially in mountainous areas that have caldera formations. The presence of alluvial fans is also a sign of flash flood potential in a local area. Because of alluvial fans are depositional landforms created where steep high-power channels enter a zone of reduced stream power. Observing the present alluvial fan at the downstream location indicate that in the past flash is ever occurred in the location.

The example is catchment area of the Beringin Sila Dam as a caldera from a volcanic eruption that has a width of up to 6 km. Looking at the morphological conditions of the

area, there is a narrowing change in river direction in the downstream part of the catchment.

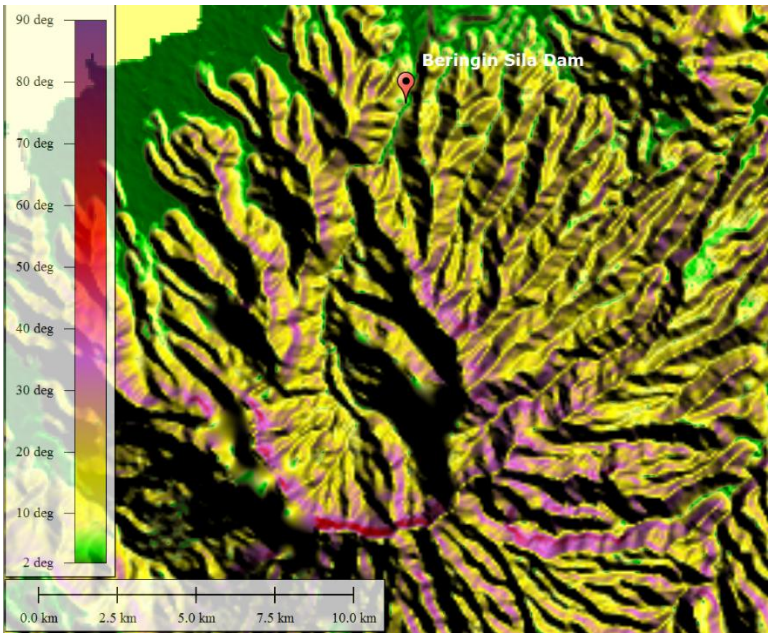



**Figure 5-27 Morphology of Beringin Sila Dam show Caldera form that has flash flood potential.**

## 5.22 LIQUEFACTION

Kuwil dam and Tiga Dihaji dam has issue about liquefaction. Liquefaction takes place when loosely packed, water-logged sediments at or near the ground surface lose their strength in response to strong ground shaking. There are three main factors for liquefaction:

1. The presence of loose sediment (sand, silty sand)
2. Saturated material conditions (near water level to ground surface)
3. Seismicity / earthquake

The density of sand in the site can be tested by Standard Penetration Test (SPT) or Cone Penetration Test (CPT). Historical of the non-cohesion soil can occur the liquefaction is when N1 (60) less than 20 and cyclic stress ration higher than 0.8 such provide in the Figure 0 28.

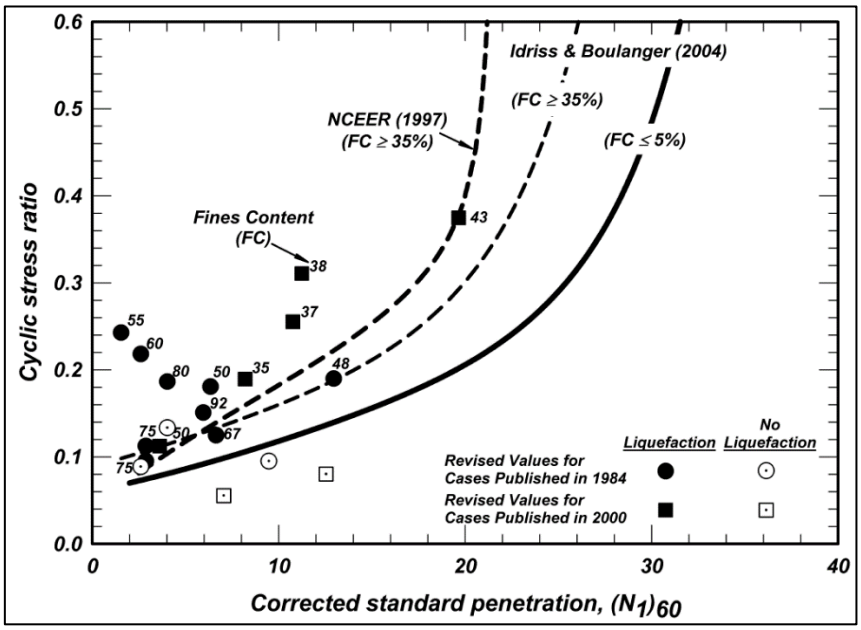



**Figure 5-28 SPT case histories of cohesionless soils with FC ≥ 35%, the NCEER/NSF workshop curve (Youd et al. 2001), and the recommended curves for both clean sands and for FC ≥ 35% for M = 7.5 and σ vc = 1 atm.**

According to geological survey of Kuwil Kawangkoan and Tiga Dihaji dam, the loose material of Kuwil Kawangkoan Dam has N-SPT (N-field) 25-35, this value need to be corrected to N1 (60) to ensure than The SPT is higher than 20. Deference condition happens to Tiga Dihadi Dam. The foundation of Tiga Dihaji Dam located in loose sand with thickness more than 20 m and N-SPT value is less than 20. Considering Tiga Dihadi Dam located at active seismicity zone (see Table 0 2), it has higher potential to liquefaction occur.

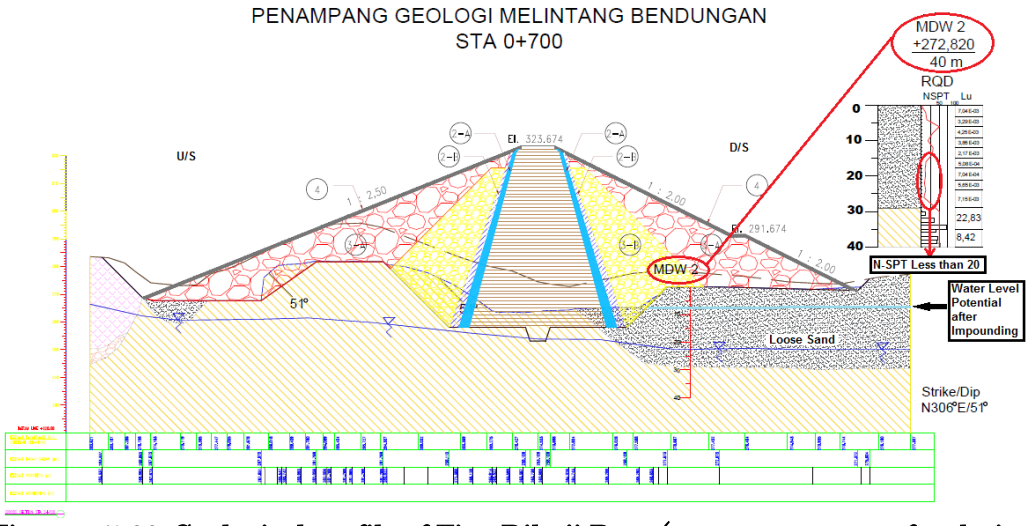



**Figure 5-29 Geological profile of Tiga Dihaji Dam (source: exposure of technical discussion of Tiga Dihadi dam, 13-April-2022)**

Based on the geological condition and liquefaction potential, some alternative can be done to avoid, such as:

1. Move dam axial to upstream until the foundation doesn't lie on loose sand (if possible)
2. Increase the density of loose sand by dynamic compaction, concrete mixing, grouting, or other method that can be applied at field to increase the density of sand.
3. Removing the loose sands with consequences increasing embankment volume.

Liquefaction is not happen directly after earthquake but take some hours or days. A common manifestation of liquefaction is the formation of sand boils or mud spouts at the ground surface by seepage of water through ground cracks or, in some cases, by the development of quick sandlike conditions over substantial areas. So it recommended to check until a week or two weeks at the loose sand location around the dam if earthquake happen to ensure the liquefaction manifestation doesn't occur. If the liquefaction is really happen a warning should be announced to the downstream area (emergency action).

## 5.23 REINSTALLATION OF INSTRUMENT

Dam monitoring instrument is important tools of dam monitoring during operation of dam. The dam characteristic can be recognized from monitoring instrument. In several dam, the Instrument is not function properly or be broken, for the reason new installation instrumentation is necessary.

Bendo Dam, Raknamo Dam and Rotiklot Dam are three dams that has malfunction or broken monitoring instrument so drilling on the dam body is considered to install new monitoring instrumentation. Drilling on the dam body has the potential to be hazardous as it concerns dam safety/dam stability.

The drilling of dam body has several risk that may harm to the dam body itself like Hydraulic fracture, collapse of drilling wall, filter contaminant, etc. To avoid or minimize the hazards that affect the safety of the dam, several things need to be considered:

1. The implementation of drilling should be used single tube core barrel with no water circulation or pressure (dry drilling). Hydraulic fracturing occurs when the water pressure exceeds the lateral stress (confining stress). Without using water it mean the hydraulic facture can be minimalized.
2. To protect the borehole from collapse, a casing should be installed in the borehole and gently lifted during instrument installation.
3. The deeper drilling has higher risk, better to choose instrument installation that has thin embankment.

## 5.24 INSPECTION GALLERY

Tiga Dihaji Dam has mayor problem of weak zone which is loose sand. The gallery inspection is recommended to be build and for entrance or exit access of the gallery, it is best to create a gallery access at the bottom of the pedestal, which can also be used to place a drain pipe (technical discussion of the construction implementation of Tiga Dihaji Dam, August 1, 2023).

Galleries can be classified into different groups based on their purpose. Based on their purpose, the galleries dam can be drainage galleries, inspection galleries, grouting galleries, access galleries, foundation galleries, and gate galleries. Inspection gallery is a gallery that gives access to the inside of the dam so that the structure can be inspected

and the behavior of the dam can be studied. It also helps get rid of water that seeps into the ground.

The thickness of loose sand foundation of Tiga Dihaji dam up to 30 meters. Considering that the loose sand contained in the Tiga Dihaji Dam is quite thick, which can also experience liquefaction, the addition of an inspection gallery is needed. In addition to facilitate the location of monitoring instrumentation in the event of a large earthquake that can trigger liquefaction or abnormalities that occur in the dam foundation, especially for loose sand.

## 5.25 WATER TREATMENT PLAN AROUND THE DAM

The Water Treatment Plant (WTP) is planned to be built around the Sepaku Semoi Dam, there are 2 alternative locations that will be used for the WTP location plan, namely on the left abutment of the dam and downstream of the dam. Geological mapping at the time of construction showed that the left abutment of the Sepaku Semoi dam site is dominated by quartz sandstone with intercalation of claystone, shale, limestone and siltstone. The mudstones, shales and siltstones at the site show slaking characteristics.

Avoiding WTP construction around the left abutment of Sepaku Semoi Dam is recommended due to geological condition and thin hill of left dam abutment. The construction of WTP will also including excavation that can trigger landslide of the dam and weakening the abutment and also may effect to instrument around the dam and grouting that had been carried out.

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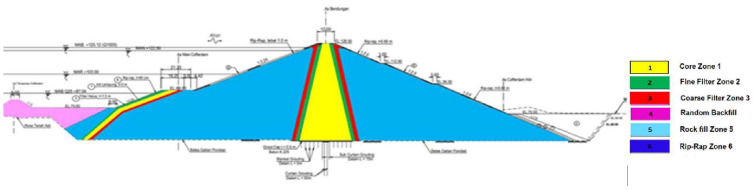
# *Attachments*

## *Attachment 1 Dam Technical Data*

## *Attachment 2 Summary of Dam Issues*

# *Attachment 1 Dam Technical Data*

| | | |
|---|---|---|
| Dam Name | : | Ameroro |
| Province | : | Sulawesi Tenggara |
| Regency | : | Konawe |
| Coordinate | : | 3° 54' 37,75" S<br>122° 0' 32,17" E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Rock-filled dam with central core |
| Height | : | 82 m |
| Elevation of crest | : | +128.5 m |
| Elevation base foundation | : | + 47 m |
| Wide of crest | : | 12 m |
| Lenght of crest | : | 327 m |
| Upstream slope | : | 1:2.5 |
| Downstream slope | : | 1:2.0 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +122.50 m |
| Elv. of low water level (LWL) | : | +103.00 m |
| Elv. of flood water level Q1000 | : | no data |
| Elv. of flood water level QPMF | : | + 125,61 m |
| Normal storage capacity | : | 88.26 million m3 |
| Dead storage capacity | : | 31.71 million m3 |
| Effective storage capacity | : | 56.55 million m3 |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 270.85 m3/sec |
| 10 year return period | : | 301.73 m3/sec |
| 25 year old return period | : | 340.71 m3/sec |
| 50 year return period | : | 369.65 m3/sec |
| 100 year return period | : | 398.34 m3/sec |
| 1000 year return period | : | 493.21 m3/sec |
| PMF return period | : | 1,222.66 m3/sec |

**Intake**

| | | |
|---|---|---|
| Type | : | Drop intakes |
| Tower Height | : | 32.60 m |
| Tower Peak Elevasion | : | 103.00 m |
| Threshold Elevation | : | +70.4 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Overflow, Ogee |
| Length | : | 329 m |
| Wide threshold | : | 40 m |
| Crest threshold elevation | : | +122.50 m |
| Type of basin | : | USBRII |

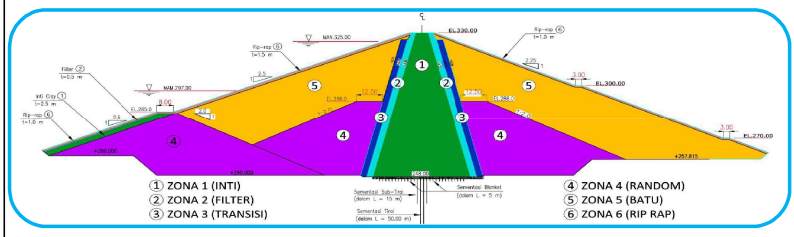
**Diversion**

| | | |
|---|---|---|
| Location | : | Right of main dam |
| Type | : | conduit |
| Length | : | 380 m |
| Dimensions | : | 4.0 x 4.0 m |
| U/S elevation | : | +71.0 m |
| D/S elevation | : | +69.0 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Paleozoic Methamorphic |
| Rock/soil | : | phyllite, slate, gneiss |
| Rock Class (CRIEPI) | : | CL,CM, CH |
| Main Dam Foundation | : | Slate |
| Spillway Foundation | : | Slate |
| Diversion Foundation | : | Slate |

| | | |
|---|---|---|
| Dam Name | : | Bagong |
| Province | : | Jawa Timur' |
| Regency | : | Trenggalek |
| Coordinate | : | 7° 59'51,63"S<br>111° 41'33,45"E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal with vertical core |
| Height | : | 82 m |
| Elevation of crest | : | +330.00 m |
| Elevation base foundation | : | +248.00 m |
| Wide of crest | : | 12 m |
| Lenght of crest | : | 620 m |
| Upstream slope | : | 1:2.50 |
| Downstream slope | : | 1:2.25 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +325.00 m |
| Elv. of low water level (LWL) | : | +297.00 m |
| Elv. of flood water level Q1000 | : | – |
| Elv. of flood water level QPMF | : | +329.23 m |
| Normal storage capacity | : | 17.4 million $m^3$ |
| Dead storage capacity | : | 3.3 million $m^3$ |
| Effective storage capacity | : | 14.1 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 154.71 $m^3/s$ |
| 10 year return period | : | 169.08 $m^3/s$ |
| 25 year old return period | : | 188.94 $m^3/s$ |
| 50 year return period | : | 194.22 $m^3/s$ |
| 100 year return period | : | 203.36 $m^3/s$ |
| 1000 year return period | : | 289.40 $m^3/s$ |
| PMF return period | : | 589.93 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Tower height | : | 40.40 m |
| Intake inlet elevation | : | +295.00 m |
| Gate dimension | : | 0.9 m (diameter) |

**Spillway**

| | | |
|---|---|---|
| Type | : | Mercu Ogee |
| Length | : | 397.92 m |
| Wide threshold | : | 30 m |
| Crest threshold elevation | : | +325.00 m |
| Stilling Basin type | : | USBR type III |

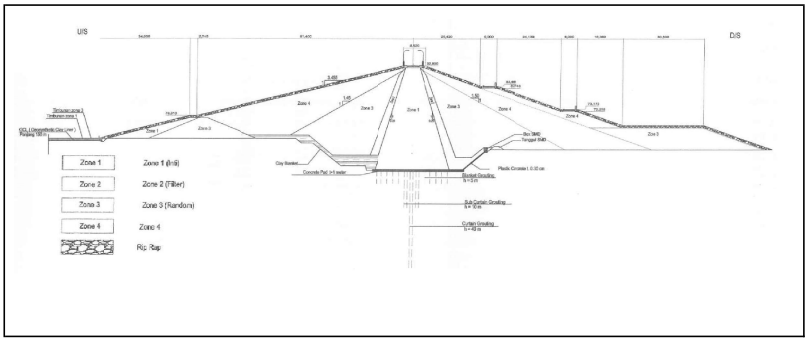
**Diversion**

| | | |
|---|---|---|
| Location | : | Right dam abutment |
| Type | : | Tunnel |
| Length | : | 422 m |
| Dimensions | : | 4.0 m |
| U/S elevation | : | +255.0 m |
| D/S elevation | : | +248.0 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Mandalika, Jaten, Wonosari |
| Rock/soil | : | colluvium, limestone, sandstone, volcanic breccia |
| Rock Class (CRIEPI) | : | D, CL, CM |
| Main Dam Foundation | : | colluvium, limestone, sandstone |
| Spillway Foundation | : | colluvium, limestone, sandstone |
| Diversion Foundation | : | limestone, sandstone, volcanic breccia |

| | | |
|---|---|---|
| Dam Name | : | Bajulmati |
| Province | : | Jawa Timut |
| Regency | : | Banyuwangi |
| Coordinate | : | 7° 54' 47.56" S<br>114° 21' 30.87" E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal with central core & Rockfill |
| Height | : | 47.8 m |
| Elevation of crest | : | + 92.8 m |
| Elevation base foundation | : | + 45.0 m |
| Wide of crest | : | 8.52 m |
| Lenght of crest | : | 250.0 m |
| Upstream slope | : | 1 : 3.45 |
| Downstream slope | : | 1 : 2.30 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +87.60 m |
| Elv. of low water level (LWL) | : | +73.40 m |
| Elv. of flood water level Q1000 | : | – |
| Elv. of flood water level QPMF | : | +90.75 m |
| Normal storage capacity | : | 10 million $m^3$ |
| Dead storage capacity | : | 2.5 million $m^3$ |
| Effective storage capacity | : | 7.5 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | |
| 10 year return period | : | |
| 20 year old return period | : | 255 $m^3/s$ |
| 50 year return period | : | |
| 100 year return period | : | |
| 1000 year return period | : | 818 $m^3/s$ |
| PMF return period | : | 1463 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | inclined |
| max. discharge | : | 4 $m^3/s$ |
| Intake inlet elevation | : | +70.5 m & +78.0 m |
| Gate dimension | : | 1.0 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side channel |
| Length | : | 288.0 m |
| Wide threshold | : | 18.0 m |
| Crest threshold elevation | : | +87.60 m |
| Stilling Basin type | : | – |

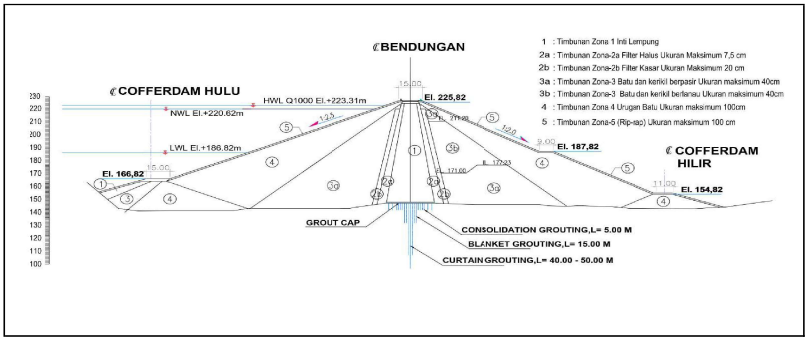
**Diversion**

| | | |
|---|---|---|
| Location | : | Left Abutment |
| Type | : | Tunnel |
| Length | : | – |
| Dimensions | : | ϕ 4.0 m |
| U/S elevation | : | +54.77 m |
| D/S elevation | : | +52.14 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Ijen volcanic & Baluran Volcanic |
| Rock/soil | : | Tuff lapilli, lahar, river deposit |
| Rock Class (CRIEPI) | : | D, CL, CM |
| Main Dam Foundation | : | River deposit, lahar, tuff lapilli |
| Spillway Foundation | : | River deposit, lahar, tuff lapilli |
| Diversion Foundation | : | River deposit, lahar, tuff lapilli |

| | | |
|---|---|---|
| Dam Name | : | Bendo |
| Province | : | Jawa Timur |
| Regency | : | Ponorogo |
| Coordinate | : | 7° 55'56.23"S<br>111° 34'57.54"E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal with Central core |
| Height | : | 74.0 m |
| Elevation of crest | : | +225.82 m |
| Elevation base foundation | : | +151.82 m |
| Wide of crest | : | 15.0 m |
| Lenght of crest | : | 344.77m |
| Upstream slope | : | 1:2.50 |
| Downstream slope | : | 1:2.00 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +220.62 m |
| Elv. of low water level (LWL) | : | +188.82 m |
| Elv. of flood water level Q1000 | : | +223.31 m |
| Elv. of flood water level QPMF | : | +224.60 m |
| Normal storage capacity | : | 43.11 million $m^3$ |
| Dead storage capacity | : | 9.17 million $m^3$ |
| Effective storage capacity | : | 33.93 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 86.07 $m^3/s$ |
| 10 year return period | : | 118.08 $m^3/s$ |
| 25 year old return period | : | 164.22 $m^3/s$ |
| 50 year return period | : | 202.75 $m^3/s$ |
| 100 year return period | : | 245.01 $m^3/s$ |
| 1000 year return period | : | 420.04 $m^3/s$ |
| PMF return period | : | 1462.04 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | incline shaft |
| Upper Intake elevation | : | +196.82 m |
| lower Intake elevation | : | +186.82 m |
| Gate dimension | : | 2m x 2.6m, 2 gates |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side chanel |
| Length | : | 312.5 m |
| Wide threshold | : | 20.0 m |
| Crest threshold elevation | : | +220.62 m |
| Stilling Basin type | : | USBR type II |

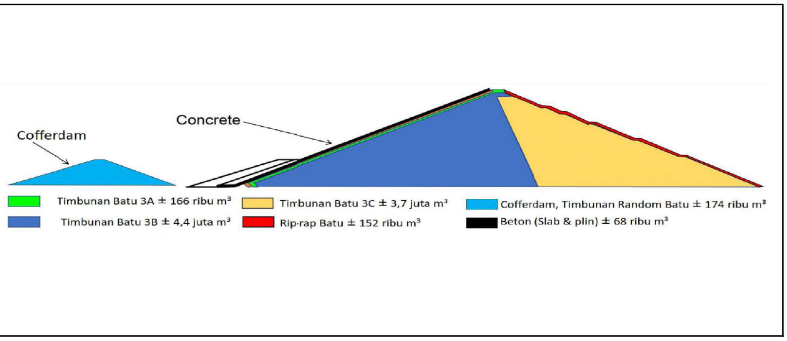
**Diversion**

| | | |
|---|---|---|
| Location | : | Left abutment |
| Type | : | Tunnel |
| Length | : | 453 m |
| Dimensions | : | 5.5 m |
| U/S elevation | : | +152.82 m |
| D/S elevation | : | +146.32 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Wuni, Argokalangan Morphocet |
| Rock/soil | : | Volcanic breccia, tuffaceous sandstone, andesit |
| Rock Class (CRIEPI) | : | D, CL, CM, CH |
| Main Dam Foundation | : | Volcanic breccia, tuffaceous sandstone, andesit |
| Spillway Foundation | : | Volcanic breccia |
| Diversion Foundation | : | Volcanic breccia |

| | | |
|---|---|---|
| Dam Name | : | Bener |
| Province | : | Jawa Tengah |
| Regency | : | Purworejo |
| Coordinate | : | 7° 35' 54,59" S<br>110° 1'12,84" E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Congcrete faced rock-filled dam (CRFD) |
| Height | : | 169.0 m |
| Elevation of crest | : | +356.00 m |
| Elevation base foundation | : | +187.0 m |
| Wide of crest | : | 12.0 m |
| Lenght of crest | : | 534.0 m |
| Upstream slope | : | 1 : 1.5 |
| Downstream slope | : | 1 : 1.4 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +350.00 m |
| Elv. of low water level (LWL) | : | +260.00 m |
| Elv. of flood water level Q1000 | : | – |
| Elv. of flood water level QPMF | : | +354.62 m |
| Normal storage capacity | : | 81.65 million m³ |
| Dead storage capacity | : | 13.31 million m³ |
| Effective storage capacity | : | 68.34 million m³ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 273.83 m³/s |
| 10 year return period | : | 326.77 m³/s |
| 25 year old return period | : | 410.18 m³/s |
| 50 year return period | : | 463.25 m³/s |
| 100 year return period | : | 531.70 m³/s |
| 1000 year return period | : | 807.64 m³/s |
| PMF return period | : | 2008.88 m³/s |

**Intake**

| | | |
|---|---|---|
| Type | : | inclined intake |
| Height | : | 133.9 m |
| Intake inlet elevation | : | +225.0 m |
| Gate dimension | : | 1.4 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | free overflow, ogee |
| Length | : | 506.6 m |
| Wide threshold | : | 90.0 m |
| Crest threshold elevation | : | +350.00 m |
| Stilling Basin type | : | USBR type II |

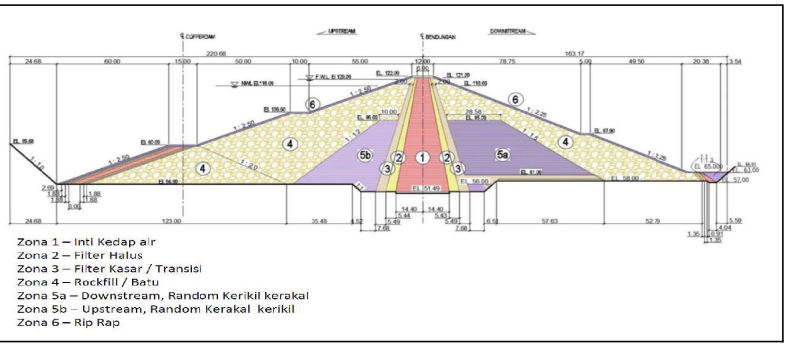
**Diversion**

| | | |
|---|---|---|
| Location | : | Right abutment |
| Type | : | Tunnel |
| Length | : | 849.44 m |
| Dimensions | : | 7.0 m |
| U/S elevation | : | +225.0 m |
| D/S elevation | : | +220.0 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Kebobutak |
| Rock/soil | : | andesitic breccia, tuff breccia, tuff, andesit lava |
| Rock Class (CRIEPI) | : | CL, CM, CH |
| Main Dam Foundation | : | andesitic breccia, tuff |
| Spillway Foundation | : | andestic breccia |
| Diversion Foundation | : | andesitic breccia |

| | | |
|---|---|---|
| Dam Name | : | Beringin Sila |
| Province | : | Nusa Tenggara Barat |
| Regency | : | Sumbawa |
| Coordinate | : | 8° 27'43,77" S<br>117° 7'21.17" E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal with central core |
| Height | : | 70.5 m |
| Elevation of crest | : | +122.0 m |
| Elevation base foundation | : | +42.0 m |
| Wide of crest | : | 12.0 m |
| Lenght of crest | : | 787.58 m |
| Upstream slope | : | 1:2.50 |
| Downstream slope | : | 1:2.25 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +116.0 m |
| Elv. of low water level (LWL) | : | +95.0 m |
| Elv. of flood water level Q1000 | : | +118.21 m |
| Elv. of flood water level QPMF | : | +120.08 m |
| Normal storage capacity | : | 27.46 million m³ |
| Dead storage capacity | : | 6.00 million m³ |
| Effective storage capacity | : | 20.72 million m³ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 177.72 m³/s |
| 10 year return period | : | 216.98 m³/s |
| 25 year old return period | : | 269.15 m³/s |
| 50 year return period | : | 309.95 m³/s |
| 100 year return period | : | 354.42 m³/s |
| 1000 year return period | : | 512.19 m³/s |
| PMF return period | : | 1,290.15 m³/s |

*source: PT. Indra Karya, 2019

**Intake**

| | | |
|---|---|---|
| Type | : | vertical Tower shaft |
| Dimensions / size | : | ϕ 3 m |
| Intake inlet elevation | : | +95.00 m |
| Tower Height | : | 27 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side Channel |
| Length | : | 511 m |
| Wide threshold | : | 60.0 m |
| Crest threshold elevation | : | +116.0 m |
| Transition channel slope | : | 1 : 2000 |

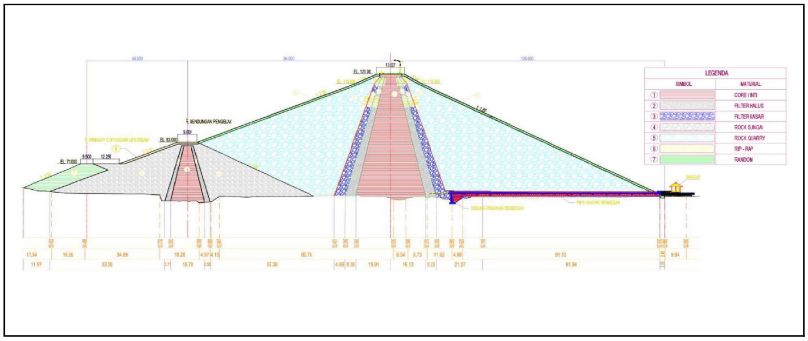
**Diversion**

| | | |
|---|---|---|
| Location | : | Left abutment |
| Type | : | Tunnel |
| Length | : | 700.0 m |
| Dimensions | : | 5.5 m, horseshoe |
| U/S elevation | : | +69.00 m |
| D/S elevation | : | +68.00 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | andesitic-basaltic breccia |
| Rock/soil | : | volcanic breccia, lahar, tuff, lava, volcanic ash |
| Rock Class (CRIEPI) | : | CL, CM, CH |
| Main Dam Foundation | : | Lapilli tuff, volcanic breccia |
| Spillway Foundation | : | Lapilli tuff, volcanic breccia, aglomerate |
| Diversion Foundation | : | Tuff breccia |

| | | |
|---|---|---|
| Dam Name | : | Bintang Bano |
| Province | : | Nusa Tenggara Barat |
| Regency | : | Sumbawa Barat |
| Coordinate | : | 8° 42'53.00" S<br>116° 59'14.89" E |



**Main Dam**

| | | |
|---|---|---|
| Type | : | Rock-filled dam with central core |
| Height | : | 72.0 m |
| Elevation of crest | : | +120.0 m |
| Elevation base foundation | : | +56.0 m |
| Wide of crest | : | 13.0 m |
| Lenght of crest | : | 471.0 m |
| Upstream slope | : | 1:2.25 |
| Downstream slope | : | 1:1.80 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +115.5 m |
| Elv. of low water level (LWL) | : | +85.07 m |
| Elv. of flood water level Q1000 | : | +118.00 m |
| Elv. of flood water level QPMF | : | +119.49 m |
| Normal storage capacity | : | 69.31 million $m^3$ |
| Dead storage capacity | : | 12.58 million $m^3$ |
| Effective storage capacity | : | 56.73 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 400.2 $m^3/s$ |
| 10 year return period | : | 499.4 $m^3/s$ |
| 25 year old return period | : | 616.9 $m^3/s$ |
| 50 year return period | : | 698.2 $m^3/s$ |
| 100 year return period | : | 780.3 $m^3/s$ |
| 1000 year return period | : | 1035.4 $m^3/s$ |
| PMF return period | : | 2735.5 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | vertical tower |
| Height | : | 28 m |
| Intake inlet elevation | : | +58.78 m |
| Gate dimension | : | 5 x 5 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | side channel and gated spillway |
| Length | : | 317.93 and 260 m |
| Wide threshold | : | 20 m and 16 m |
| Crest threshold elevation | : | +115.5m & +106.0 m |
| Stilling Basin type | : | – |

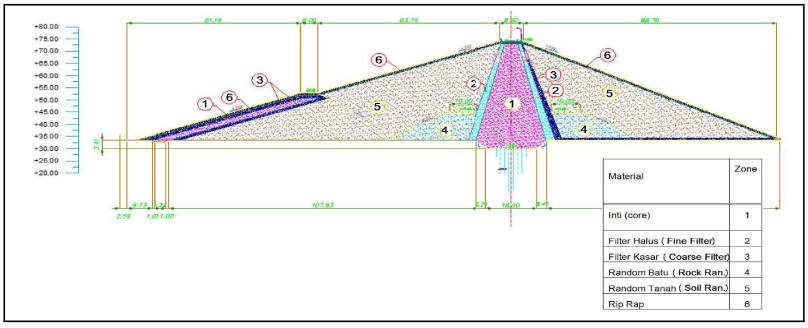
**Diversion**

| | | |
|---|---|---|
| Location | : | Left abutment |
| Type | : | Tunnel |
| Length | : | 354 .0 m |
| Dimensions | : | 5 m |
| U/S elevation | : | – |
| D/S elevation | : | – |

**Geology**

| | | |
|---|---|---|
| Formation | : | Tuff Breccia unit |
| Rock/soil | : | Tuff breccia, limestone and andesit intrusion |
| Rock Class (CRIEPI) | : | CM, CH |
| Main Dam Foundation | : | Tuff breccia, limestone and andesit intrusion |
| Spillway Foundation | : | Tuff breccia, limestone |
| Diversion Foundation | : | andesit intrusion |

| | | |
|---|---|---|
| Dam Name | : | Budong Budong |
| Province | : | Sulawesi Barat |
| Regency | : | Mamuju Tengah |
| Coordinate | : | 119°27'16" E<br>2°01'0.6" S |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal earth-filled Dam |
| Height | : | 44 m |
| Elevation of crest | : | + 74.0 m |
| Elevation base foundation | : | + 30.0 m |
| Wide of crest | : | 8.5 m |
| Lenght of crest | : | 291.0 m |
| Upstream slope | : | 1:3 |
| Downstream slope | : | 1:2.25 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +70.0 m |
| Elv. of low water level (LWL) | : | + 52.4 m |
| Elv. of flood water level Q1000 | : | +71.25 m |
| Elv. of flood water level QPMF | : | + 72.19 m |
| Normal storage capacity | : | 57.26 million $m^3$ |
| Dead storage capacity | : | 10.72 million $m^3$ |
| Effective storage capacity | : | 46.54 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 291.17 $m^3/s$ |
| 10 year return period | : | 315.76 $m^3/s$ |
| 25 year old return period | : | 341.59 $m^3/s$ |
| 50 year return period | : | 357.95 $m^3/s$ |
| 100 year return period | : | 372.36 $m^3/s$ |
| 1000 year return period | : | 410.85 $m^3/s$ |
| PMF return period | : | 698.87 $m^3/s$ |

DED PT. Mettana 2017

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Tower height | : | – |
| Intake inlet elevation | : | + 496.00 m |
| Gate dimension | : | 2.0 x 2.5 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side Channel |
| Length | : | 252.71 m |
| Wide threshold | : | 70.0 m |
| Crest threshold elevation | : | +70.0 m |
| Stilling Basin type | : | USBR type III |

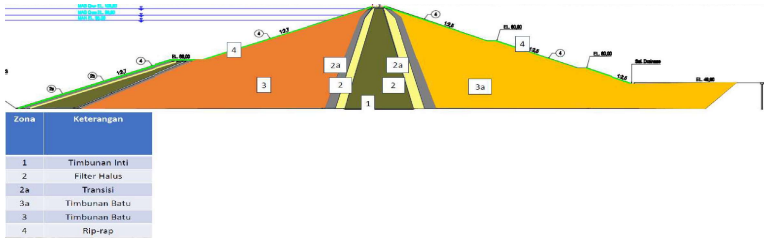
**Diversion**

| | | |
|---|---|---|
| Location | : | Left abutment |
| Type | : | Tunnel |
| Length | : | – |
| Dimensions | : | 5.0 m (diameter) |
| U/S elevation | : | + 35.5 m |
| D/S elevation | : | + 32.5 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Lamasi |
| Rock/soil | : | Alluvium, breccia |
| Rock Class (CRIEPI) | : | D,CL, CH |
| Main Dam Foundation | : | Alluvium, breccia |
| Spillway Foundation | : | Breccia |
| Diversion Foundation | : | Breccia |

| | | |
|---|---|---|
| Dam Name | : | Bulango Ulu |
| Province | : | Gorontalo |
| Regency | : | Bone Bolango |
| Coordinate | : | 0° 39' 32" N<br>123° 05' 51" E |



| Zona | Keterangan |
|---|---|
| 1 | Timbunan Inti |
| 2 | Filter Halus |
| 2a | Transisi |
| 3a | Timbunan Batu |
| 3 | Timbunan Batu |
| 4 | Rip-rap |

**Main Dam**

| | | |
|---|---|---|
| Type | : | Rock Fill Dam with Cental Core |
| Height | : | 75 m |
| Elevation of crest | : | + 105.0 m |
| Elevation base foundation | : | + 30.0 m |
| Wide of crest | : | 11 m |
| Lenght of crest | : | 358.75 m |
| Upstream slope | : | 1:2.7 |
| Downstream slope | : | 1:2.5 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | + 95.0 m |
| Elv. of low water level (LWL) | : | + 78.0 m |
| Elv. of flood water level Q1000 | : | – |
| Elv. of flood water level QPMF | : | + 103.83 m |
| Normal storage capacity | : | 84.1 million $m^3$ |
| Dead storage capacity | : | 24.47 million $m^3$ |
| Effective storage capacity | : | 59.63 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | – |
| 10 year return period | : | – |
| 25 year old return period | : | – |
| 50 year return period | : | 489.5 $m^3/s$ |
| 100 year return period | : | |
| 1000 year return period | : | 909.2 $m^3/s$ |
| PMF return period | : | 3013.2 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Tower height | : | 47 m |
| Intake inlet elevation | : | + 78.0 m |
| Gate dimension | : | 1.8 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Free Over Flow Elevated |
| Length | : | 360 m (tunnel) |
| Wide threshold | : | 8 m |
| Crest threshold elevation | : | + 95.0 m & + 97.5 m |
| Stilling Basin type | : | USBR Tipe III |

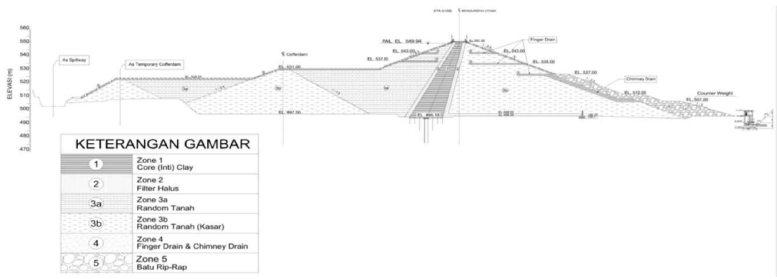
**Diversion**

| | | |
|---|---|---|
| Location | : | Left Abutment |
| Type | : | Tunnel |
| Length | : | 477.0 m |
| Dimensions | : | 7.0 m |
| U/S elevation | : | + 51.0 m |
| D/S elevation | : | + 45.0 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Diorite Bone |
| Rock/soil | : | Diorite, Granodiorite, Granite, andesite |
| Rock Class (CRIEPI) | : | CL, CM, CH |
| Main Dam Foundation | : | Diorite, Granodiorite, Granite, andesite |
| Spillway Foundation | : | Diorite, Granodiorite, Granite, andesite |
| Diversion Foundation | : | Diorite, Granodiorite, Granite, andesite |

| | | |
|---|---|---|
| Dam Name | : | Ciawi |
| Province | : | Jawa Barat |
| Regency | : | Bogor |
| Coordinate | : | 6° 39'26.44"S<br>106° 52'49.93"E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal with inclined core |
| Height | : | 55 m |
| Elevation of crest | : | +551.0 m |
| Elevation base foundation | : | +496.0 m |
| Wide of crest | : | 9.0 m |
| Lenght of crest | : | 334.5 m |
| Upstream slope | : | 1:2.3 |
| Downstream slope | : | 1:2.3 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +546.75 m |
| Elv. of low water level (LWL) | : | – |
| Elv. of flood water level Q1000 | : | +547.40 m |
| Elv. of flood water level QPMF | : | +549.94 m |
| Normal storage capacity | : | – |
| Dead storage capacity | : | – |
| Effective storage capacity | : | 5.03 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 242.86 $m^3/s$ |
| 10 year return period | : | 281.59 $m^3/s$ |
| 25 year old return period | : | 330.70 $m^3/s$ |
| 50 year return period | : | 365.00 $m^3/s$ |
| 100 year return period | : | 403.00 $m^3/s$ |
| 1000 year return period | : | 524.10 $m^3/s$ |
| PMF return period | : | 1242.96 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | – |
| Tower height | : | – |
| Intake inlet elevation | : | – |
| Gate dimension | : | – |

**Spillway**

| | | |
|---|---|---|
| Type | : | side channel |
| Length | : | 334.0 m |
| Wide threshold | : | 62.0 m |
| Crest threshold elevation | : | +546.75 m |
| Stilling Basin type | : | – |

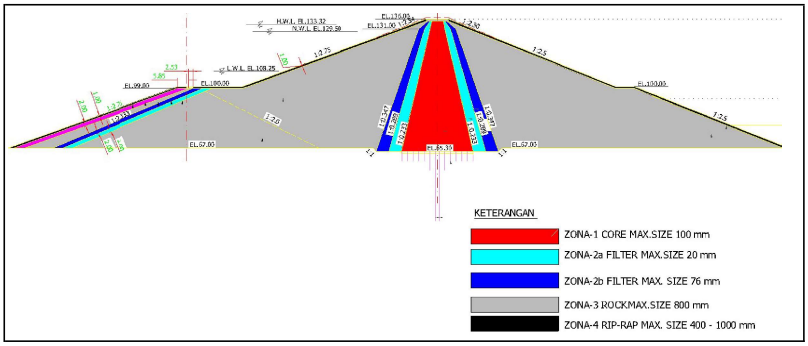
**Diversion**

| | | |
|---|---|---|
| Location | : | Right abutment |
| Type | : | Conduit |
| Length | : | 398.0 m |
| Dimensions | : | 2x4, 2 linement |
| U/S elevation | : | +504.2 m |
| D/S elevation | : | – |

**Geology**

| | | |
|---|---|---|
| Formation | : | Pangrango volcanic and alluvium fan |
| Rock/soil | : | tuff–lapilli, breccia, breccia sandstone–intercalated |
| Rock Class (CRIEPI) | : | D, CL, CM |
| Main Dam Foundation | : | tuff–lapilli, breccia |
| Spillway Foundation | : | tuff–lapilli, breccia, breccia sandstone–intercalated |
| Diversion Foundation | : | breccia, breccia sandstone–intercalated |

| | | |
|---|---|---|
| Dam Name | : | Cipanas |
| Province | : | Jawa Barat |
| Regency | : | Sumedang |
| Coordinate | : | 6° 39' 51,33" S<br>108° 1' 40,18" E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Rock-filled dam with central core |
| Height | : | 71.7 m |
| Elevation of crest | : | +136.00 m |
| Elevation base foundation | : | + 64.3 m |
| Wide of crest | : | 12 m |
| Lenght of crest | : | 355.54 m |
| Upstream slope | : | 1:2.75 |
| Downstream slope | : | 1:2.5 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | + 129.5 m |
| Elv. of low water level (LWL) | : | + 108.25 m |
| Elv. of flood water level Q1000 | : | no data |
| Elv. of flood water level QPMF | : | +133.32 m |
| Normal storage capacity | : | 250.81 million m3 |
| Dead storage capacity | : | 42.17 million m3 |
| Effective storage capacity | : | 190.52 million m3 |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 199.60 m3/sec |
| 10 year return period | : | 227,00 m3/sec |
| 25 year old return period | : | 252,90 m3/sec |
| 50 year return period | : | 259,60 m3/sec |
| 100 year return period | : | 281,30 m3/sec |
| 1000 year return period | : | 354,30 m3/sec |
| PMF return period | : | 831,60 m3/sec |

**Intake**

| | | |
|---|---|---|
| Type | : | shaft |
| Dimensions / size | : | 2.5 m |
| Intake inlet elevation | : | +104.00 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side channel |
| Length | : | 186.51 m |
| Wide threshold | : | 40.00 m |
| Crest threshold elevation | : | + 129.50 m |
| Downstream slope of mercu | : | 1:10 |

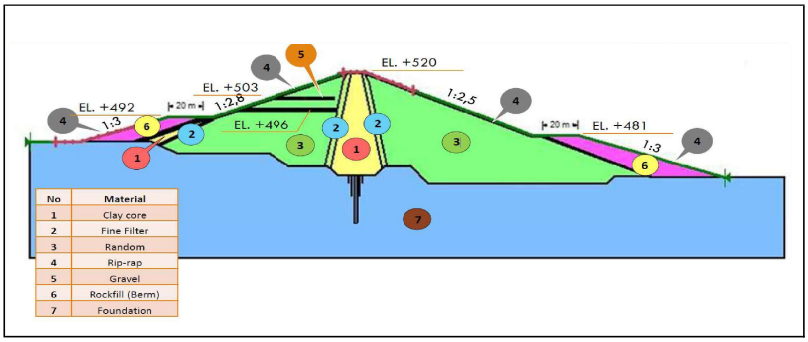
**Diversion**

| | | |
|---|---|---|
| Location | : | Right Bank |
| Type | : | Conduit |
| Length | : | 399.81 m |
| Dimensions | : | 5.00 m |
| U/S elevation | : | +70.92 m |
| D/S elevation | : | +70.00 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Citalang |
| Rock/soil | : | Conglemerate, breccia, sandstone |
| Rock Class (CRIEPI) | : | D, CL, CM |
| Main Dam Foundation | : | Breccia, tuff, sandstone |
| Spillway Foundation | : | tuf. sandstone, tuff, sandstone |
| Diversion Foundation | : | Breccia, tuff, sandstone |

| | | |
|---|---|---|
| Dam Name | : | Gondang |
| Province | : | Jawa Tengah |
| Regency | : | Karanganyar |
| Coordinate | : | 110° 40'-110° 70' E<br>7° 28'-7° 46' S |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal random filled with central core |
| Height | : | 71.0 m |
| Elevation of crest | : | +520.0 m |
| Elevation base foundation | : | +449.0 m |
| Wide of crest | : | 10.5 m |
| Lenght of crest | : | 604.0 m |
| Upstream slope | : | 1:2.8 |
| Downstream slope | : | 1:2.5 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +515.0 m |
| Elv. of low water level (LWL) | : | +496.0 m |
| Elv. of flood water level Q1000 | : | – |
| Elv. of flood water level QPMF | : | +517.89 m |
| Normal storage capacity | : | 9.15 million $m^3$ |
| Dead storage capacity | : | 2.09 million $m^3$ |
| Effective storage capacity | : | 7.06 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 124 $m^3/s$ |
| 10 year return period | : | 158.5 $m^3/s$ |
| 25 year old return period | : | 207.3 $m^3/s$ |
| 50 year return period | : | 244.7 $m^3/s$ |
| 100 year return period | : | 286.5 $m^3/s$ |
| 1000 year return period | : | 450.4 $m^3/s$ |
| PMF return period | : | 678.4 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| base foundation elevation | : | +460.6 m |
| Intake inlet elevation | : | +496.0 m |
| Gate dimension | : | 2.5 x 2.5 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side channel overflow |
| Length | : | 443 m |
| Wide threshold | : | 45 m |
| Crest threshold elevation | : | +515.0 m |
| Stilling Basin type | : | – |

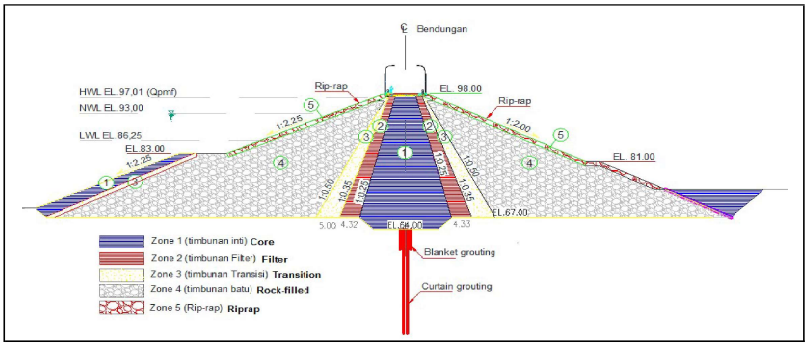
**Diversion**

| | | |
|---|---|---|
| Location | : | Left of river bank |
| Type | : | Conduit |
| Length | : | 393.0 m |
| Dimensions | : | 2.5 x 2.5 m |
| U/S elevation | : | +472.0 m |
| D/S elevation | : | +452.0 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Lawu Volcanic |
| Rock/soil | : | Terace, colluvium, tuff-lapilli, volcanic breccia |
| Rock Class (CRIEPI) | : | CL, CM, CH |
| Main Dam Foundation | : | tuff-lapilli volcanic breccia |
| Spillway Foundation | : | Volcanic breccia |
| Diversion Foundation | : | Volcanic breccia |

| | | |
|---|---|---|
| Dam Name | : | Gongseng |
| Province | : | Jawa Timur |
| Regency | : | Bojonegoro |
| Coordinate | : | 8° 27'43.77" S<br>117° 7'21.17" E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Rock–filled dam with central core |
| Height | : | 34.0 m |
| Elevation of crest | : | +98.0 m |
| Elevation base foundation | : | +64.0 m |
| Wide of crest | : | 9.0 m |
| Lenght of crest | : | 422.0 m |
| Upstream slope | : | 1:2.25 |
| Downstream slope | : | 1:2.00 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +93.00 m |
| Elv. of low water level (LWL) | : | +86.25 m |
| Elv. of flood water level Q1000 | : | +95.07 m |
| Elv. of flood water level QPMF | : | +97.01 m |
| Normal storage capacity | : | 22.43 million m3 |
| Dead storage capacity | : | 7.68 million m3 |
| Effective storage capacity | : | 14.75 million m3 |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 236.86 $m^3$/sec |
| 10 year return period | : | – |
| 25 year old return period | : | 319.63 $m^3$/sec |
| 50 year return period | : | 355.13 $m^3$/sec |
| 100 year return period | : | 391.27 $m^3$/sec |
| 1000 year return period | : | 528.71 $m^3$/sec |
| PMF return period | : | 1322.38 $m^3$/sec |

**Intake**

| | | |
|---|---|---|
| Type | : | ungated, submarge tower |
| Dimensions / size | : | 1.75X1.75 m |
| Intake inlet elevation | : | +86.25 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side channel |
| Length | : | 325.1 |
| Wide threshold | : | 55.0 m |
| Crest threshold elevation | : | +93.00 m |
| Stilling basin type | : | Modified USBR III |

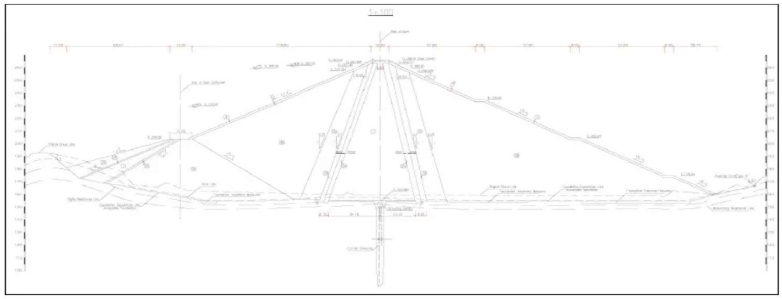
**Diversion**

| | | |
|---|---|---|
| Location | : | Right river bank |
| Type | : | conduit |
| Length | : | 210 m |
| Dimensions | : | 2@ 3.5x3.5 m |
| U/S elevation | : | +70.8 m |
| D/S elevation | : | +70.0 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Klitik and Kalibeng |
| Rock/soil | : | calcarenite, marl |
| Rock Class (CRIEPI) | : | D, CL, CM |
| Main Dam Foundation | : | calcarenite, marl |
| Spillway Foundation | : | calcarenite, marl |
| Diversion Foundation | : | marl |

| | | |
|---|---|---|
| Dam Name | : | Jatigede |
| Province | : | Jawa Barat |
| Regency | : | Sumedang |
| Coordinate | : | 6° 51'23.42"S<br>108° 5'47.72"E |



**Main Dam**

| | | |
|---|---|---|
| Type | : | Rock filled with vertical core |
| Height | : | 110.0 m |
| Elevation of crest | : | +265.0 m |
| Elevation base foundation | : | – |
| Wide of crest | : | 12.0 m |
| Lenght of crest | : | 1715.0 m |
| Upstream slope | : | 1:2 |
| Downstream slope | : | 1:1.9 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +260.0 m |
| Elv. of low water level (LWL) | : | +230.0 m |
| Elv. of flood water level Q1000 | : | – |
| Elv. of flood water level QPMF | : | +262.0 m |
| Normal storage capacity | : | 980 million $m^3$ |
| Dead storage capacity | : | 103 million $m^3$ |
| Effective storage capacity | : | 877 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | – |
| 10 year return period | : | – |
| 25 year old return period | : | – |
| 50 year return period | : | – |
| 100 year return period | : | 2968 $m^3$/s |
| 1000 year return period | : | 4316 $m^3$/s |
| PMF return period | : | 4422 $m^3$/s |

**Intake**

| | | |
|---|---|---|
| Type | : | Reinforced concrete conduit |
| Location | : | under spillway |
| Intake inlet elevation | : | + 221.0 m |
| Gate dimension | : | D = 4.5 m; L = 400 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | gated with chute way |
| Length | : | 330.0 m |
| Wide threshold | : | 50.0 m |
| Crest threshold elevation | : | +247.0 m |
| Stilling Basin type | : | Plunge pool |

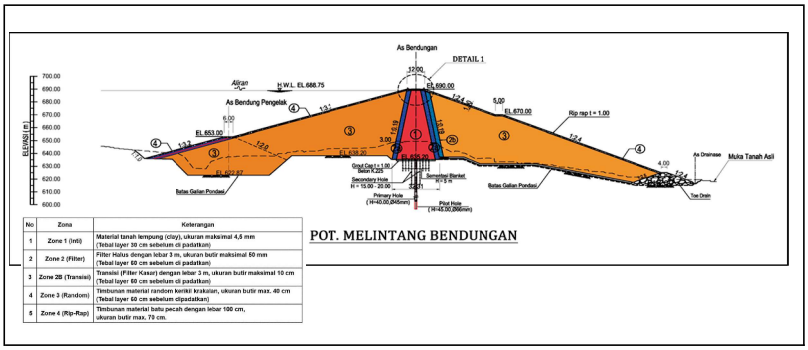
**Diversion**

| | | |
|---|---|---|
| Location | : | Under spillway |
| Type | : | tunnel |
| Length | : | 556.0 m |
| Dimensions | : | 10.0 m diameter |
| U/S elevation | : | +164.0 m |
| D/S elevation | : | – |

**Geology**

| | | |
|---|---|---|
| Formation | : | volcanit, halang |
| Rock/soil | : | Breccia, claystone |
| Rock Class (CRIEPI) | : | – |
| Main Dam Foundation | : | Breccia, claystone |
| Spillway Foundation | : | Breccia, claystone |
| Diversion Foundation | : | Breccia, claystone |

| | | |
|---|---|---|
| Dam Name | : | Jlantah |
| Province | : | Jawa Tengah |
| Regency | : | Karanganyar |
| Coordinate | : | 7°42' 44,05" S<br>111°4' 47,51" E |




| No | Zona | Keterangan |
|---|---|---|
| 1 | Zone 1 (Inti) | Material tanah lempung (clay), ukuran maksimal 4,8 mm (Tebal layer 30 cm sebelum di padatkan) |
| 2 | Zone 2 (Filter) | Filter Halus dengan lebar 3 m, ukuran butir maksimal 50 mm (Tebal layer 60 cm sebelum di padatkan) |
| 3 | Zone 2B (Transisi) | Transisi (Filter Kasar) dengan lebar 3 m, ukuran butir maksimal 10 cm (Tebal layer 60 cm sebelum di padatkan) |
| 4 | Zone 3 (Random) | Timbunan material random kerikil krakalan, ukuran butir max. 40 cm (Tebal layer 60 cm sebelum dipadatkan) |
| 5 | Zone 4 (Rip-Rap) | Timbunan material batu pecah dengan lebar 100 cm, ukuran butir max. 70 cm. |

**Main Dam**

| | | |
|---|---|---|
| Type | : | Gravel Pebble Random, Central Core |
| Height | : | 70 m |
| Elevation of crest | : | + 690 m |
| Elevation base foundation | : | + 620 m |
| Wide of crest | : | 12 m |
| Lenght of crest | : | 404 m |
| Upstream slope | : | 1:3.2 |
| Downstream slope | : | 1:2.4 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | + 685.00 m |
| Elv. of low water level (LWL) | : | + 662.00 m |
| Elv. of flood water level Q1000 | : | '+ – m |
| Elv. of flood water level QPMF | : | '+ – m |
| Normal storage capacity | : | 10.97 million m3 |
| Dead storage capacity | : | 2.67 million m3 |
| Effective storage capacity | : | 8.30 million m3 |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 88.90 $m^3$/sec |
| 10 year return period | : | 103.73 $m^3$/sec |
| 25 year old return period | : | 125.57 $m^3$/sec |
| 50 year return period | : | 144.29 $m^3$/sec |
| 100 year return period | : | 165.30 $m^3$/sec |
| 1000 year return period | : | 256.61 $m^3$/sec |
| PMF return period | : | 477.69 $m^3$/sec |

**Intake**

| | | |
|---|---|---|
| Type | : | Shafts |
| Dimensions / size | : | 2.0 m |
| Location | : | righ abutment |
| Intake inlet elevation | : | + 661.00 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Ogee |
| Length | : | 221.0 m |
| Wide threshold | : | 25.0 m |
| Crest threshold elevation | : | +685.00 m |
| Stilling basin type | : | USBR type II |

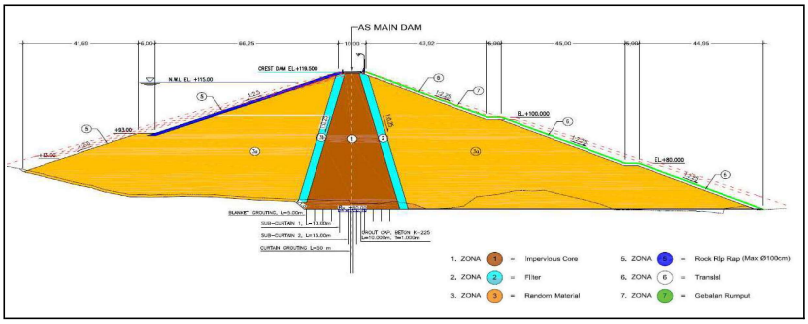
**Diversion**

| | | |
|---|---|---|
| Location | : | right bank |
| Type | : | conduit & tunnel |
| Length | : | 167.0 m & 223.7 |
| Dimensions | : | 4.2 m |
| U/S elevation | : | +635.00 m |
| D/S elevation | : | +618.00 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Lahar, lava |
| Rock/soil | : | andesit, basalt, breccia, lahar |
| Rock Class (CRIEPI) | : | CL and CM |
| Main Dam Foundation | : | tuff, lapilli, aglomerate, breccia |
| Spillway Foundation | : | tuff, aglomerate, breccia |
| Diversion Foundation | : | tuff, lapilli, breccia |

| | | |
|---|---|---|
| Dam Name | : | Jragung |
| Province | : | Jawa Tengah |
| Regency | : | Semarang |
| Coordinate | : | 7° 8'52.22"S<br>110° 32'37.07"E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal with centre core |
| Height | : | 59.5 m |
| Elevation of crest | : | +119.5 m |
| Elevation base foundation | : | +60.0 m |
| Wide of crest | : | 10.0 m |
| Lenght of crest | : | 1.350 m |
| Upstream slope | : | 1 : 3.0 |
| Downstream slope | : | 1 : 2.5 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | + 115.00 m |
| Elv. of low water level (LWL) | : | + 93.00 m |
| Elv. of flood water level Q1000 | : | + 117.28 m |
| Elv. of flood water level QPMF | : | + 118.65 m |
| Normal storage capacity | : | 90 juta m3 |
| Dead storage capacity | : | 21 juta m3 |
| Effective storage capacity | : | 69 juta m3 |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 179.87 $m^3$/s |
| 10 year return period | : | 220.99 $m^3$/s |
| 25 year old return period | : | 278.76 $m^3$/s |
| 50 year return period | : | 326.39 $m^3$/s |
| 100 year return period | : | 378.18 $m^3$/s |
| 1000 year return period | : | 822.27 $m^3$/s |
| PMF return period | : | 1580.3 $m^3$/s |

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Tower height | : | 40.5 m |
| Intake inlet elevation | : | + 82.00 m |
| Gate dimension | : | Ø1.8 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | free overflow |
| Length | : | 403.89 m |
| Wide threshold | : | 60 m |
| Crest threshold elevation | : | + 115 m |
| Stilling Basin type | : | USBR Tipe II |

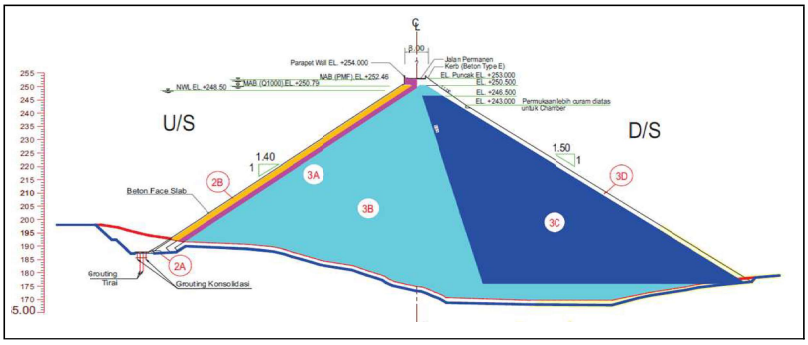
**Diversion**

| | | |
|---|---|---|
| Location | : | Right abutment |
| Type | : | tunnel and open chanel |
| Length | : | 1,315 m |
| Dimensions | : | 5,3 m & 10x3,5 m |
| U/S elevation | : | + 67.0 m |
| D/S elevation | : | + 60.0 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Kalibeng |
| Rock/soil | : | Claystone, siltstone, sandstone |
| Rock Class (CRIEPI) | : | D, CL, CM |
| Main Dam Foundation | : | Claystone, siltstone, sandstone |
| Spillway Foundation | : | Claystone, siltstone, sandstone |
| Diversion Foundation | : | Claystone, siltstone, sandstone |

| | | |
|---|---|---|
| Dam Name | : | Karralloe |
| Province | : | Sulawesi Selatan |
| Regency | : | Gowa |
| Coordinate | : | 119°48 ' 11 ,8" E<br>5° 30 ' 54 ,6" S |




| Main Dam | | |
|---|---|---|
| Type | : | Concrete face rock-filled Dam (CRFD) |
| Height | : | 85 .0 m |
| Elevation of crest | : | +253.0 m |
| Elevation base foundation | : | – |
| Wide of crest | : | 10.0 m |
| Lenght of crest | : | 398.0 m |
| Upstream slope | : | 1:1.4 |
| Downstream slope | : | 1:1.5 |

| RESERVOIR | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +248.5 m |
| Elv. of low water level (LWL) | : | – |
| Elv. of flood water level Q1000 | : | +250.75 m |
| Elv. of flood water level QPMF | : | +252.46 m |
| Normal storage capacity | : | 40.5 million $m^3$ |
| Dead storage capacity | : | 11.0 million $m^3$ |
| Effective storage capacity | : | 29.5 million $m^3$ |

| Hidrological Discharge | | |
|---|---|---|
| 5 year return period | : | 330.9 $m^3/s$ |
| 10 year return period | : | 441.9 $m^3/s$ |
| 25 year old return period | : | 596.5 $m^3/s$ |
| 50 year return period | : | 721 $m^3/s$ |
| 100 year return period | : | 847.5 $m^3/s$ |
| 1000 year return period | : | 1345.7 $m^3/s$ |
| PMF return period | : | 2202.6 $m^3/s$ |

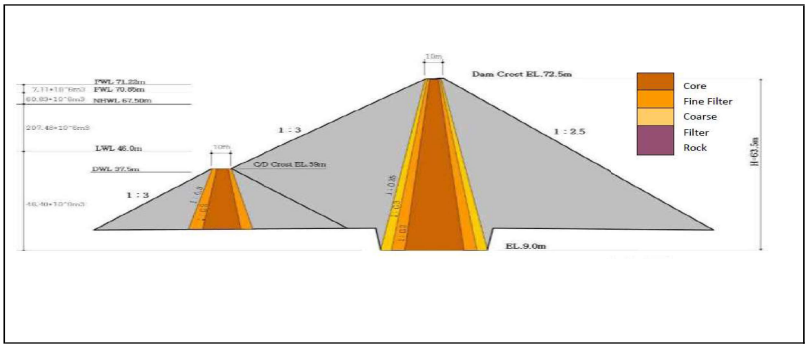
| Intake | | |
|---|---|---|
| Type | : | Tower |
| Tower height | : | 31.5 m |
| Intake inlet elevation | : | +173.0 m |
| Gate dimension | : | 2.5 m |

| Spillway | | |
|---|---|---|
| Type | : | Side chanel, ungated |
| Length | : | – |
| Wide threshold | : | 100 m |
| Crest threshold elevation | : | +248.5 m |
| Stilling Basin type | : | flip bucket and plunge pool |

| Diversion | | |
|---|---|---|
| Location | : | Right Abutment |
| Type | : | Tunnel |
| Length | : | 539.0 m |
| Dimensions | : | 6.0 m diameter |
| U/S elevation | : | +182. m |
| D/S elevation | : | +172. m |

| Geology | | |
|---|---|---|
| Formation | : | Lampobatang volcanic, Baturape-Cindako Volcanic |
| Rock/soil | : | Volcanic breccia, andesitic lava, tuff breccia |
| Rock Class (CRIEPI) | : | CM.CH.B |
| Main Dam Foundation | : | Volcanic breccia, andesitic lava, tuff breccia |
| Spillway Foundation | : | Volcanic breccia, andesitic lava |
| Diversion Foundation | : | andesitic lava |

| | | |
|---|---|---|
| Dam Name | : | Karian |
| Province | : | Banten |
| Regency | : | Lebak |
| Coordinate | : | 105°48' E<br>7° 10' S |




| Main Dam | | |
|---|---|---|
| Type | : | Central Cored Rockfill Dam |
| Height | : | 65.6 m |
| Elevation of crest | : | +72.5 m |
| Elevation base foundation | : | – |
| Wide of crest | : | 10.0 m |
| Lenght of crest | : | 514. 72 m |
| Upstream slope | : | 1:3.0 |
| Downstream slope | : | 1:2.5 |

| RESERVOIR | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +67.50 m |
| Elv. of low water level (LWL) | : | +46.00 m |
| Elv. of flood water level Q1000 | : | +70.85 m |
| Elv. of flood water level QPMF | : | + 71.22 m |
| Normal storage capacity | : | 314.71 mil.m3 |
| Dead storage capacity | : | 46.40 mil.m3 |
| Effective storage capacity | : | 207.48 mil.m3 |

| Hidrological Discharge | | |
|---|---|---|
| 5 year return period | : | – |
| 10 year return period | : | 615 m3/sec |
| 20 year old return period | : | 775 m3/sec |
| 50 year return period | : | 890 m3/sec |
| 100 year return period | : | 1010 m3/sec |
| 1000 year return period | : | 1421 m3/sec |
| PMF return period | : | 3671 m3/sec |

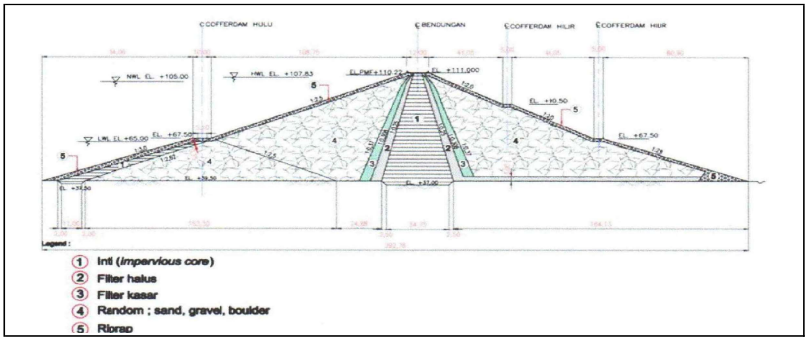
| Intake | | |
|---|---|---|
| Type | : | Steel roller gate |
| Dimensions / size | : | 2.5x2.5 m |
| Number of gate | : | 4 |
| Intake inlet elevation | : | +39.5m, +46m, +52.9m,+59m |

| Spillway | | |
|---|---|---|
| Type | : | side channel spillway. Ogee |
| Length | : | 162.12 m |
| Wide threshold | : | 50m/25m (chanel/ogee) |
| Crest threshold elv. (chanel) | : | +67.50 m |
| Crest threshold elv. (ogeel) | : | +57.50 m |

| Diversion | | |
|---|---|---|
| Location | : | right side of the dam |
| Type | : | tunnel |
| Length | : | 512.6 m |
| Dimensions | : | 4.5 m |
| U/S elevation | : | +20 m |
| D/S elevation | : | +19 m |

| Geology | | |
|---|---|---|
| Formation | : | Genteng Formation (Tpg) |
| Rock/soil | : | tuff, lapilli, sandsotne, breccia |
| Rock Class (CRIEPI) | : | D, CL, CM |
| Main Dam Foundation | : | Sandstone, conlomerate |
| Spillway Foundation | : | Sandstone, conlomerate, claystone, lapilli pucmice |
| Diversion Foundation | : | sandstone, lapilli, tuff |

| | | |
|---|---|---|
| Dam Name | : | Keureuto |
| Province | : | Aceh |
| Regency | : | Aceh Utara |
| Coordinate | : | 4° 56'12.26"N<br>97° 9'1.82" E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal random rock with central core |
| Height | : | 74.0 m |
| Elevation of crest | : | +107.5 m |
| Elevation base foundation | : | +33.5 m |
| Wide of crest | : | 12.0 m |
| Lenght of crest | : | 400.0 m |
| Upstream slope | : | 1:2.5 |
| Downstream slope | : | 1:2.5 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +101.51 m |
| Elv. of low water level (LWL) | : | +73.43 m |
| Elv. of flood water level Q1000 | : | +103.86 m |
| Elv. of flood water level QPMF | : | +106,32 m |
| Normal storage capacity | : | 215.94 $m^3$ |
| Dead storage capacity | : | 33.95 $m^3$ |
| Effective storage capacity | : | 167.22 $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | – |
| 10 year return period | : | – |
| 25 year old return period | : | 707.78 $m^3/s$ |
| 50 year return period | : | – |
| 100 year return period | : | 842.67 $m^3/s$ |
| 1000 year return period | : | 1039,77 $m^3/s$ |
| PMF return period | : | 2680.88 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Drop inlet |
| Operatin discharge | : | 14.6 $m^3/s$ |
| Intake inlet elevation | : | +69.68 m |
| Gate dimension | : | 2.5 x 2.5 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Ogee type I |
| Length | : | 634.4 m |
| Wide threshold | : | 54.0 m |
| Crest threshold elevation | : | +101.51 m |
| Stilling Basin type | : | USBR type III |

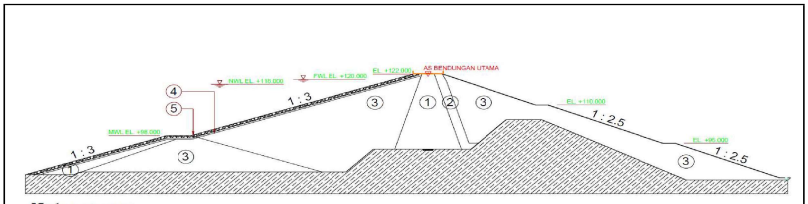
**Diversion**

| | | |
|---|---|---|
| Location | : | Right Abutment |
| Type | : | Tunnel |
| Length | : | 409.16 m |
| Dimensions | : | 5.0 m |
| U/S elevation | : | +37.51 m |
| D/S elevation | : | +37.28 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Baong |
| Rock/soil | : | Mudstone |
| Rock Class (CRIEPI) | : | CL–CM |
| Main Dam Foundation | : | Mudstone |
| Spillway Foundation | : | Mudstone |
| Diversion Foundation | : | Mudstone |

| | | |
|---|---|---|
| Dam Name | : | Kuningan |
| Province | : | Jawa Barat |
| Regency | : | Kuningan |
| Coordinate | : | 108° 42' 19.102" E7° 3' 45.299" S |




**Keterangan:**
1. Zona-1 (core)
2. Zona-2 (filter)
3. Zona-3 (random)
4. Zona-4 (transisi)
5. Zona-5 (rip-rap)

**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal with vertical core |
| Height | : | 43.0 m |
| Elevation of crest | : | +122.0 m |
| Elevation base foundation | : | – |
| Wide of crest | : | 10.0 m |
| Lenght of crest | : | 229.0 m |
| Upstream slope | : | 1:3 |
| Downstream slope | : | 1:2.5 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +118.0 m |
| Elv. of low water level (LWL) | : | +98.0 m |
| Elv. of flood water level Q1000 | : | +120.0 m |
| Elv. of flood water level QPMF | : | +120.86 m |
| Normal storage capacity | : | 24.6 million $m^3$ |
| Dead storage capacity | : | 2.4 million $m^3$ |
| Effective storage capacity | : | 22.2 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 133.91 $m^3/s$ |
| 10 year return period | : | 149.15 $m^3/s$ |
| 25 year old return period | : | 169.78 $m^3/s$ |
| 50 year return period | : | 186.11 $m^3/s$ |
| 100 year return period | : | 203.28 $m^3/s$ |
| 1000 year return period | : | 268.47 $m^3/s$ |
| PMF return period | : | 660.15 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Submarge Tower |
| Intake crest elevation | : | +103.0 m |
| Intake inlet elevation | : | +98.0 m |
| Gate dimension | : | 1.4 m (diameter) |

**Spillway**

| | | |
|---|---|---|
| Type | : | Ungated, Ogee |
| Length | : | 73 m (chute chanel) |
| Wide threshold | : | 14.0 m |
| Crest threshold elevation | : | +118,0 m |
| Stilling Basin type | : | Modified USBR type II |

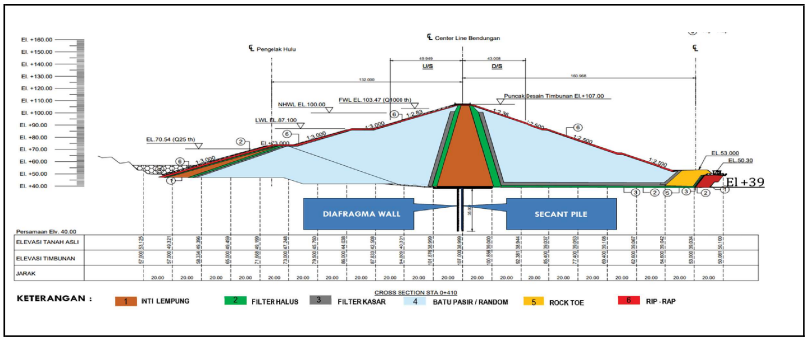
**Diversion**

| | | |
|---|---|---|
| Location | : | Dam left abutment |
| Type | : | Tunnel (circle) |
| Length | : | 260.2 m |
| Dimensions | : | 3 m |
| U/S elevation | : | +87.0 m |
| D/S elevation | : | +85.8 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Halang |
| Rock/soil | : | Claystone, claystone–sandstone alternation, breccia |
| Rock Class (CRIEPI) | : | – |
| Main Dam Foundation | : | Claystone, claystone–sandstone alternation, breccia |
| Spillway Foundation | : | claystone, claystone–sandstone alternation |
| Diversion Foundation | : | claystone, claystone–sandstone alternation |

| | | |
|---|---|---|
| Dam Name | : | Kuwil Kawangkoan |
| Province | : | Sulawesi Utara |
| Regency | : | Minahasa Utara |
| Coordinate | : | 1° 26'33.06"N<br>124° 55'50.37"E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | random rock with central core |
| Height | : | 67.0 m |
| Elevation of crest | : | +106.0 m |
| Elevation base foundation | : | +39.0 m |
| Wide of crest | : | 11.0 m |
| Lenght of crest | : | 345 m |
| Upstream slope | : | 1:3.00 |
| Downstream slope | : | 1:2.50 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +100,20 m |
| Elv. of low water level (LWL) | : | + 83,50 |
| Elv. of flood water level Q1000 | : | +103,69 m |
| Elv. of flood water level QPMF | : | +105,06 m |
| Normal storage capacity | : | 26.89 million $m^3$ |
| Dead storage capacity | : | 7.63 million $m^3$ |
| Effective storage capacity | : | 19.26 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 381.5 $m^3/s$ |
| 10 year return period | : | 438.6 $m^3/s$ |
| 25 year old return period | : | 519.7 $m^3/s$ |
| 50 year return period | : | 587.3 $m^3/s$ |
| 100 year return period | : | 661.3 $m^3/s$ |
| 1000 year return period | : | 1064.3 $m^3/s$ |
| PMF return period | : | 2046.6 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Tower (drop inlet) |
| Tower height | : | 24.5 m |
| Intake inlet elevation | : | +83.50 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | combination free and gated |
| Length | : | 282.3 m |
| Wide threshold | : | 55.0 m |
| Crest threshold elevation | : | +100.2 m (free)<br>+95.5 m (gated) |
| Stilling Basin type | : | – |

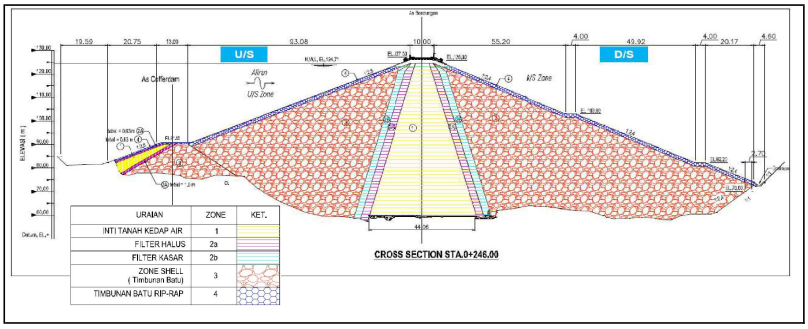
**Diversion**

| | | |
|---|---|---|
| Location | : | Right dam abutment |
| Type | : | Tunnel |
| Length | : | 550 m |
| Dimensions | : | ϕ 5.6 m |
| U/S elevation | : | +56.0 m |
| D/S elevation | : | +52.0 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Tondano tuff |
| Rock/soil | : | sandy Tuff, tuff lapilli, cleyey tuff |
| Rock Class (CRIEPI) | : | D, CL, CM, CH |
| Main Dam Foundation | : | sandy Tuff, tuff lapilli, cleyey tuff |
| Spillway Foundation | : | sandy Tuff, tuff lapilli, cleyey tuff |
| Diversion Foundation | : | tuff lapilli, cleyey tuff |

| | | |
|---|---|---|
| Dam Name | : | Ladongi |
| Province | : | Sulawesi Tenggara |
| Regency | : | Kolaka Timur |
| Coordinate | : | |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal rockfill with vertical core |
| Height | : | 66.0 m |
| Elevation of crest | : | +127.00 m |
| Elevation base foundation | : | +61.00 m |
| Wide of crest | : | 10.0 m |
| Lenght of crest | : | 417.0 m |
| Upstream slope | : | 1:2.6 |
| Downstream slope | : | 1:2.4 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | + 119.80 m |
| Elv. of low water level (LWL) | : | + 96.00 m |
| Elv. of flood water level Q1000 | : | +122.61 m |
| Elv. of flood water level QPMF | : | +124.71 m |
| Normal storage capacity | : | 36.37 million $m^3$ |
| Dead storage capacity | : | 7.34 million $m^3$ |
| Effective storage capacity | : | 29.03 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 196.43 $m^3/s$ |
| 10 year return period | : | 240.35 $m^3/s$ |
| 25 year old return period | : | 309.19 $m^3/s$ |
| 50 year return period | : | 351.76 $m^3/s$ |
| 100 year return period | : | 369.09 $m^3/s$ |
| 1000 year return period | : | 542.52 $m^3/s$ |
| PMF return period | : | 1105.61 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | shaft Intake |
| Discharge capacity | : | 29.82 $m^3/s$ |
| Intake inlet elevation | : | +95.5 m |
| Gate dimension | : | dia. 2.5 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Overflow |
| Length | : | 320.0 m |
| Wide threshold | : | 31.0 m |
| Crest threshold elevation | : | + 119.80 m |
| Stilling Basin type | : | USBR type II |

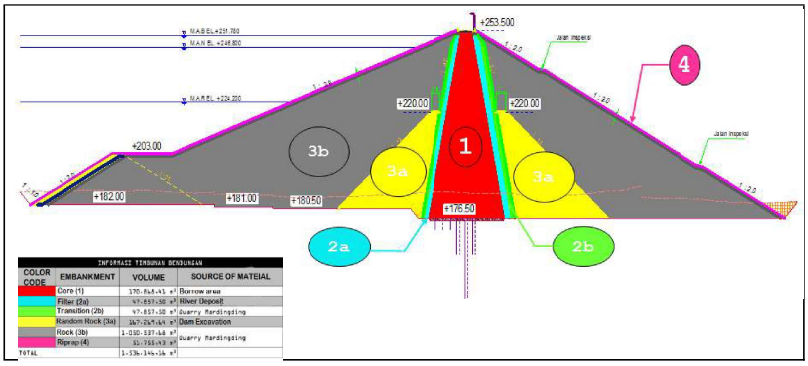
**Diversion**

| | | |
|---|---|---|
| Location | : | Right Abutment |
| Type | : | Tunnel |
| Length | : | 389.5 m |
| Dimensions | : | dia. 5.35 m |
| U/S elevation | : | +70.00 m |
| D/S elevation | : | +68.00 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Paleozoikum rock |
| Rock/soil | : | Alluvium, schist micca |
| Rock Class (CRIEPI) | : | CL. CM CH |
| Main Dam Foundation | : | schist micca |
| Spillway Foundation | : | schist micca |
| Diversion Foundation | : | schist micca |

| | | |
|---|---|---|
| Dam Name | : | Lausimeme |
| Province | : | Sumatera Utara |
| Regency | : | Deli Serdang |
| Coordinate | : | 03° 19'14"–03° 21'12"N 98° 37'35"–98° 39'08"E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal Rock–filled Dam with Centre Core |
| Height | : | 77 m |
| Elevation of crest | : | +253.50 m |
| Elevation base foundation | : | +176.5 m |
| Wide of crest | : | 11.0 m |
| Lenght of crest | : | 205 m |
| Upstream slope | : | 1:2.9 |
| Downstream slope | : | 1:2.0 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +246.8 m |
| Elv. of low water level (LWL) | : | +224.2 m |
| Elv. of flood water level Q1000 | : | +250.04 m |
| Elv. of flood water level QPMF | : | +251.78 m |
| Normal storage capacity | : | 21.07 million m3 |
| Dead storage capacity | : | 4.4 million m3 |
| Effective storage capacity | : | 16.67 million m3 |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 367.23 m3/sec |
| 10 year return period | : | 439.49 m3/sec |
| 25 year old return period | : | 542.41 m3/sec |
| 50 year return period | : | 609.32 m3/sec |
| 100 year return period | : | 697.78 m3/sec |
| 1000 year return period | : | 1,024.25 m3/sec |
| PMF return period | : | 1,963.78 m3/sec |

source: final report PT. Wahana Adya KSO, DED Lausimeme Dam 201

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Central axial point elv. | : | +184.3 m |
| Dimension | : | 4m x 4m |
| Threshold Elevation | : | +223 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side Channel |
| Length | : | 456 m |
| Wide threshold | : | 75 m |
| Crest threshold elevation | : | +246.8 m |

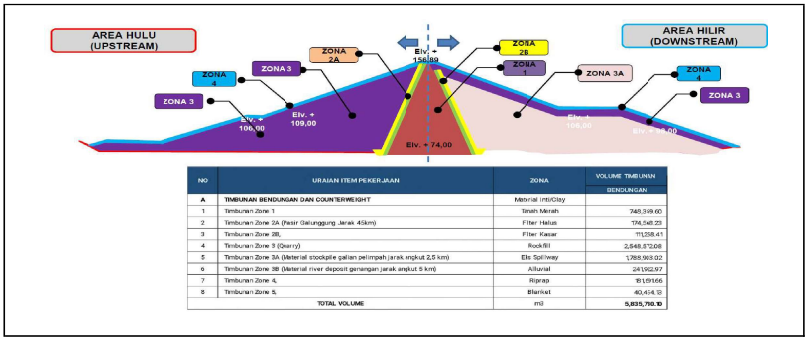
**Diversion**

| | | |
|---|---|---|
| Location | : | Left bank of dam abutment |
| Type | : | Tunnel |
| Length | : | 652.38m |
| Dimensions | : | – |
| U/S elevation | : | – |
| D/S elevation | : | – |

**Geology**

| | | |
|---|---|---|
| Formation | : | Mentar Unit |
| Rock/soil | : | Pumiceous Pyroclastic |
| Rock Class (CRIEPI) | : | D, CL, CM |
| Main Dam Foundation | : | Tuff–Breccia, Tuff, Sandstone, Pumiceous tuff–breccia |
| Spillway Foundation | : | Tuff–Breccia, Tuff, Sandstone, Pumiceous tuff–breccia |
| Diversion Foundation | : | Tuff–Breccia, Tuff, Sandstone, Pumiceous tuff–breccia |

| | | |
|---|---|---|
| Dam Name | : | Leuwikeris |
| Province | : | Jawa Barat |
| Regency | : | Ciamis–Tasikmalaya |
| Coordinate | : | 7° 21'41.66"S 108° 23'46.01"E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Rock–filled Dam, with central core |
| Height | : | 84.90 m |
| Elevation of crest | : | + 156.69 m |
| Elevation base foundation | : | + 72.69 m |
| Wide of crest | : | 14.50 m |
| Lenght of crest | : | 409.09 m |
| Upstream slope | : | 1:2.5 & 1:3.0 |
| Downstream slope | : | 1:2.3 & 1:2.5 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | + 150.00 m |
| Elv. of low water level (LWL) | : | + 133.00 m |
| Elv. of flood water level Q1000 | : | + 155.27 m |
| Elv. of flood water level QPMF | : | + 156.05 m |
| Normal storage capacity | : | 81.44 million $m^3$ |
| Dead storage capacity | : | 36.09 million $m^3$ |
| Effective storage capacity | : | 36.09 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | – |
| 10 year return period | : | – |
| 25 year old return period | : | – |
| 50 year return period | : | – |
| 100 year return period | : | 600.30 $m^3/s$ |
| 1000 year return period | : | 1066.90 $m^3/s$ |
| PMF return period | : | 4767.4 $m^3/s$ |

*source: PT. Vitraha, 2017

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| intake gate dimension | : | 2.9 x 2.9 m |
| Intake inlet elevation | : | + 133.00 m |
| Intake dimension | : | 3 x 3 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Combination Side channel |
| Length | : | – |
| Wide threshold | : | 85 m |
| Crest threshold elevation | : | +149,32 m |
| Stilling Basin type | : | USBR type II |

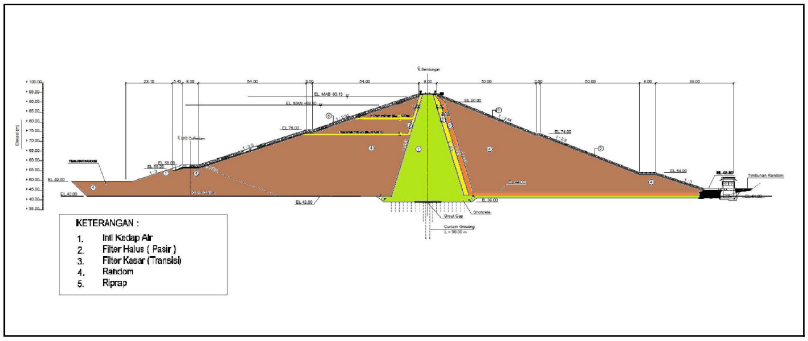
**Diversion**

| | | |
|---|---|---|
| Location | : | Left abutment |
| Type | : | Tunnel |
| Length | : | 1,074m & 1,049m |
| Dimensions | : | 2 X ø 6.25 m |
| U/S elevation | : | +84.8 m, +84.9 m |
| D/S elevation | : | +77.75 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Quartenary Volcanic |
| Rock/soil | : | Volcanic breccia, sandstone, claystone, tuff, conglomerate |
| Rock Class (CRIEPI) | : | – |
| Main Dam Foundation | : | Volcanic breccia, sandstone, claystone, tuff, conglomerate |
| Spillway Foundation | : | Volcanic breccia, sandstone |
| Diversion Foundation | : | Volcanic breccia, sandstone, claystone, tuff, conglomerate |

| | | |
|---|---|---|
| Dam Name | : | Logung |
| Province | : | Jawa Tengah |
| Regency | : | Kudus |
| Coordinate | : | 6° 45'29.07"S<br>110° 55'21.98"E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Earthfill Random zonal with vertical core |
| Height | : | 55 m |
| Elevation of crest | : | +94.00 m |
| Elevation base foundation | : | – |
| Wide of crest | : | 9 m |
| Lenght of crest | : | 350 m |
| Upstream slope | : | 1:3 |
| Downstream slope | : | 1:2.5 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +88.50 m |
| Elv. of low water level (LWL) | : | +74.00 m |
| Elv. of flood water level Q1000 | : | +90.98 m |
| Elv. of flood water level QPMF | : | +93.22 m |
| Normal storage capacity | : | 20.15 million $m^3$ |
| Dead storage capacity | : | 6.43 million $m^3$ |
| Effective storage capacity | : | 13.72 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 148.9 $m^3/s$ |
| 10 year return period | : | 182.0 $m^3/s$ |
| 25 year old return period | : | 224.2 $m^3/s$ |
| 50 year return period | : | 250.6 $m^3/s$ |
| 100 year return period | : | 276.5 $m^3/s$ |
| 1000 year return period | : | 354.3 $m^3/s$ |
| PMF return period | : | 840.6 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Tower height | : | – |
| Intake inlet elevation | : | +74.00 m |
| Gate dimension | : | – |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side Channel, ungated ogee |
| Length | : | 343.5 m |
| Wide threshold | : | 32.5 m |
| Crest threshold elevation | : | + 88.50 m |
| Stilling Basin type | : | USBR type II |

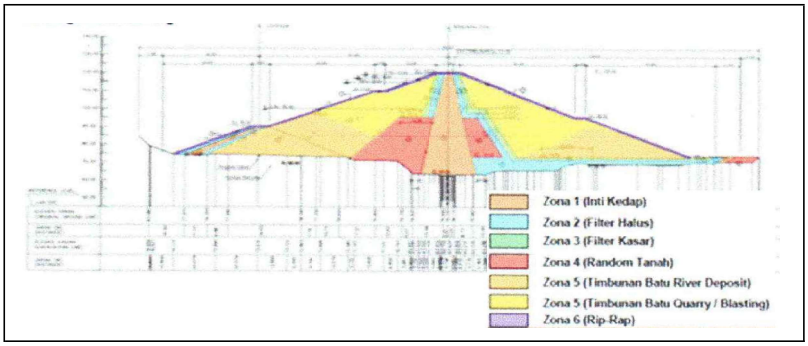
**Diversion**

| | | |
|---|---|---|
| Location | : | Right of river bank |
| Type | : | Conduit |
| Length | : | 370 m |
| Dimensions | : | 2@ 3.5 x 3.5 m |
| U/S elevation | : | +45.0 m |
| D/S elevation | : | +40.0 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Patiayam |
| Rock/soil | : | Tuff, Lapilli–tuff, conglomerate, tuffaceous sandstone |
| Rock Class (CRIEPI) | : | CL. CM |
| Main Dam Foundation | : | Tuff, Lapilli–tuff, conglomerate, tuffaceous sandstone |
| Spillway Foundation | : | Tuff, conglomerate, tuffaceous sandstone |
| Diversion Foundation | : | Tuff, tuffaceous sandstone |

| | | |
|---|---|---|
| Dam Name | : | Lolak |
| Province | : | Sulawesi Utara |
| Regency | : | Bolang Mongondow |
| Coordinate | : | 0° 48"15.3612" N<br>24° 4'4.3104" E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal with central core |
| Height | : | 58 m |
| Elevation of crest | : | +120 m |
| Elevation base foundation | : | +62 m |
| Wide of crest | : | 11 m |
| Lenght of crest | : | 604.5 m |
| Upstream slope | : | 1 : 2.50 |
| Downstream slope | : | 1 : 2.25 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | + 114.5 m |
| Elv. of low water level (LWL) | : | + 99.65 m |
| Elv. of flood water level Q1000 | : | +118.32 m |
| Elv. of flood water level QPMF | : | +119.24 m |
| Normal storage capacity | : | 16.23 million m3 |
| Dead storage capacity | : | 3.89 million m3 |
| Effective storage capacity | : | 12.43 million m3 |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 192.83 m3/s |
| 10 year return period | : | 269.39 m3/s |
| 25 year old return period | : | 399.95 m3/s |
| 50 year return period | : | 527.00 m3/s |
| 100 year return period | : | 682.53 m3/s |
| 1000 year return period | : | 1,467.44 m3/s |
| PMF return period | : | 1,999.61 m3/s |

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Tower Height | : | 27.35 m |
| Apron elevation | : | +98.99 m |
| Intake inlet elevation | : | +95.15 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side Channel, Ogee |
| length | : | 330.7 m |
| Wide threshold | : | 70.00 m |
| Crest threshold elevation | : | +114.50 m |
| Wide of stilling basin | : | 17.5 m |

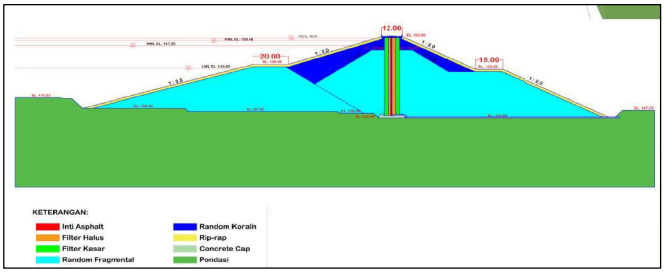
**Diversion**

| | | |
|---|---|---|
| Location | : | left bank of river |
| Type | : | Conduit |
| Length | : | 284 m |
| Dimensions | : | 4 x 4 m @2 units |
| U/S elevation | : | + 81.00 m |
| D/S elevation | : | + 65.00 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Tinombo volcanic facies |
| Rock/soil | : | lava, tuffaceous sandstone, shale–sandstone |
| Rock Class (CRIEPI) | : | D, CL, CM |
| Main Dam Foundation | : | tuffaceous sandstone, shale–sandstone |
| Spillway Foundation | : | tuffaceous sandstone, shale–sandstone |
| Diversion Foundation | : | lava, tuffaceous sandstone, shale–sandstone |

| | | |
|---|---|---|
| Dam Name | : | Manikin |
| Province | : | Nusa Tenggara Timor |
| Regency | : | Kupang |
| Coordinate | : | 9° 42'30" S<br>124° 27 '40" E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Limestone Random Fill with asphalt core |
| Height | : | 50 m |
| Elevation of crest | : | +153 m |
| Elevation base foundation | : | +105 m |
| Wide of crest | : | 12 m |
| Lenght of crest | : | 335.0 m |
| Upstream slope | : | 1:3.5 |
| Downstream slope | : | 1:2 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +147.50 m |
| Elv. of low water level (LWL) | : | +133.60 m |
| Elv. of flood water level Q1000 | : | +150.47 m |
| Elv. of flood water level QPMF | : | +152.13 m |
| Normal storage capacity | : | 20.45 million m3 |
| Dead storage capacity | : | 4.79 million m3 |
| Effective storage capacity | : | 15.63 million m3 |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 292.94 m3/sec |
| 10 year return period | : | 343.05 m3/sec |
| 20 year old return period | : | 404.33 m3/sec |
| 50 year return period | : | 443.26 m3/sec |
| 100 year return period | : | 480.45 m3/sec |
| 1000 year return period | : | 592.64 m3/sec |
| PMF return period | : | 1,156.72 m3/sec |

**Intake**

| | | |
|---|---|---|
| Type | : | Drop Intake |
| Dimensions / size | : | 2.5 x 2.5 m |
| Base outlet elevation | : | +132.20 m |
| Intake inlet elevation | : | +132.20 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Shaft (morning glory) |
| Press Height (Hd) | : | 2.98 m |
| Wide threshold | : | 37.0 m |
| Crest threshold elevation | : | +147.5 m |
| Threshold Diameter | : | 11.78 m |

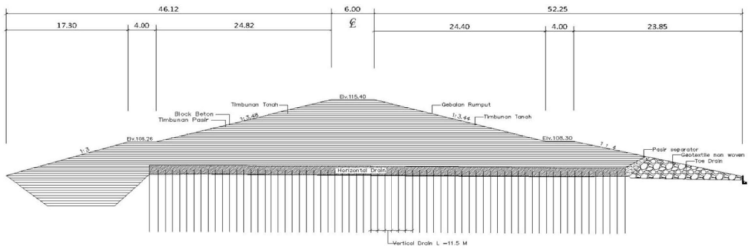
**Diversion**

| | | |
|---|---|---|
| Location | : | – |
| Type | : | – |
| Length | : | – m |
| Dimensions | : | – m |
| U/S elevation | : | + m |
| D/S elevation | : | + m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Noele, Bononaro |
| Rock/soil | : | Scaly Claystone, Exotic block |
| Rock Class (CRIEPI) | : | D, CL |
| Main Dam Foundation | : | Scaly Claystone |
| Spillway Foundation | : | Scaly Claystone |
| Diversion Foundation | : | Scaly Claystone, Exotic block |

| | | |
|---|---|---|
| Dam Name | : | Marangkayu |
| Province | : | Kalimantan Timur |
| Regency | : | Kutai Kartanegara |
| Coordinate | : | 00° 01' – 00° 15' S<br>117° 15'–117° 30' E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Homogeneous Dam |
| Height | : | 15.40 m |
| Elevation of crest | : | + 115.40 m |
| Elevation base foundation | : | + 102.00 m |
| Wide of crest | : | 6.0 m |
| Lenght of crest | : | 803.3 m |
| Upstream slope | : | 1:4 |
| Downstream slope | : | 1:4 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | + 110.00 m |
| Elv. of low water level (LWL) | : | + 104.30 m |
| Elv. of flood water level Q1000 | : | + 111.05 m |
| Elv. of flood water level QPMF | : | + 113.25 m |
| Normal storage capacity | : | 12.33 million $m^3$ |
| Dead storage capacity | : | 0.67 million $m^3$ |
| Effective storage capacity | : | 11.66 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 257.86 $m^3/s$ |
| 10 year return period | : | 301.49 $m^3/s$ |
| 25 year old return period | : | 350.17 $m^3/s$ |
| 50 year return period | : | 382.18 $m^3/s$ |
| 100 year return period | : | 412.59 $m^3/s$ |
| 1000 year return period | : | 495.78 $m^3/s$ |
| PMF return period | : | 2005.24 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Drop inlet |
| Capacity | : | 4.27 $m^3/s$ |
| Intake inlet elevation | : | + 104.50 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | side chanel |
| Length | : | 200.0 m |
| Wide side chanel | : | u/s = 25 m; d/s = 30 m |
| Crest threshold elevation | : | + 110.00 m |

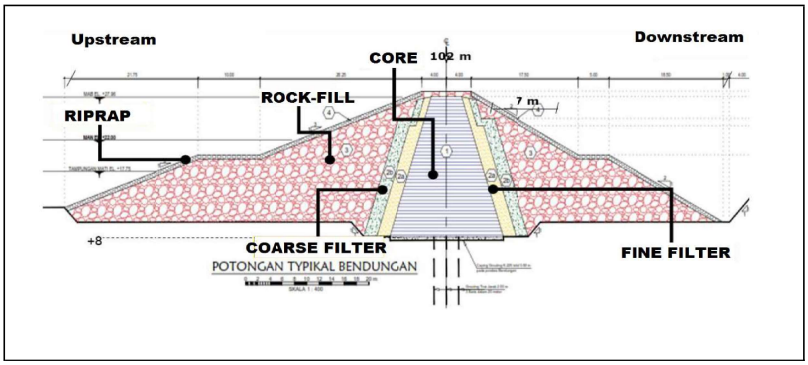
**Diversion**

| | | |
|---|---|---|
| Location | : | Right of river bank |
| Type | : | conduit |
| Length | : | 110 m |
| Dimensions | : | 3 x 3 m, 2 pieces |
| U/S elevation | : | + 100.00 m |
| D/S elevation | : | + 99.00 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Kapungbaru |
| Rock/soil | : | Alluvium, sandy silty clay |
| Soil Class | : | Soft to very stiff |
| Main Dam Foundation | : | Alluvium, sandy silty clay |
| Spillway Foundation | : | sandy silty clay |
| Diversion Foundation | : | Alluvium, sandy silty clay |

| | | |
|---|---|---|
| Dam Name | : | Margatiga |
| Province | : | Lampung |
| Regency | : | Lampung Timur |
| Coordinate | : | 105° 29' 40"E<br>5° 12' 27"S. |




**Main Dam**

| | | |
|---|---|---|
| Type | : | gravity concrete–rock–fill dam, central core |
| Height | : | 20 m |
| Elevation of crest | : | +28.75 m |
| Elevation base foundation | : | no data |
| Wide of crest | : | 7 m |
| Lenght of crest | : | 321.76 m |
| Upstream slope | : | 1:3 |
| Downstream slope | : | 1:2 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | + 22.00 m |
| Elv. of low water level (LWL) | : | – |
| Elv. of flood water level Q1000 | : | +24.99 m |
| Elv. of flood water level QPMF | : | + 27.28 m |
| Normal storage capacity | : | 29.96 million m3 |
| Dead storage capacity | : | 3.2 million m3 |
| Effective storage capacity | : | – |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 481,63 m3/s |
| 10 year return period | : | 511,37 m3/s |
| 20 year old return period | : | 571,12 m3/s |
| 50 year return period | : | 621,90 m3/s |
| 100 year return period | : | 664,80 m3/s |
| 1000 year return period | : | 821,83 m3/s |
| PMF return period | : | 4465,09 m3/s |

**Intake**

| | | |
|---|---|---|
| Type | : | Sliding gate |
| Location | : | middle |
| Dimensions / size | : | 8 m (h) x 5 m (w) |
| Inlet base elevation | : | +14 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Overflow |
| Location | : | middle of dam |
| Wide threshold | : | 82.50 m |
| Crest threshold elevation | : | + 22.00 m |
| Apron elevation | : | +16.00 m |

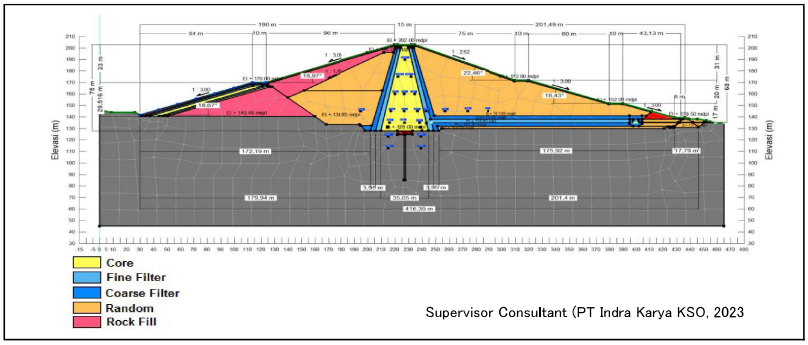
**Diversion**

| | | |
|---|---|---|
| Location | : | left bank |
| Type | : | open channels |
| Length | : | 600 m |
| Dimensions | : | – |
| U/S elevation | : | – |
| D/S elevation | : | – |

**Geology**

| | | |
|---|---|---|
| Formation | : | Sukadana (Qbs) & Lampung (QTl) |
| Rock/soil | : | basalt, tuff, tuffeceous sandstone |
| Rock Class (CRIEPI) | : | D, CL, CM |
| Main Dam Foundation | : | Basalt, tuff, tuf. sandstone |
| Spillway Foundation | : | Basalt, tuff, tuf. sandstone |
| Diversion Foundation | : | Basalt, tuff, tuf. sandstone |

| | | |
|---|---|---|
| Dam Name | : | Meninting |
| Province | : | Nusa Tenggara Barat |
| Regency | : | Lombok Barat |
| Coordinate | : | 8°31'11" S<br>116°9'10" E |




Supervisor Consultant (PT Indra Karya KSO, 2023

**Main Dam**

| | | |
|---|---|---|
| Type | : | Radom filled dam with central core |
| Height | : | 74.0 m |
| Elevation of crest | : | +202.0 m |
| Elevation base foundation | : | +128.00 m |
| Wide of crest | : | 15.0 m |
| Lenght of crest | : | 430.0 m |
| Upstream slope | : | 1:3.0 |
| Downstream slope | : | 1:2.6(top) & 1:3.0(bot) |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +196.0 m |
| Elv. of low water level (LWL) | : | +169.0 m |
| Elv. of flood water level Q1000 | : | +198.80 m |
| Elv. of flood water level QPMF | : | +200.60 m |
| Normal storage capacity | : | 9.91 million $m^3$ |
| Dead storage capacity | : | 1.72 million $m^3$ |
| Effective storage capacity | : | 8.19 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 169.68 $m^3/s$ |
| 10 year return period | : | 207.18 $m^3/s$ |
| 25 year old return period | : | 274.14 $m^3/s$ |
| 50 year return period | : | 238.6 $m^3/s$ |
| 100 year return period | : | 315.24 $m^3/s$ |
| 1000 year return period | : | 377.45 $m^3/s$ |
| PMF return period | : | 830.49 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Tower height | : | 33 m |
| Intake inlet elevation | : | +168.0 m |
| Gate dimension | : | 6 x 6 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side channel (tunnel) |
| Length | : | 357.0 m |
| Wide threshold | : | 30.0 m |
| Crest threshold elevation | : | +196.0 m |
| Stilling Basin type | : | Flip Bucket |

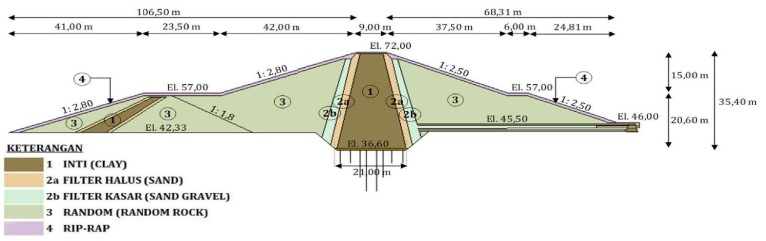
**Diversion**

| | | |
|---|---|---|
| Location | : | Right abutment |
| Type | : | conduit & tunnel |
| Length | : | 118 m & 308 m |
| Dimensions | : | 5.0 x 6.0 m |
| U/S elevation | : | +148.57 m |
| D/S elevation | : | +147.72 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Lekopiko |
| Rock/soil | : | Breccia, andesite lava |
| Rock Class (CRIEPI) | : | D, CL,CM |
| Main Dam Foundation | : | Breccia, andesite lava |
| Spillway Foundation | : | Breccia, andesite lava |
| Diversion Foundation | : | Breccia |

| | | |
|---|---|---|
| Dam Name | : | Mila |
| Province | : | Nusa Tenggara Barat |
| Regency | : | Dompu |
| Coordinate | : | 118° 14' – 118° 27' E<br>8° 28' –8° 36'S |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Random filled with vertical core |
| Height | : | 35.4 m |
| Elevation of crest | : | + 72.0 m |
| Elevation base foundation | : | 36.6 m |
| Wide of crest | : | 9 m |
| Lenght of crest | : | 183.6 m |
| Upstream slope | : | 1 : 2.8 |
| Downstream slope | : | 1 : 2.5 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +67.0 m |
| Elv. of low water level (LWL) | : | +61.1 m |
| Elv. of flood water level Q1000 | : | – |
| Elv. of flood water level QPMF | : | – |
| Normal storage capacity | : | 6.73 million $m^3$ |
| Dead storage capacity | : | 2.59 million $m^3$ |
| Effective storage capacity | : | 4.14 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 85 $m^3/s$ |
| 10 year return period | : | 101 $m^3/s$ |
| 25 year old return period | : | 122 $m^3/s$ |
| 50 year return period | : | 137 $m^3/s$ |
| 100 year return period | : | 152 $m^3/s$ |
| 1000 year return period | : | 201 $m^3/s$ |
| PMF return period | : | 378 $m^3/s$ |

*source: detail design PT. Tata Guna Patria

**Intake**

| | | |
|---|---|---|
| Type | : | Drop inlet |
| Intake inlet elevation | : | +61.10 m |
| Intake outlet elevation | : | +46.35 m |
| Gate dimension | : | 2.0 x 2.0 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Over Flow |
| Length | : | 380.85 m |
| Wide threshold | : | 10 m |
| Crest threshold elevation | : | +67.0 m |
| Stilling Basin type | : | USBR Type II |

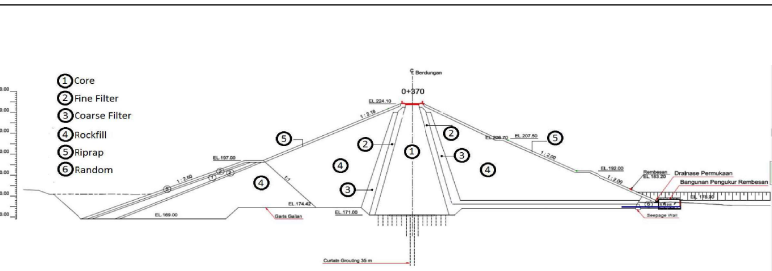
**Diversion**

| | | |
|---|---|---|
| Location | : | Right of river bank |
| Type | : | conduit |
| Length | : | 199.9 m |
| Dimensions | : | 3.6m (h) x3.0m (w) |
| U/S elevation | : | +48.0 m |
| D/S elevation | : | +45.6 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Old volcanic |
| Rock/soil | : | andesit (dyke), andesite (lava), lapill–tuff, breccia–tuff |
| Rock Class (CRIEPI) | : | A, B, CH, CM, CL, D |
| Main Dam Foundation | : | andesit (dyke), andesite (lava), lapill–tuff, breccia–tuff |
| Spillway Foundation | : | lapill–tuff |
| Diversion Foundation | : | lapill–tuff, tuff–breccia, andesite lava |

| | | |
|---|---|---|
| Dam Name | : | Napun Gete |
| Province | : | Nusa Tenggara Timur |
| Regency | : | Sikka |
| Coordinate | : | 122° 35' 038" E<br>08° 33' 129" S |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Rock–filled dam with central core |
| Height | : | 52.0 m |
| Elevation of crest | : | +223.0 m |
| Elevation base foundation | : | +171.0 m |
| Wide of crest | : | 10 m |
| Lenght of crest | : | 585 m |
| Upstream slope | : | 1 : 2.18 |
| Downstream slope | : | 1 : 1.87 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +218.0 m |
| Elv. of low water level (LWL) | : | +209.11 m |
| Elv. of flood water level Q1000 | : | +219.98 m |
| Elv. of flood water level QPMF | : | +221.56 m |
| Normal storage capacity | : | 11.22 million $m^3$ |
| Dead storage capacity | : | 4.96 million $m^3$ |
| Effective storage capacity | : | 6.26 milliom $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 74.38 $m^3/s$ |
| 10 year return period | : | 99.57 $m^3/s$ |
| 25 year old return period | : | 134.46 $m^3/s$ |
| 50 year return period | : | 162.05 $m^3/s$ |
| 100 year return period | : | 190.61 $m^3/s$ |
| 1000 year return period | : | 291.76 $m^3/s$ |
| PMF return period | : | 973.92 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Tower height | : | 27.12 m |
| Intake inlet elevation | : | +209.00 m |
| Gate dimension | : | ϕ1.2 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side channel, ungated |
| Length | : | 222.54 m |
| Wide threshold | : | 30 m |
| Crest threshold elevation | : | +218.0 m |
| Stilling Basin type | : | none |

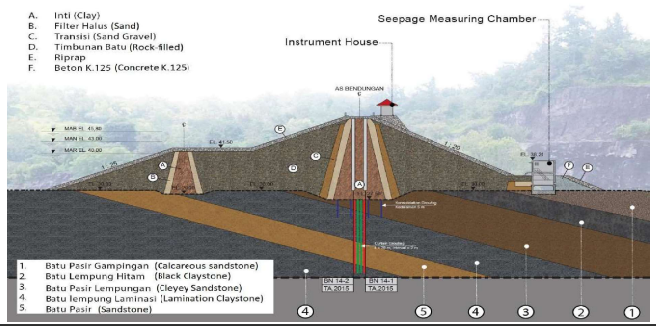
**Diversion**

| | | |
|---|---|---|
| Location | : | Right of river bank |
| Type | : | conduit |
| Length | : | 543.65 m |
| Dimensions | : | 2@ 3x3 m |
| U/S elevation | : | +181.5 m |
| D/S elevation | : | +180.0 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | older volcanic |
| Rock/soil | : | tuffaceous sandstone, andesitic breccia, volcanic breccia |
| Rock Class (CRIEPI) | : | D, CL, CM CH |
| Main Dam Foundation | : | tuffaceous sandstone, andesitic breccia, volcanic breccia |
| Spillway Foundation | : | tuffaceous sandstone, andesitic breccia, volcanic breccia |
| Diversion Foundation | : | tuffaceous sandstone, andesitic breccia, volcanic breccia |

| | | |
|---|---|---|
| Dam Name | : | Nipah |
| Province | : | Jawa Timur |
| Regency | : | Sampang |
| Coordinate | : | 6° 56'7.36"S<br>113° 11'38.95"E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Rock-filled dam with central core |
| Height | : | 22.5 m |
| Elevation of crest | : | +50.0 m |
| Elevation base foundation | : | +27.5 m |
| Wide of crest | : | 7.0 m |
| Lenght of crest | : | 110.85 m |
| Upstream slope | : | 1:2.5 |
| Downstream slope | : | 1:2.0 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +43.0 m |
| Elv. of low water level (LWL) | : | +40.0 m |
| Elv. of flood water level Q1000 | : | +45.36 m |
| Elv. of flood water level QPMF | : | +47.95 m |
| Normal storage capacity | : | 1.56 million $m^3$ |
| Dead storage capacity | : | 0.75 million $m^3$ |
| Effective storage capacity | : | 0.81 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 127.41 $m^3/s$ |
| 10 year return period | : | 152.37 $m^3/s$ |
| 25 year old return period | : | 186.92 $m^3/s$ |
| 50 year return period | : | 213.24 $m^3/s$ |
| 100 year return period | : | 239.66 $m^3/s$ |
| 1000 year return period | : | 313.2 $m^3/s$ |
| PMF return period | : | 935.29 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Wide of threshold | : | 4.0 m |
| Intake inlet elevation | : | +40.0 m |
| Gate dimension | : | 2x2 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side channel |
| Length | : | 160.75 m |
| Wide threshold | : | 56.0 m |
| Crest threshold elevation | : | +43.0 m |
| Stilling Basin type | : | USBR type IV |

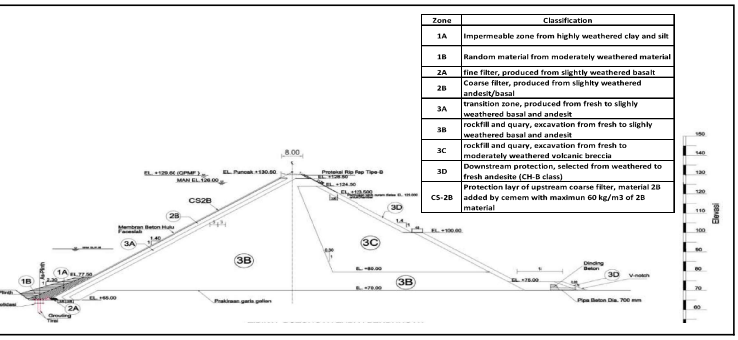
**Diversion**

| | | |
|---|---|---|
| Location | : | Right dam abutment |
| Type | : | Tunnel |
| Length | : | 234.5 m |
| Dimensions | : | 4 m |
| U/S elevation | : | +31.0 m |
| D/S elevation | : | +30.0 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Nyrayong |
| Rock/soil | : | sandstone and claystone |
| Rock Class (CRIEPI) | : | - |
| Main Dam Foundation | : | sandstone and claystone |
| Spillway Foundation | : | sandstone and claystone |
| Diversion Foundation | : | sandstone and claystone |

| | | |
|---|---|---|
| Dam Name | : | Pamukkulu |
| Province | : | Sulawesi Selatan |
| Regency | : | Takalar |
| Coordinate | : | 119° 34' 45.3" – 119° 38' 33.9"E<br>5° 23' 23.6" – 5° 25' 56.8" |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Concrete Face Rock-filled Dams (CRFD) |
| Height | : | 65.5 m |
| Elevation of crest | : | +130.5 m |
| Elevation base foundation | : | No data |
| Wide of crest | : | 8 m |
| Lenght of crest | : | 860.0m |
| Upstream slope | : | 1:1.4 |
| Downstream slope | : | 1:1.4 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +126.00 m |
| Elv. of low water level (LWL) | : | +91.50 m |
| Elv. of flood water level Q1000 | : | No data |
| Elv. of flood water level QPMF | : | +129.68 m |
| Normal storage capacity | : | 82.57 million m3 |
| Dead storage capacity | : | 4.95 million m3 |
| Effective storage capacity | : | 77.62 million m3 |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 428.6 m3/sec |
| 10 year return period | : | 508.2 m3/sec |
| 25 year old return period | : | 644.3 m3/sec |
| 50 year return period | : | 719.2 m3/sec |
| 100 year return period | : | 773.9 m3/sec |
| 1000 year return period | : | 1,087.3 m3/sec |
| PMF return period | : | 1,661.1 m3/sec |

**Intake**

| | | |
|---|---|---|
| Type | : | Vertical Intake Shaft |
| Dimensions / size | : | 2.00 x 2.00 m |
| Max Debit | : | 8.90 to 9 m3/s |
| Intake inlet elevation | : | +91.50 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side Chanel, ogee |
| Length | : | 480 m |
| Wide threshold | : | 80 m |
| Crest threshold elevation | : | +126.0 m |
| Downstream slope of mercu | : | No data |

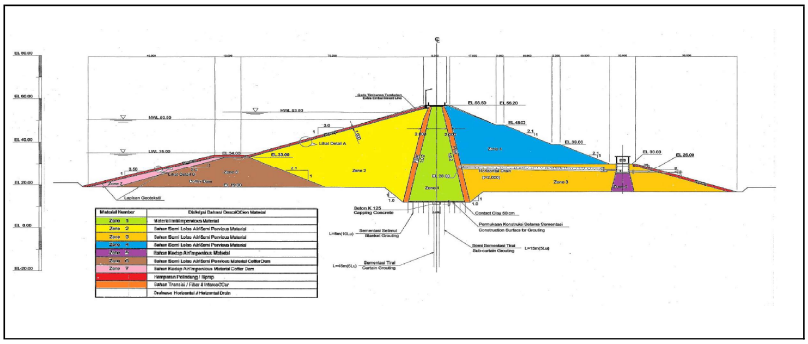
**Diversion**

| | | |
|---|---|---|
| Location | : | Left Abutment |
| Type | : | tunnel |
| Length | : | 460 m |
| Dimensions | : | ø6 m |
| U/S elevation | : | +77.00 m |
| D/S elevation | : | +71.00 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Baturape-Cindako Volcanic |
| Rock/soil | : | Breccia, basalt-andesite lava |
| Rock Class (CRIEPI) | : | CL,CM,CH,B |
| Main Dam Foundation | : | Breccia, basalt-andesite lava |
| Spillway Foundation | : | Breccia, basalt-andesite lava |
| Diversion Foundation | : | Breccia, basalt-andesite lava |

| | | |
|---|---|---|
| Dam Name | : | Paselloreng |
| Province | : | Sulawesi Selatan |
| Regency | : | Wajo |
| Coordinate | : | 3°53' 2.69'' S<br>120° 10' 54.08'' E. |



**Main Dam**

| | | |
|---|---|---|
| Type | : | Earth-filled zonal with central core |
| Height | : | 42.0 m |
| Elevation of crest | : | +56.50 m |
| Elevation base foundation | : | +14.5 m |
| Wide of crest | : | 10.0 m |
| Lenght of crest | : | 323.4 m |
| Upstream slope | : | 1 :3 |
| Downstream slope | : | 1 :2.1 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +50.5 m |
| Elv. of low water level (LWL) | : | +35.0 m |
| Elv. of flood water level Q1000 | : | + 52.27 m |
| Elv. of flood water level QPMF | : | + 54.76 m |
| Normal storage capacity | : | 128.12 milion $m^3$ |
| Dead storage capacity | : | 15.18 milion $m^3$ |
| Effective storage capacity | : | 112.93 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 232.3 $m^3/s$ |
| 10 year return period | : | 342.6 $m^3/s$ |
| 25 year old return period | : | 510.7 $m^3/s$ |
| 50 year return period | : | 636.8 $m^3/s$ |
| 100 year return period | : | 758.7 $m^3/s$ |
| 1000 year return period | : | 1187.8 $m^3/s$ |
| PMF return period | : | 3698.4 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Incline Tower |
| Discharge capacity | : | 7.14 – 23.07 $m^3/s$ |
| Intake inlet elevation | : | +35.00 m |
| Gate dimension | : | Ø 1.65 m, 2 gates |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side channel, ogee |
| Length | : | – |
| Wide threshold | : | 77.0 m |
| Crest threshold elevation | : | +50.5 m |
| Stilling Basin type | : | USBR type II |

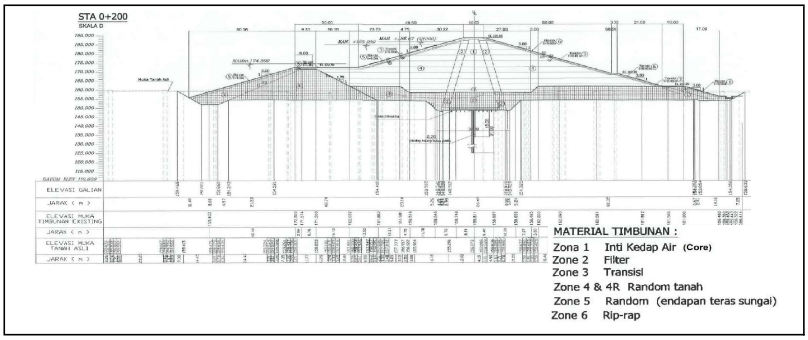
**Diversion**

| | | |
|---|---|---|
| Location | : | Right abutment |
| Type | : | Tunnel |
| Length | : | – |
| Dimensions | : | – |
| U/S elevation | : | – |
| D/S elevation | : | – |

**Geology**

| | | |
|---|---|---|
| Formation | : | Walanae |
| Rock/soil | : | conglomerate, sandstone, claystone |
| Rock Class (CRIEPI) | : | – |
| Main Dam Foundation | : | conglomerate, sandstone |
| Spillway Foundation | : | sandstone |
| Diversion Foundation | : | sandstone, claystone |

| | | |
|---|---|---|
| Dam Name | : | Pidekso |
| Province | : | Jawa Tengah |
| Regency | : | Wonogiri |
| Coordinate | : | 7° 32° – 8° 15° S<br>110° 41° – 111° 18° E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Random earth-fill with central core |
| Height | : | 44 m |
| Elevation of crest | : | +189.00 m |
| Elevation base foundation | : | +145.00 m |
| Wide of crest | : | 10 m |
| Lenght of crest | : | 387 m |
| Upstream slope | : | 1:3.0 |
| Downstream slope | : | 1:3.0 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +185.00 m |
| Elv. of low water level (LWL) | : | +174.50 m |
| Elv. of flood water level Q1000 | : | +186.00 m |
| Elv. of flood water level QPMF | : | +188.02 m |
| Normal storage capacity | : | 25 million m3 |
| Dead storage capacity | : | 8 million m3 |
| Effective storage capacity | : | 17 million m3 |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 156.1 m3/sec |
| 10 year return period | : | 179.4 m3/sec |
| 25 year old return period | : | 208.8 m3/sec |
| 50 year return period | : | 230.6 m3/sec |
| 100 year return period | : | 252.3 m3/sec |
| 1000 year return period | : | 323.8 m3/sec |
| PMF return period | : | 775.3 m3/sec |

source: Final Report, PT. Mettana 2011

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Dimensions / size | : | 1.5 m |
| Tower height | : | 15 m |
| Intake inlet elevation | : | + 174.5 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Ogee (ungated) |
| Length | : | 451 m |
| Wide threshold | : | 56 m |
| Crest threshold elevation | : | +185.00 m |
| Stilling basin type | : | USBR Tipe-II |

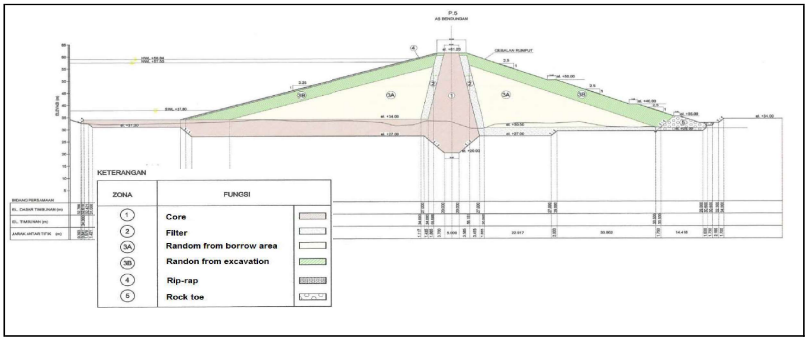
**Diversion**

| | | |
|---|---|---|
| Location | : | left river bank |
| Type | : | Conduit |
| Length | : | 228 m |
| Dimensions | : | 2@ 2.5m x 2.5m |
| U/S elevation | : | +159.00 m |
| D/S elevation | : | +158.00 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Baturetno, Semilir, Mandalika |
| Rock/soil | : | tuff, pumiceous breccia, tuffaceos sandstone, dasitic lava, dasitic tuff |
| Rock Class (CRIEPI) | : | D, CL, CM |
| Main Dam Foundation | : | Unconsolidated piroclastic, sandy tuff, lapilli tuff |
| Spillway Foundation | : | Unconsolidated piroclastic, sandy tuff, lapilli tuff |
| Diversion Foundation | : | lapilli tuff |

| | | |
|---|---|---|
| Dam Name | : | Rajui |
| Province | : | Aceh |
| Regency | : | Pidie |
| Coordinate | : | 5° 24′ 25,8″ N<br>95° 48′ 47,1″ E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Random zonal with vertical core |
| Height | : | 41.2 m |
| Elevation of crest | : | +61.2 m |
| Elevation base foundation | : | +20.0 m |
| Wide of crest | : | 10.0 m |
| Lenght of crest | : | – |
| Upstream slope | : | 1:3.25 |
| Downstream slope | : | 1:2.50 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +57.5 m |
| Elv. of low water level (LWL) | : | +33.0 m |
| Elv. of flood water level Q1000 | : | – |
| Elv. of flood water level QPMF | : | +58.84 m |
| Normal storage capacity | : | 2.67 million $m^3$ |
| Dead storage capacity | : | 0.02 million $m^3$ |
| Effective storage capacity | : | 2.64 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 21.19 $m^3/s$ |
| 10 year return period | : | 26.74 $m^3/s$ |
| 25 year old return period | : | 32.16 $m^3/s$ |
| 50 year return period | : | 33.25 $m^3/s$ |
| 100 year return period | : | 37.50 $m^3/s$ |
| 1000 year return period | : | 48.09 $m^3/s$ |
| PMF return period | : | 126.58 $m^3/s$ |

PT. Parasi Consultant

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Tower height | : | 29.0 m |
| Intake inlet elevation | : | + 33.0 m |
| maximun discharge | : | 2.08 $m^3/s$ |

**Spillway**

| | | |
|---|---|---|
| Type | : | Free Overflows, ogee |
| Length | : | 115 m |
| Wide threshold | : | 10.0 m |
| Crest threshold elevation | : | +57.5 m |
| Stilling Basin type | : | USBR type II |

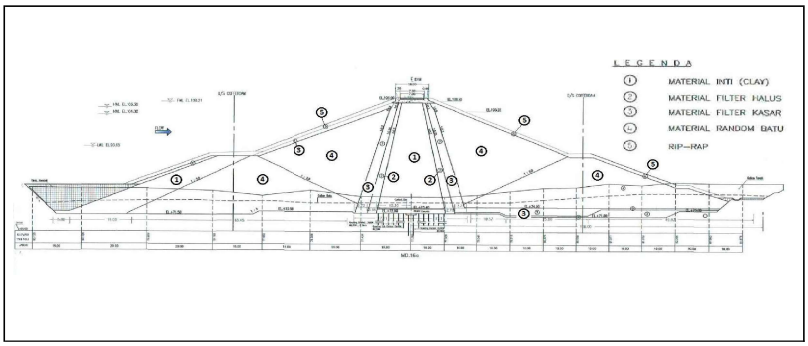
**Diversion**

| | | |
|---|---|---|
| Location | : | Left abutment |
| Type | : | Tunnel |
| Length | : | 256.0 m |
| Dimensions | : | dia. 1.75 m |
| U/S elevation | : | +33.0 m |
| D/S elevation | : | +31.7 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Kotabakti |
| Rock/soil | : | sandstone, silty sandston, claystone, clay |
| Rock Class (CRIEPI) | : | ;– |
| Main Dam Foundation | : | sandstone, silty sandston, claystone, clay |
| Spillway Foundation | : | sandstone, silty sandston, claystone, clay |
| Diversion Foundation | : | sandstone, silty sandston, claystone, clay |

| | | |
|---|---|---|
| Dam Name | : | Raknamo |
| Province | : | Nuta Tenggara Timur |
| Regency | : | Kupang |
| Coordinate | : | 124°26'49.8" E<br>9°43'6.24" S |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal, with centre core |
| Height | : | 37.2 m |
| Elevation of crest | : | +110.2 m |
| Elevation base foundation | : | +73.0 m |
| Wide of crest | : | 10.0 m |
| Lenght of crest | : | 438.0 m |
| Upstream slope | : | 1: 3.0 |
| Downstream slope | : | 1: 2.5 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | + 104.00 m |
| Elv. of low water level (LWL) | : | +95.15 m |
| Elv. of flood water level Q1000 | : | +106.30 m |
| Elv. of flood water level QPMF | : | +108.21 m |
| Normal storage capacity | : | 14.09 million $m^3$ |
| Dead storage capacity | : | 3.83 million $m^3$ |
| Effective storage capacity | : | 9.31 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 211.46 $m^3/s$ |
| 10 year return period | : | 242.64 $m^3/s$ |
| 25 year old return period | : | 267.87 $m^3/s$ |
| 50 year return period | : | 281.44 $m^3/s$ |
| 100 year return period | : | 310.02 $m^3/s$ |
| 1000 year return period | : | 434.71 $m^3/s$ |
| PMF return period | : | 1076.08 $m^3/s$ |

*review design PT Indra Karya 2014

**Intake**

| | | |
|---|---|---|
| Type | : | Drop Intake |
| Tower height | : | 19.15 m |
| Irigation discharge | : | 1.4 l/s/ha |
| Raw water discharge | : | 100 l/s |

**Spillway**

| | | |
|---|---|---|
| Type | : | side channel |
| Length | : | 270.5 m |
| Wide threshold | : | 40.0 m |
| Crest threshold elevation | : | + 104.00 m |
| Stilling Basin type | : | USBR type II |

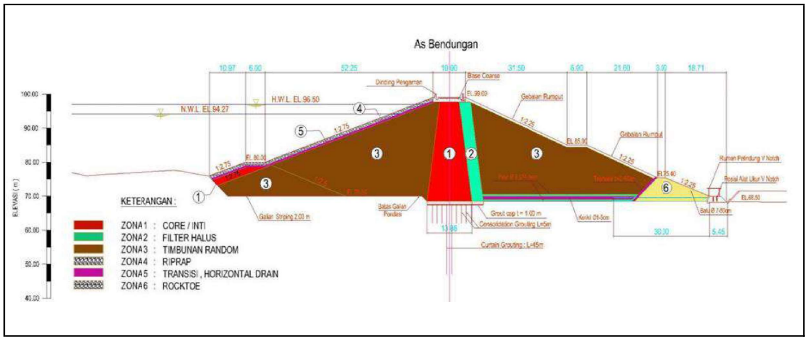
**Diversion**

| | | |
|---|---|---|
| Location | : | right abutment |
| Type | : | tunnel and conduit |
| Length | : | 187.0 m |
| Dimensions | : | 4 m |
| U/S elevation | : | + 77.0 m |
| D/S elevation | : | + 76.0 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Bobonaro |
| Rock/soil | : | Claystone. Siltstone, claystone–siltstone alternation, siltstone–intercaltion claystone |
| Rock Class (CRIEPI) | : | CL, CM |
| Main Dam Foundation | : | Siltstone, claystone–siltstone alt., siltstone–inc. claystone |
| Spillway Foundation | : | Siltstone, claystone–siltstone alt., siltstone–inc. claystone |
| Diversion Foundation | : | claystone–siltstone alt., siltstone–inc claystone |

| | | |
|---|---|---|
| Dam Name | : | Randugunting |
| Province | : | Jawa Tengah |
| Regency | : | Blora |
| Coordinate | : | 52'19.41"S<br>111° 05' 30.20" E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal with vertical core |
| Height | : | 31 m |
| Elevation of crest | : | +99.00 m |
| Elevation base foundation | : | +68.00 m |
| Wide of crest | : | 10 m |
| Lenght of crest | : | 363.35 m |
| Upstream slope | : | 1:2.75 |
| Downstream slope | : | 1:2.25 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +94.27 m |
| Elv. of low water level (LWL) | : | – |
| Elv. of flood water level Q1000 | : | – |
| Elv. of flood water level QPMF | : | +98.02 m |
| Normal storage capacity | : | 10.27 million $m^3$ |
| Dead storage capacity | : | 1.79 million $m^3$ |
| Effective storage capacity | : | 7.65 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | – |
| 10 year return period | : | 50.3 $m^3/s$ |
| 25 year old return period | : | 66.7 $m^3/s$ |
| 50 year return period | : | 79.5 $m^3/s$ |
| 100 year return period | : | 93.9 $m^3/s$ |
| 1000 year return period | : | 160.2 $m^3/s$ |
| PMF return period | : | 329.4 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Intake tower elevation | : | +89.20 m |
| Intake inlet elevation | : | +86.70 m |
| Closere Gate dimension | : | 2 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side Chanel, ogee |
| Length | : | 229.57 m |
| Wide threshold | : | 20.0 m |
| Crest threshold elevation | : | +94.27 m |
| Stilling Basin type | : | USBR type II |

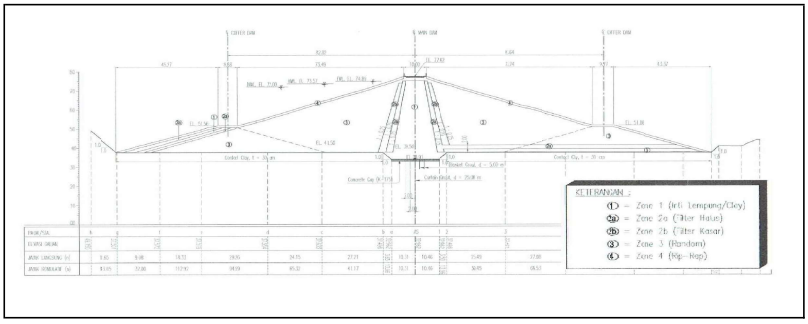
**Diversion**

| | | |
|---|---|---|
| Location | : | River right bank |
| Type | : | Conduit |
| Length | : | 333.7 m |
| Dimensions | : | 2@ 2x3 m |
| U/S elevation | : | +73.00 m |
| D/S elevation | : | +69.1 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Ledok |
| Rock/soil | : | Siltstone, sandstone |
| Rock Class (CRIEPI) | : | D–CL, CM, CH |
| Main Dam Foundation | : | Siltstone, sandstone |
| Spillway Foundation | : | Siltstone, sandstone |
| Diversion Foundation | : | Siltstone, sandstone |

| | | |
|---|---|---|
| Dam Name | : | Rotiklot |
| Province | : | Nusa Tenggara Timur |
| Regency | : | Belu |
| Coordinate | : | 9° 4'2.48" S<br>124° 50'10.50" E. |



**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal |
| Height | : | 42,50 m |
| Elevation of crest | : | + 76,50 m |
| Elevation base foundation | : | + 34,00 m |
| Wide of crest | : | 10,00 m |
| Lenght of crest | : | 415,82 m |
| Upstream slope | : | 1: 3,00 |
| Downstream slope | : | 1: 3,00 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +72,00 m |
| Elv. of low water level (LWL) | : | + 60,00 m |
| Elv. of flood water level Q1000 | : | + 74,89 m |
| Elv. of flood water level QPMF | : | + 75,05 m |
| Normal storage capacity | : | 2.67 million $m^3$ |
| Dead storage capacity | : | 0.57 million $m^3$ |
| Effective storage capacity | : | 2.1 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 48.67 $m^3/s$ |
| 10 year return period | : | 53.7 $m^3/s$ |
| 25 year old return period | : | 55.64 $m^3/s$ |
| 50 year return period | : | 57.89 $m^3/s$ |
| 100 year return period | : | 63.19 $m^3/s$ |
| 1000 year return period | : | 65.95 $m^3/s$ |
| PMF return period | : | 324.15 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Drop intake |
| Intake inlet elevation | : | +60.00 m |
| Gate dimension | : | 2.0 x 2.0 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side Channel |
| Length | : | 255.59 m |
| Wide threshold | : | 31.00 m |
| Crest threshold elevation | : | +72.00 m |
| Stilling Basin type | : | – |

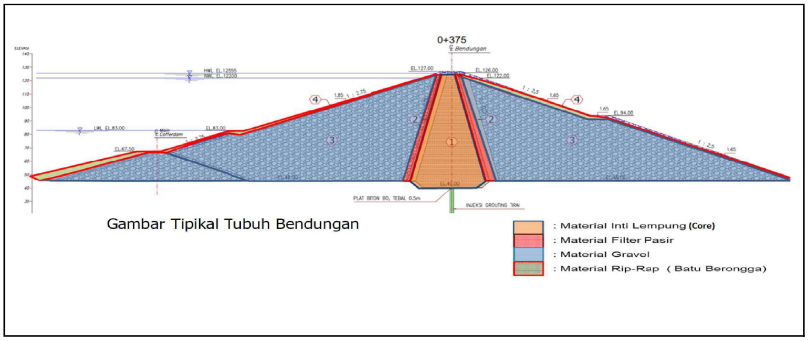
**Diversion**

| | | |
|---|---|---|
| Location | : | Left of river bank |
| Type | : | conduit |
| Length | : | 229.25 m |
| Dimensions | : | 3.0 x 3.0 m |
| U/S elevation | : | + 38.44 m |
| D/S elevation | : | + 37.31 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Maubesse, Bobonaro |
| Rock/soil | : | Claystone |
| Rock Class (CRIEPI) | : | CL, CM–CH |
| Main Dam Foundation | : | Claystone |
| Spillway Foundation | : | Claystone |
| Diversion Foundation | : | Claystone |

| | | |
|---|---|---|
| Dam Name | : | Rukoh |
| Province | : | Aceh |
| Regency | : | Pidie |
| Coordinate | : | 5° 12 '11,40" N<br>95° 53 '40,70" E |



Gambar Tipikal Tubuh Bendungan

**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal with vertical core |
| Height | : | 84.0 m |
| Elevation of crest | : | +127.00 m |
| Elevation base foundation | : | +40 m |
| Wide of crest | : | 12 m |
| Lenght of crest | : | 220.0 m |
| Upstream slope | : | 1:2.75 |
| Downstream slope | : | 1:2.50 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +122.00 m |
| Elv. of low water level (LWL) | : | +83.00 m |
| Elv. of flood water level Q1000 | : | +123.20 m |
| Elv. of flood water level QPMF | : | +125.55 m |
| Normal storage capacity | : | 128.65 million $m^3$ |
| Dead storage capacity | : | 2.96 million $m^3$ |
| Effective storage capacity | : | 125.70 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | – |
| 10 year return period | : | – |
| 25 year old return period | : | – |
| 50 year return period | : | – |
| 100 year return period | : | 133.71 $m^3/s$ |
| 1000 year return period | : | 170.66 $m^3/s$ |
| PMF return period | : | 622.10 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Vertical Intake |
| Location | : | Left Abutment |
| Intake inlet elevation | : | +79.00 m |
| Gate dimension | : | 3.5 x 3.5 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Ungated Ogee |
| Wide threshold | : | 15 m |
| Crest threshold elevation | : | +122 m |
| Stilling type | : | MDO |
| Stilling Basin base elevation | : | +52 m |

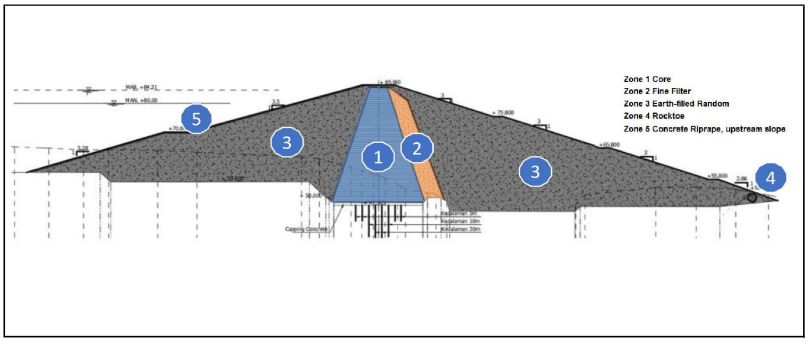
**Diversion**

| | | |
|---|---|---|
| Location | : | Right abutment |
| Type | : | tunnel |
| Length | : | 510.0 m |
| Dimensions | : | 3.0 m |
| U/S elevation | : | +58.5 m |
| D/S elevation | : | – |

**Geology**

| | | |
|---|---|---|
| Formation | : | Kotabakti |
| Rock/soil | : | silty sandtone, claystone |
| Rock Class (CRIEPI) | : | CL, CL–CM |
| Main Dam Foundation | : | silty sandtone, claystone |
| Spillway Foundation | : | silty sandtone, claystone |
| Diversion Foundation | : | silty sandtone, claystone |

| | | |
|---|---|---|
| Dam Name | : | Sadawarna |
| Province | : | Jawa Barat |
| Regency | : | Subang & Sumedang |
| Coordinate | : | 6° 35'14.26"S<br>107° 50'55.15"E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Earth–filled dam, central core |
| Height | : | 40 m |
| Elevation of crest | : | +85.00 m |
| Elevation base foundation | : | +45.00 m |
| Wide of crest | : | 10 m |
| Lenght of crest | : | 929 m |
| Upstream slope | : | 1:3.5 |
| Downstream slope | : | 1:3.0 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +80.00 m |
| Elv. of low water level (LWL) | : | +64.00 m |
| Elv. of flood water level Q1000 | : | – |
| Elv. of flood water level QPMF | : | +84.20 m |
| Normal storage capacity | : | 44.61 million m3 |
| Dead storage capacity | : | 3.58 million m3 |
| Effective storage capacity | : | 41.03 million m3 |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | – |
| 10 year return period | : | – |
| 25 year old return period | : | 728.00 m3/s |
| 50 year return period | : | 875.00 m3/s |
| 100 year return period | : | 1,039.00 m3/s |
| 1000 year return period | : | 1,404.00 m3/s |
| PMF return period | : | 2,625.00 m3/s |

*source: final report PT. Tata Guna Patria, 2016

**Intake**

| | | |
|---|---|---|
| Type | : | Submarge |
| Intake inlet elevation | : | +64.00 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Ungated spillway (semi circle), Ogee |
| Length | : | 375.47 m |
| Wide threshold | : | 132 (semi circle) |
| Crest threshold elevation | : | +80.00 m |
| Stilling Basin type | : | USBR tipe II |

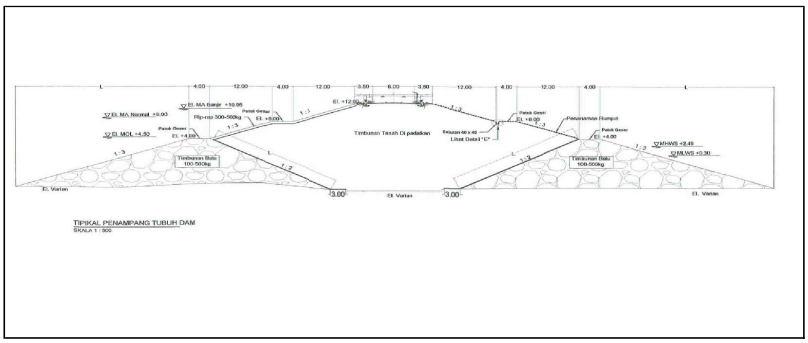
**Diversion**

| | | |
|---|---|---|
| Location | : | river right bank |
| Type | : | open cut conduit |
| Length | : | 620.6 m |
| Dimensions | : | 2 @ 4.0 m x 6.0 m |
| U/S elevation | : | +49.0 m |
| D/S elevation | : | +48.0 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Citalang & Subang |
| Rock/soil | : | Claystone, sandstone, Breccia |
| Rock Class (CRIEPI) | : | D, CL, CM |
| Main Dam Foundation | : | Claystone, sandstone, Breccia |
| Spillway Foundation | : | claystone, Breccia |
| Diversion Foundation | : | Sandstone, Breccia |

| | | |
|---|---|---|
| Dam Name | : | Sei Gong |
| Province | : | Batam City |
| Regency | : | Kepulauan Riau |
| Coordinate | : | 1° 10'35.58" N<br>104° 5'16.59"E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Homogeneous earth-fill dam |
| Height | : | 16.0 m |
| Elevation of crest | : | +12.0 m |
| Elevation base foundation | : | −4.0 m |
| Wide of crest | : | 15.0 m |
| Lenght of crest | : | 280.0 m |
| Upstream slope | : | 1:3 |
| Downstream slope | : | 1:3 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +9.0 m |
| Elv. of low water level (LWL) | : | – |
| Elv. of flood water level Q1000 | : | – |
| Elv. of flood water level QPMF | : | +10.95 m |
| Normal storage capacity | : | 11.7 million $m^3$ |
| Dead storage capacity | : | 2.8 million $m^3$ |
| Effective storage capacity | : | 8.9 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 152.8 $m^3/s$ |
| 10 year return period | : | 188.9 $m^3/s$ |
| 25 year old return period | : | 238.5 $m^3/s$ |
| 50 year return period | : | 278.4 $m^3/s$ |
| 100 year return period | : | 320.9 $m^3/s$ |
| 1000 year return period | : | 484.8 $m^3/s$ |
| PMF return period | : | 626.4 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | – |
| Tower height | : | – |
| Intake inlet elevation | : | – |
| Gate dimension | : | – |

**Spillway**

| | | |
|---|---|---|
| Type | : | Ogee |
| Length | : | 60.0 m |
| Wide threshold | : | 20.0 m |
| Crest threshold elevation | : | +9.0 m |
| Stilling Basin type | : | – |

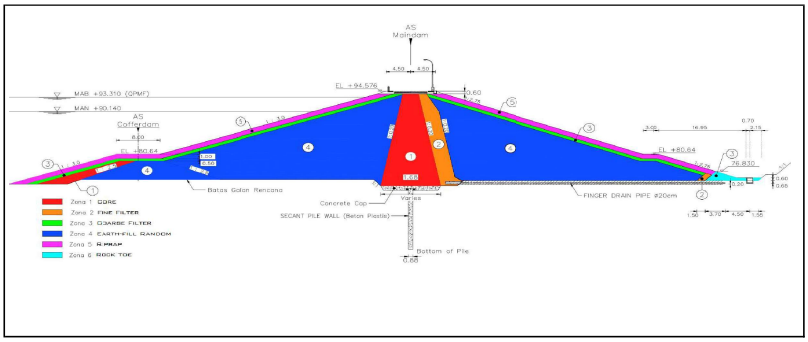
**Diversion**

| | | |
|---|---|---|
| Location | : | Right of river bank |
| Type | : | Open channel & conduit |
| Length | : | 80 m (conduit) |
| Dimensions | : | 2@ 1.5x2.2 m |
| U/S elevation | : | +0.5 m |
| D/S elevation | : | '+0.3 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Tanjungkerotang |
| Rock/soil | : | quartz sandstone, claystone, sandy claystone, sandy tuff |
| Rock Class (CRIEPI) | : | |
| Main Dam Foundation | : | quartz sandstone, claystone, sandy claystone, sandy tuff |
| Spillway Foundation | : | sandy claystone |
| Diversion Foundation | : | residual soil, sandy tuff, quartz sandstone |

| | | |
|---|---|---|
| Dam Name | : | Semantok |
| Province | : | Jawa Timur |
| Regency | : | Nganjuk |
| Coordinate | : | 07° 29' 42" S<br>111° 53' 26" E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal Earth-Filled Dam, Central core |
| Height | : | 30 m |
| Elevation of crest | : | +94.5 m |
| Wide of crest | : | 9 m |
| Lenght of crest | : | 3,100 m |
| Upstream slope | : | 1:3.00 |
| Downstream slope | : | 1:2.75 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +90.14 m |
| Elv. of low water level (LWL) | : | – |
| Elv. of flood water level Q1000 | : | +92.98 m |
| Elv. of flood water level QPMF | : | +93.31 m |
| Normal storage capacity | : | 22.41 million m3 |
| Dead storage capacity | : | 4.1 million m3 |
| Effective storage capacity | : | 18.31 million m3 |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 198.09 m3/sec |
| 10 year return period | : | 215.81 m3/sec |
| 25 year old return period | : | 237.18 m3/sec |
| 50 year return period | : | 249.59 m3/sec |
| 100 year return period | : | 262.49 m3/sec |
| 1000 year return period | : | 301.96 m3/sec |
| PMF return period | : | 869.67 m3/sec |

*main report, PT Virama Karya 2017

**Intake**

| | | |
|---|---|---|
| Type | : | Submarge Tower |
| Tower height | : | 16.38 m |
| Intake inlet elevation | : | +80.64 m |
| valve dimension | : | 1.2 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Ungated Spillway, ogee |
| Length | : | – |
| threshold length | : | 62.69 m |
| Crest threshold elevation | : | +90.14 m |
| Stilling Basin type | : | – |

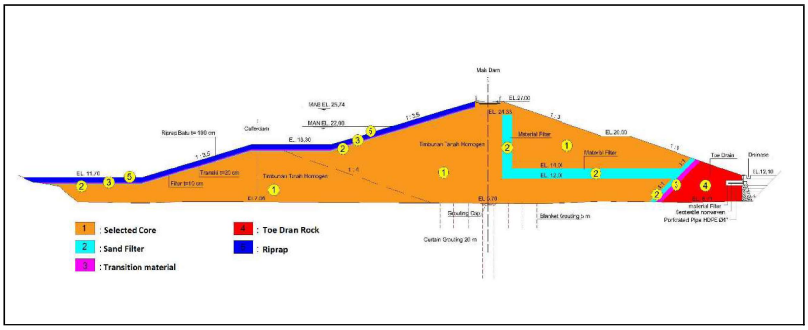
**Diversion**

| | | |
|---|---|---|
| Location | : | Right bank of river |
| Type | : | Conduit |
| Length | : | – |
| Dimensions | : | – |
| U/S elevation | : | +66.3 m |
| D/S elevation | : | +65.5 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Kabuh (QPk) |
| Rock/soil | : | sandstone, claystone |
| Rock Class (CRIEPI) | : | D, CL, CM |
| Main Dam Foundation | : | claystone, sandstone |
| Spillway Foundation | : | claystone, sandstone |
| Diversion Foundation | : | sandstone |

| | | |
|---|---|---|
| Dam Name | : | Sepaku Semoi |
| Province | : | Kalimantan Timur |
| Regency | : | Penajam Paser Utara |
| Coordinate | : | 0°54' 33,5" N<br>116° 50' 24,7" S |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Homogeneous Dam |
| Height | : | 22.0 m |
| Elevation of crest | : | + 27.0 m |
| Elevation base foundation | : | + 5.0 m |
| Wide of crest | : | 6.0 m |
| Lenght of crest | : | 450 m |
| Upstream slope | : | 1:3.5 |
| Downstream slope | : | 1:3.0 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +22.0 m |
| Elv. of low water level (LWL) | : | + 18.0 m |
| Elv. of flood water level Q1000 | : | + 23.88 m |
| Elv. of flood water level QPMF | : | + 25.74 m |
| Normal storage capacity | : | 16.17 million m3 |
| Dead storage capacity | : | 3.44 million m3 |
| Effective storage capacity | : | 17.73 million m3 |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 259.6 m3/sec |
| 10 year return period | : | 319.4 m3/sec |
| 25 year old return period | : | 391.6 m3/sec |
| 50 year return period | : | 441.7 m3/sec |
| 100 year return period | : | 488.7 m3/sec |
| 1000 year return period | : | 625.6 m3/sec |
| PMF return period | : | 1612.6 m3/sec |

**Intake**

| | | |
|---|---|---|
| Type | : | Drop Inlet, Hollow Cone |
| Dimensions / size | : | 1.1 m |
| Intake inlet elevation | : | +16.5 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | side channel, ogee |
| Length | : | 179 m |
| Wide threshold | : | 60 m |
| Crest threshold elevation | : | + 22.0 m |
| Downstream slope of mercu | : | 1:500 |

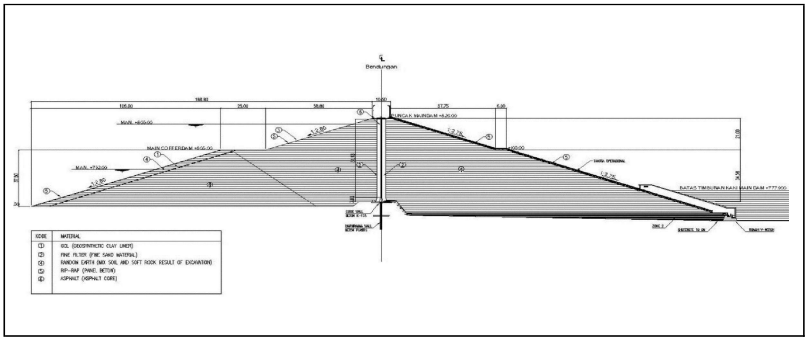
**Diversion**

| | | |
|---|---|---|
| Location | : | right bank |
| Type | : | Conduit |
| Length | : | 161.0 m |
| Dimensions | : | 4x4m, 2 pieces |
| U/S elevation | : | + 10.50 m |
| D/S elevation | : | + 9.50 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Pamaluan (Tomp) |
| Rock/soil | : | quartz sandstone intercalated claystone, limestone, siltstone |
| Rock Class (CRIEPI) | : | CL, CM |
| Main Dam Foundation | : | sandstone, claystone, limestone |
| Spillway Foundation | : | claystone (CL) |
| Diversion Foundation | : | claystone (CL) |

| | | |
|---|---|---|
| Dam Name | : | Sidan |
| Province | : | Bali |
| Regency | : | Badung & Gianyar |
| Coordinate | : | 8° 18'47,43"S<br>115° 14'51,39"E |



**Main Dam**

| | | |
|---|---|---|
| Type | : | Rock filled dam with Asphalt core |
| Height | : | 68.0 m |
| Elevation of crest | : | +826.00 m |
| Elevation base foundation | : | +758.00 m |
| Wide of crest | : | 10.5 m |
| Lenght of crest | : | 185.0 m |
| Upstream slope | : | 1:2.8 |
| Downstream slope | : | 1:2.75 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +820.00 m |
| Elv. of low water level (LWL) | : | +794.00 m |
| Elv. of flood water level Q1000 | : | +823.20 m |
| Elv. of flood water level QPMF | : | +823.95 m |
| Normal storage capacity | : | 3.82 million $m^3$ |
| Dead storage capacity | : | 3.17 million $m^3$ |
| Effective storage capacity | : | 0.65 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | – |
| 10 year return period | : | – |
| 25 year old return period | : | – |
| 50 year return period | : | 446.24 $m^3/s$ |
| 100 year return period | : | 496.24 $m^3/s$ |
| 1000 year return period | : | 749.87 $m^3/s$ |
| PMF return period | : | 1022.5 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | shaft and tower |
| Tower height | : | 64.56 m |
| Intake inlet elevation | : | +794.00 m |
| Gate dimension | : | 2.58 x 2.50 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side channel tunnel, ogee |
| Length | : | 528.57 m |
| Wide threshold | : | 60.00 m |
| Crest threshold elevation | : | +820.00 m |
| Stilling Basin type | : | Flip Bucket |

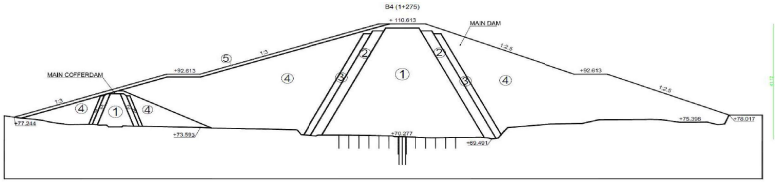
**Diversion**

| | | |
|---|---|---|
| Location | : | Left Abutment |
| Type | : | Tunnel |
| Length | : | 452.0 m |
| Dimensions | : | 5.0 m |
| U/S elevation | : | +771.00 m |
| D/S elevation | : | +751.00 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Buyan–Bratan–Batur Volcanic |
| Rock/soil | : | Andesitic breccia, volcanic breccia, sandy tuff |
| Rock Class (CRIEPI) | : | – |
| Main Dam Foundation | : | Andesitic breccia, volcanic breccia, sandy tuff |
| Spillway Foundation | : | volcanic breccia, sandy tuff |
| Diversion Foundation | : | volcanic breccia, sandy tuff |

| | | |
|---|---|---|
| Dam Name | : | Sindang Heula |
| Province | : | Banten |
| Regency | : | Serang |
| Coordinate | : | 106°6'52" E<br>6° 10'52.4" S |




KETERANGAN

1. INTI LEMPUNG CLAY CORE
2. FILTER Tebal 3.00m FILTER thickness 3 m
3. TRANSISI Tebal 2.00m TRANSITION thickness 2 m
4. URUGAN BATU ROCK-FILLED
5. URUGAN BATU ROCK-FILLED

**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal with central core |
| Height | : | 42.0 m |
| Elevation of crest | : | 110.63 m |
| Elevation base foundation | : | +68.63 m |
| Wide of crest | : | 14.0 m |
| Lenght of crest | : | 205.2 m |
| Upstream slope | : | 1:3.0 |
| Downstream slope | : | 1:2.5 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | '+106.61 m |
| Elv. of low water level (LWL) | : | +86.61 m |
| Elv. of flood water level Q1000 | : | – |
| Elv. of flood water level QPMF | : | +108.61 m |
| Normal storage capacity | : | 9.25 million $m^3$ |
| Dead storage capacity | : | 8.99 million $m^3$ |
| Effective storage capacity | : | 0.26 million $m^3$ |

Punya saddle dam

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 143.77 $m^3/s$ |
| 10 year return period | : | 143.77 $m^3/s$ |
| 25 year old return period | : | 322.55 $m^3/s$ |
| 50 year return period | : | 402.33 $m^3/s$ |
| 100 year return period | : | 488.06 $m^3/s$ |
| 1000 year return period | : | 785.07 $m^3/s$ |
| PMF return period | : | 1445.27 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Gate Type | : | sliding gate |
| Intake inlet elevation | : | +83.6 m |
| Gate dimension | : | 1.2 x 1.2 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | ungated overflow, ogee |
| Length | : | 155.0 m |
| Wide threshold | : | 50.0 m |
| Crest threshold elevation | : | +106.61 m |
| Stilling Basin type | : | – |

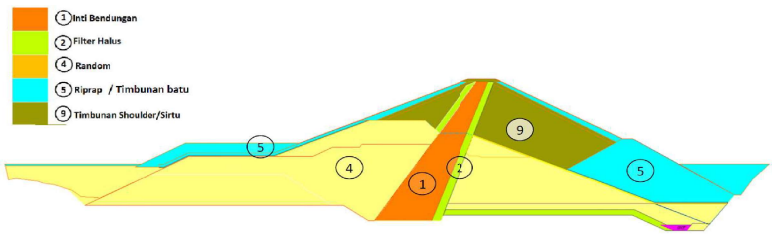
**Diversion**

| | | |
|---|---|---|
| Location | : | right abutmet |
| Type | : | conduit |
| Length | : | 204.0 m |
| Dimensions | : | 3.5 m |
| U/S elevation | : | +76.61 m |
| D/S elevation | : | +76.61 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Bantem tuff |
| Rock/soil | : | Pumiceous tuff, welded tuff (ignimbrite ) |
| Rock Class (CRIEPI) | : | – |
| Main Dam Foundation | : | Pumiceous tuff, welded tuff (ignimbrite ) |
| Spillway Foundation | : | Pumiceous tuff |
| Diversion Foundation | : | Pumiceous tuff, welded tuff (ignimbrite ) |

| | | |
|---|---|---|
| Dam Name | : | Sukamahi |
| Province | : | Jawa Barat |
| Regency | : | Bogor |
| Coordinate | : | 106° 52' 20'' E<br>06 ° 39' 28'' S |




**Main Dam**

| | | |
|---|---|---|
| Type | : | zonal random filled with incline core |
| Height | : | 50 m |
| Elevation of crest | : | +601.00 m |
| Elevation base foundation | : | +551.00 m |
| Wide of crest | : | 9.0 m |
| Lenght of crest | : | 177.98 m |
| Upstream slope | : | 1:2.00 |
| Downstream slope | : | 1:1.70 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +596.75 m |
| Elv. of low water level (LWL) | : | – |
| Elv. of flood water level Q1000 | : | – |
| Elv. of flood water level QPMF | : | +599.87 m |
| Normal storage capacity | : | – |
| Dead storage capacity | : | – |
| Effective storage capacity | : | 1.38 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 38.80 $m^3/s$ |
| 10 year return period | : | 44.42 $m^3/s$ |
| 25 year old return period | : | 51.54 $m^3/s$ |
| 50 year return period | : | 56.52 $m^3/s$ |
| 100 year return period | : | 62.12 $m^3/s$ |
| 1000 year return period | : | 79.59 $m^3/s$ |
| PMF return period | : | 253.97 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Tower height | : | – |
| Intake inlet elevation | : | +577.85 m |
| Gate dimension | : | 3x3 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side Channel, ogee |
| Length | : | 207.7 m |
| Wide threshold | : | 16.0 m |
| Crest threshold elevation | : | +596.75 m |
| Stilling Basin type | : | USBR type III |

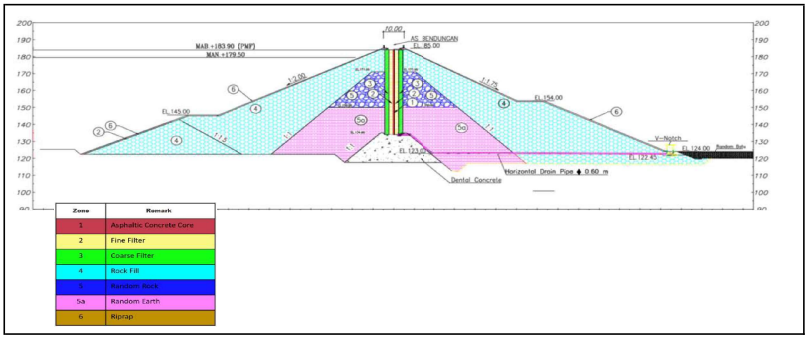
**Diversion**

| | | |
|---|---|---|
| Location | : | right of river bank |
| Type | : | conduit |
| Length | : | 201.5 m |
| Dimensions | : | 3 m, 2 pieces |
| U/S elevation | : | +565.00 m |
| D/S elevation | : | +545.44 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Pangarango Volcanic |
| Rock/soil | : | Breccia |
| Rock Class (CRIEPI) | : | Residual soil, D, CL, CM |
| Main Dam Foundation | : | Breccia |
| Spillway Foundation | : | Breccia |
| Diversion Foundation | : | Breccia |

| | | |
|---|---|---|
| Dam Name | : | Tamblang |
| Province | : | Bali |
| Regency | : | Buleleng |
| Coordinate | : | 8° 03'40"–8° 23'00" S<br>114° 25'55"–115° 27'28" E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | ACCED |
| Height | : | 70 m |
| Elevation of crest | : | +185 m |
| Elevation base foundation | : | +115 m |
| Wide of crest | : | 10 m |
| Lenght of crest | : | 260 m |
| Upstream slope | : | 1:2.25 & 1:2.00 |
| Downstream slope | : | 1:2.00 & 1:1.75 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +179.5 m |
| Elv. of low water level (LWL) | : | +161.0 m |
| Elv. of flood water level Q1000 | : | +181.8 m |
| Elv. of flood water level QPMF | : | +183.9 m |
| Normal storage capacity | : | 7.6 million m³ |
| Dead storage capacity | : | 2.0 million m³ |
| Effective storage capacity | : | 5.6 million m³ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 88.91 m³/sec |
| 10 year return period | : | 135.28 m³/sec |
| 25 year old return period | : | 210.63 m³/sec |
| 50 year return period | : | 279.76 m³/sec |
| 100 year return period | : | 360.55 m³/sec |
| 1000 year return period | : | 733.61 m³/sec |
| PMF return period | : | 1577.57 m³/sec |

*source: PT. Vitraha, 2017

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Tower height | : | 56 m |
| Intake inlet elevation | : | +161.0 m |
| Gate dimension | : | 3.0 x 3.0 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side Channel, ogee |
| Length | : | 220.47 m |
| Wide threshold | : | 70 m |
| Crest threshold elevation | : | +179 m |
| Stilling Basin type | : | Sky Jump |

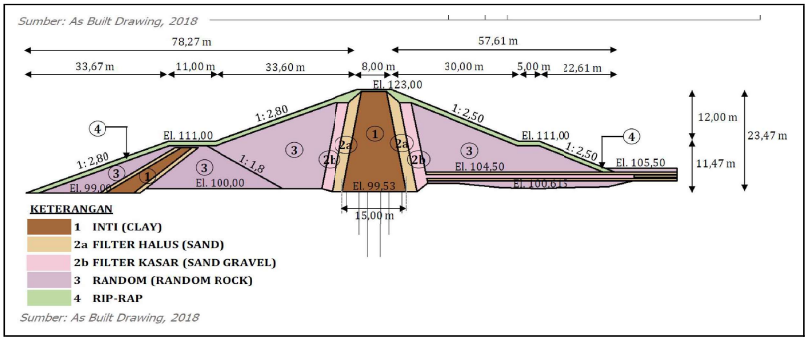
**Diversion**

| | | |
|---|---|---|
| Location | : | Right abutment of Dam |
| Type | : | Tunnel |
| Length | : | 349.4 m |
| Dimensions | : | 4.5 m |
| U/S elevation | : | +128 m |
| D/S elevation | : | +122 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Volcanic rock |
| Rock/soil | : | Andesit lava, volcanic breccia, tuff |
| Rock Class (CRIEPI) | : | D, CL, CM, CH |
| Main Dam Foundation | : | Andesit lava, volcanic breccia, tuff |
| Spillway Foundation | : | volcanic breccia, tuff |
| Diversion Foundation | : | Andesit lava, volcanic breccia, tuff |

| | | |
|---|---|---|
| Dam Name | : | Tanju |
| Province | : | Nusa Tenggara Barat |
| Regency | : | Dompu |
| Coordinate | : | 118 0 20 57" E<br>8 0 28 20" S |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Random fill with central core |
| Height | : | 23.47 m |
| Elevation of crest | : | +123.0 m |
| Elevation base foundation | : | +99.53 m |
| Wide of crest | : | 8.0 m |
| Lenght of crest | : | 106.4 m |
| Upstream slope | : | 1:2.8 |
| Downstream slope | : | 1:2.5 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +120.0 m |
| Elv. of low water level (LWL) | : | +112.0 m |
| Elv. of flood water level Q1000 | : | ,+120.62 m |
| Elv. of flood water level QPMF | : | +121.49 m |
| Normal storage capacity | : | 18.27 million m³ |
| Dead storage capacity | : | 1.74 million m³ |
| Effective storage capacity | : | 17.16 million m³ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 84.52 m³/s |
| 10 year return period | : | 99.74 m³/s |
| 25 year old return period | : | 111.6 m³/s |
| 50 year return period | : | 118.0 m³/s |
| 100 year return period | : | 175.0 m³/s |
| 1000 year return period | : | 196.2 m³/s |
| PMF return period | : | 606.2 m³/s |

**Intake**

| | | |
|---|---|---|
| Type | : | Drop inlet |
| Intake inlet elevation | : | +112.0 m |
| Gate dimension | : | 2 x 2 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Overflow |
| Length | : | 142 m |
| Wide threshold | : | 20.0 m |
| Crest threshold elevation | : | +120.0 m |
| Stilling Basin type | : | USBR tye II |

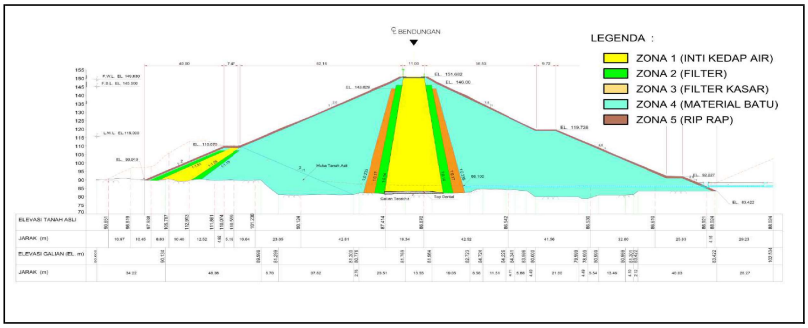
**Diversion**

| | | |
|---|---|---|
| Location | : | Right of river bank |
| Type | : | Conduit |
| Length | : | 420.0 m |
| Dimensions | : | 3.0 x 3.0 m |
| U/S elevation | : | +104.00 m |
| D/S elevation | : | +101.00 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Breksi Tuff unit |
| Rock/soil | : | andesite, breccia |
| Rock Class (CRIEPI) | : | CM, CH, B |
| Main Dam Foundation | : | andesite |
| Spillway Foundation | : | andesite |
| Diversion Foundation | : | andesite, breccia |

| | | |
|---|---|---|
| Dam Name | : | Tapin |
| Province | : | Kalimantan Selatan |
| Regency | : | Tapin |
| Coordinate | : | Tapin |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Rock-filled dam with vertical core |
| Height | : | 70.0 m |
| Elevation of crest | : | +151.00 m |
| Elevation base foundation | : | +81.0 m |
| Wide of crest | : | 12.0 m |
| Lenght of crest | : | 262.7 m |
| Upstream slope | : | 1:2.0 |
| Downstream slope | : | 1:1.8 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +145.50 m |
| Elv. of low water level (LWL) | : | +116.00 m |
| Elv. of flood water level Q1000 | : | +148.81 m |
| Elv. of flood water level QPMF | : | +150.85 m |
| Normal storage capacity | : | 56.72 millioin $m^3$ |
| Dead storage capacity | : | 6.51 millioin $m^3$ |
| Effective storage capacity | : | 50.21 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 262.0 $m^3/s$ |
| 10 year return period | : | 338.7 $m^3/s$ |
| 25 year old return period | : | 449.2 $m^3/s$ |
| 50 year return period | : | 541.5 $m^3/s$ |
| 100 year return period | : | 641.4 $m^3/s$ |
| 1000 year return period | : | 1034 $m^3/s$ |
| PMF return period | : | 1926.6 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Inclined Shaft Intake |
| Incline length | : | 38.55 m |
| Intake inlet elevation | : | +116.00 m |
| Gate dimension | : | 2 pieces, 2.70 x 3.00 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Ungated side chanel |
| Length | : | – |
| Wide threshold | : | 52.0 m |
| Crest threshold elevation | : | +145.50 m |
| Stilling Basin type | : | USBR type II |

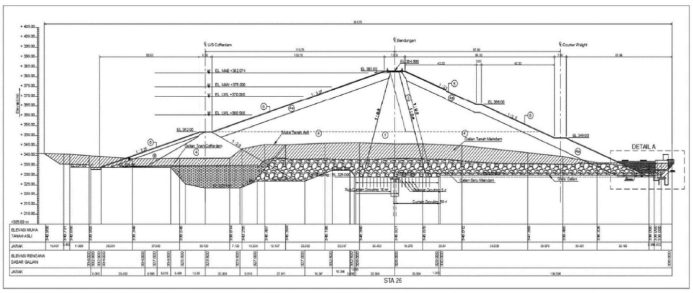
**Diversion**

| | | |
|---|---|---|
| Location | : | Dam left abutment |
| Type | : | Tunnel |
| Length | : | – |
| Dimensions | : | – |
| U/S elevation | : | +90.00 m |
| D/S elevation | : | +89.00 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Haruyan volcanic |
| Rock/soil | : | Andesit, basalt |
| Rock Class (CRIEPI) | : | D, CL-CM, CM-CH |
| Main Dam Foundation | : | Andesit |
| Spillway Foundation | : | Andesit |
| Diversion Foundation | : | Andesit |

| | | |
|---|---|---|
| Dam Name | : | Temef |
| Province | : | Nusa Tenggara Timur |
| Regency | : | Timor Tengah Selatan |
| Coordinate | : | 9° 42'30" S; 124° 27 '40" E |



**Main Dam**

| | | |
|---|---|---|
| Type | : | Selective random-Fill with Central Core |
| Height | : | 53.0 m |
| Elevation of crest | : | +383.00m |
| Elevation base foundation | : | No data |
| Wide of crest | : | 12.0 m |
| Lenght of crest | : | 535.0 m |
| Upstream slope | : | 1:3.25 |
| Downstream slope | : | 1:2.50 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +375.00 m |
| Elv. of low water level (LWL) | : | +360.00 m |
| Elv. of flood water level Q1000 | : | No data |
| Elv. of flood water level QPMF | : | +382.07 m |
| Normal storage capacity | : | No data |
| Dead storage capacity | : | No data |
| Effective storage capacity | : | No data |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 195.24 m3/sec |
| 10 year return period | : | 268.60 m3/sec |
| 25 year old return period | : | 362.97 m3/sec |
| 50 year return period | : | 433.86 m3/sec |
| 100 year return period | : | 504.82 m3/sec |
| 1000 year return period | : | 742.26 m3/sec |
| PMF return period | : | 3274.93 m3/sec |

**Intake**

| | | |
|---|---|---|
| Type | : | Stand-up Tower |
| Dimensions / size | : | 20.00 x 23.00 m |
| Tall tower from foundation | : | 47.12 m |
| Intake inlet elevation | : | +360.50m & +370.00m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side channel |
| Length | : | 520.0 m |
| Wide threshold | : | 70.0 m |
| Width of side channel | : | 35 – 50 m |
| Downstream slope of mercu | : | 1:2000 |

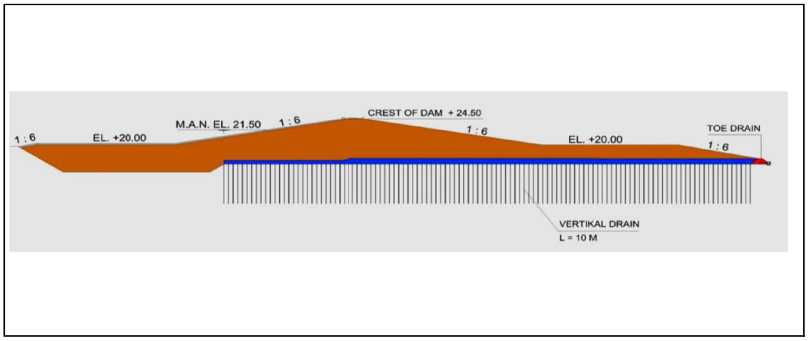
**Diversion**

| | | |
|---|---|---|
| Location | : | Left Abutment |
| Type | : | Conduit |
| Length | : | 490.00 m |
| Dimensions | : | 2 x 5.50m x 5.50m |
| U/S elevation | : | +338.00 m |
| D/S elevation | : | +337.00 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Bobonaro, Noele, Coraline |
| Rock/soil | : | sandstone, claystone, limestone |
| Rock Class (ISRM) | : | R0, R1, R2 |
| Main Dam Foundation | : | sandstone, claystone |
| Spillway Foundation | : | sandstone, claystone, scaly clay |
| Diversion Foundation | : | sandstone, claystone |

| | | |
|---|---|---|
| Dam Name | : | Teritip |
| Province | : | Kalimantan Timur |
| Regency | : | Balikpapan |
| Coordinate | : | 1° 9'0,34"S<br>116° 58'54,15"E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Homogeneous earth filled dam |
| Height | : | 11.65 m |
| Elevation of crest | : | +24.50 m |
| Elevation base foundation | : | +12.85 m |
| Wide of crest | : | 7.0 m |
| Lenght of crest | : | 650.0 m |
| Upstream slope | : | 1 : 6 |
| Downstream slope | : | 1 : 6 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | + 21.50 m |
| Elv. of low water level (LWL) | : | + 19.10 m |
| Elv. of flood water level Q1000 | : | + 22.67 m |
| Elv. of flood water level QPMF | : | + 23.66 m |
| Normal storage capacity | : | 2.43 million $m^3$ |
| Dead storage capacity | : | 0.278 million $m^3$ |
| Effective storage capacity | : | 2.15 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 109.49 $m^3/s$ |
| 10 year return period | : | 124.74 $m^3/s$ |
| 25 year old return period | : | 144.85 $m^3/s$ |
| 50 year return period | : | 158.34 $m^3/s$ |
| 100 year return period | : | 171.77 $m^3/s$ |
| 1000 year return period | : | 178.92 $m^3/s$ |
| PMF return period | : | 685.12 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Capacity | : | 260 liter/sec |
| Intake inlet elevation | : | + 17.40 m |
| Pipe dimension | : | 0.8 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Fixed treshold, ogee |
| Length | : | – |
| Wide threshold | : | 20.0 m |
| Crest threshold elevation | : | + 21.50 m |
| Stilling Basin type | : | USBR type III |

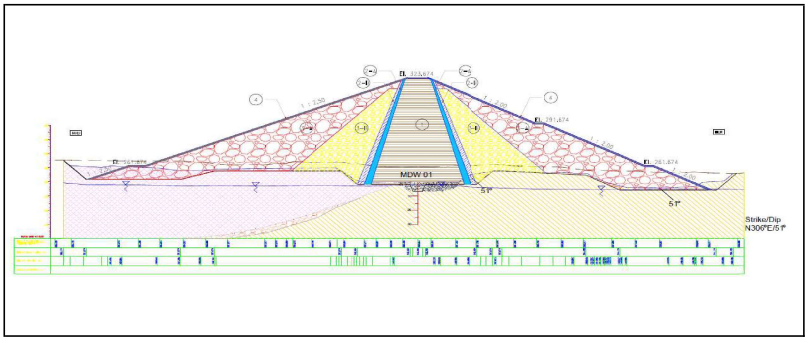
**Diversion**

| | | |
|---|---|---|
| Location | : | Right of river bank |
| Type | : | Conduit |
| Length | : | 148.7 m |
| Dimensions | : | 3.0 x 3.0 m, 2@ |
| U/S elevation | : | + 15.00 m |
| D/S elevation | : | + 14.50 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Kampungbaru |
| Rock/soil | : | Clay, quartz sand |
| Rock Class (CRIEPI) | : | – |
| Main Dam Foundation | : | Clay, quartz sand |
| Spillway Foundation | : | Clay, quartz sand |
| Diversion Foundation | : | Clay, quartz sand |

| | | |
|---|---|---|
| Dam Name | : | Tiga Dihaji |
| Province | : | Sumatra Selatan |
| Regency | : | OKU selatan |
| Coordinate | : | 4° 37'46,83"S<br>103° 52'40,90"E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Rock fill with vertical core |
| Height | : | 122.0 m |
| Elevation of crest | : | +332.0 m |
| Elevation base foundation | : | +210.0 m |
| Wide of crest | : | 12.0 m |
| Lenght of crest | : | 950.0 m |
| Upstream slope | : | 1:2.5 |
| Downstream slope | : | 1:2.0 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +324.0 m |
| Elv. of low water level (LWL) | : | +301,5 m |
| Elv. of flood water level Q1000 | : | +324.7 m |
| Elv. of flood water level QPMF | : | +328.9 m |
| Normal storage capacity | : | 104.8 million $m^3$ |
| Dead storage capacity | : | 40.19 million $m^3$ |
| Effective storage capacity | : | 64.6 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | – |
| 10 year return period | : | – |
| 25 year old return period | : | 910.7 $m^3/s$ |
| 50 year return period | : | – |
| 100 year return period | : | 1074.9 $m^3/s$ |
| 1000 year return period | : | 1210.6 $m^3/s$ |
| PMF return period | : | 3763.9 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Tower |
| Tower height | : | 37.75 m |
| Intake inlet elevation | : | + 301.5 m |
| Gate dimension | : | 5 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | geted frontal ogee |
| Length | : | – |
| Wide threshold | : | 80.0 m |
| Crest threshold elevation | : | +324.0 m |
| Stilling Basin type | : | USBR type II |

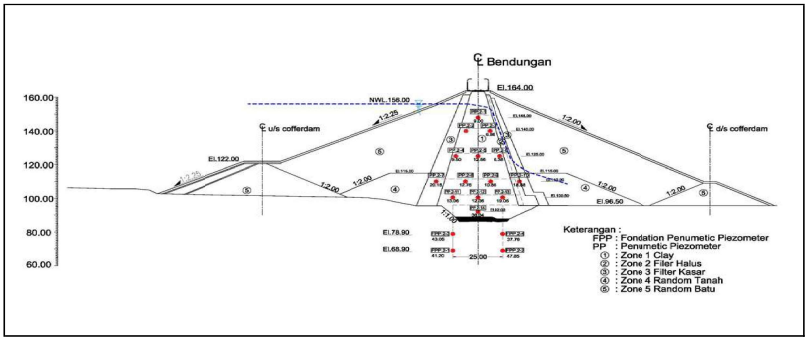
**Diversion**

| | | |
|---|---|---|
| Location | : | right abutment |
| Type | : | tunnel |
| Length | : | 595 m |
| Dimensions | : | 7,0 m |
| U/S elevation | : | +221.00 m |
| D/S elevation | : | +218.22 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Ranau & gumai |
| Rock/soil | : | Sand, tuff, sandston–claystone alternation |
| Rock Class (CRIEPI) | : | – |
| Main Dam Foundation | : | Sand, tuff, sandston–claystone alternation |
| Spillway Foundation | : | Sand, tuff, sandston–claystone alternation |
| Diversion Foundation | : | sand, tuff |

| | | |
|---|---|---|
| Dam Name | : | Titab |
| Province | : | Bali |
| Regency | : | Buleleng |
| Coordinate | : | 8° 14'39.76"S<br>114° 56'34.73"E |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Randam rockfilled dam with verical core |
| Height | : | 82.4 m |
| Elevation of crest | : | +162.4 m |
| Elevation base foundation | : | – |
| Wide of crest | : | 12.0 m |
| Lenght of crest | : | 210.0 m |
| Upstream slope | : | 1:2.25 |
| Downstream slope | : | 1:2.00 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +156.0 m |
| Elv. of low water level (LWL) | : | +130.8 m |
| Elv. of flood water level Q1000 | : | +158.93 m |
| Elv. of flood water level QPMF | : | +162.72 m |
| Normal storage capacity | : | 12.80 million $m^3$ |
| Dead storage capacity | : | 2.72 million $m^3$ |
| Effective storage capacity | : | 10.08 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 110.2 $m^3/s$ |
| 10 year return period | : | 146.1 $m^3/s$ |
| 25 year old return period | : | 158.3 $m^3/s$ |
| 50 year return period | : | 198.3 $m^3/s$ |
| 100 year return period | : | 241.8 $m^3/s$ |
| 1000 year return period | : | 412.8 $m^3/s$ |
| PMF return period | : | 1314.9 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Submerge intake |
| Discharge capacity | : | – |
| Intake inlet elevation | : | +130.8 m |
| Gate dimension | : | – |

**Spillway**

| | | |
|---|---|---|
| Type | : | Ungated side channel |
| Length | : | 194.0 m |
| Wide threshold | : | 30.0 m |
| Crest threshold elevation | : | +156.0 m |
| Stilling Basin type | : | USBR type III |

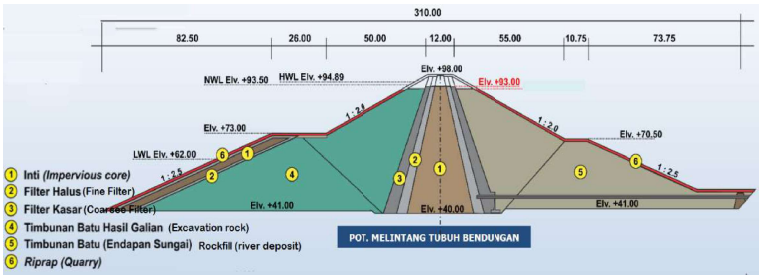
**Diversion**

| | | |
|---|---|---|
| Location | : | Right of river bank |
| Type | : | conduit |
| Length | : | 258.87 m |
| Dimensions | : | 2@ 3 m |
| U/S elevation | : | +102.2 m |
| D/S elevation | : | +96.0 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Jembrana volcanic |
| Rock/soil | : | andesitic breccia, tuffaceous sandstone tuffaceous |
| Rock Class (CRIEPI) | : | CL, CM |
| Main Dam Foundation | : | andesitic breccia, tuffaceous sandstone tuffaceous |
| Spillway Foundation | : | tuffaceous sandstone tuffaceous mudstone |
| Diversion Foundation | : | tuffaceous sandstone tuffaceous mudstone |

| | | |
|---|---|---|
| Dam Name | : | Tiu Suntuk |
| Province | : | Nusa Tenggara Barat |
| Regency | : | Sumbawa Barat |
| Coordinate | : | 116.927° E<br>8.794° S |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Rock–filled da with central core |
| Height | : | 58 m |
| Elevation of crest | : | +98.00 m |
| Elevation base foundation | : | +40.00 m |
| Wide of crest | : | 12 m |
| Lenght of crest | : | 380 m |
| Upstream slope | : | 1:2 |
| Downstream slope | : | 1:2 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +93.50 m |
| Elv. of low water level (LWL) | : | +62.00 m |
| Elv. of flood water level Q1000 | : | no data |
| Elv. of flood water level QPMF | : | no data |
| Normal storage capacity | : | 55.90 million m3 |
| Dead storage capacity | : | 3.21 million m3 |
| Effective storage capacity | : | no data |

**Hidrological Discharge***

| | | |
|---|---|---|
| 5 year return period | : | 423.48 |
| 10 year return period | : | 497.17 |
| 25 year old return period | : | 590.66 |
| 50 year return period | : | 659.23 |
| 100 year return period | : | 727.66 |
| 1000 year return period | : | 953.21 |
| PMF return period | : | 1874 |

**Intake**

| | | |
|---|---|---|
| Type | : | Submerge intake |
| Height | : | 10.8 m |
| Emergency release | : | 0.9 & 0.5 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | side channel |
| Length | : | 430 m |
| Wide threshold | : | 40 m |
| Crest threshold elevation | : | +93.50 m |
| Type of basin | : | sky jump |

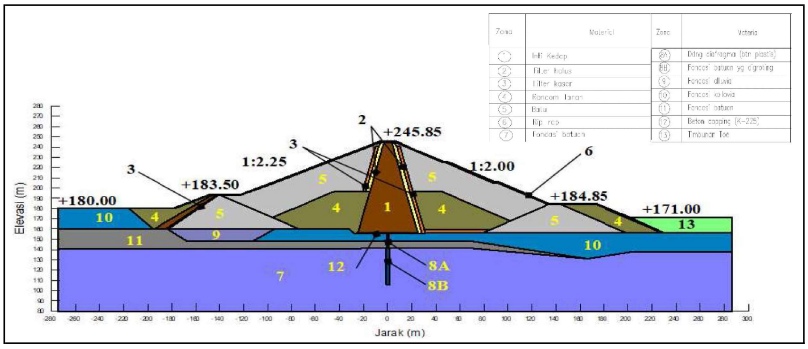
**Diversion**

| | | |
|---|---|---|
| Location | : | Left of river bank |
| Type | : | Conduit |
| Length | : | 387.0 m |
| Dimensions | : | 3.0 x 3.0 m |
| U/S elevation | : | +45.75 m |
| D/S elevation | : | +45.00 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Intrusive Rock |
| Rock/soil | : | Andesit |
| Rock Class (CRIEPI) | : | CL, CM, CH, B |
| Main Dam Foundation | : | Andesit |
| Spillway Foundation | : | Andesit |
| Diversion Foundation | : | Andesit |

| | | |
|---|---|---|
| Dam Name | : | Tugu |
| Province | : | Jawa Timur |
| Regency | : | Trenggalek |
| Coordinate | : | 111° 34' – 111° 37' E<br>8° 1' – 8° 3' |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal with vertical core |
| Height | : | 89.85 m |
| Elevation of crest | : | +245.85 m |
| Elevation base foundation | : | – |
| Wide of crest | : | 12.00 m |
| Lenght of crest | : | 433.00 m |
| Upstream slope | : | 1:2.25 |
| Downstream slope | : | 1:2.00 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +239.05 m |
| Elv. of low water level (LWL) | : | +202.35 m |
| Elv. of flood water level Q1000 | : | +243.40 m |
| Elv. of flood water level QPMF | : | +245.09 m |
| Normal storage capacity | : | 9.71 milliom m³ |
| Dead storage capacity | : | 1.04 milliom m³ |
| Effective storage capacity | : | 8.67 milliom m³ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | – |
| 10 year return period | : | – |
| 25 year old return period | : | – |
| 50 year return period | : | – |
| 100 year return period | : | 368.98 m3/s |
| 1000 year return period | : | 670.95 m3/s |
| PMF return period | : | 1,136.60 m3/s |

**Intake**

| | | |
|---|---|---|
| Type | : | Submarge |
| Dimensions / size | : | 1.5 x 1.5 m |
| Height | : | 29.60 m |
| Intake inlet elevation | : | +202,35 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side Channel, ungated ogee |
| Length | : | 480.86 m |
| Wide threshold | : | 35.0 m |
| Threshold elevation | : | +239.05 m |
| Stilling basin type | : | USBR Type II |

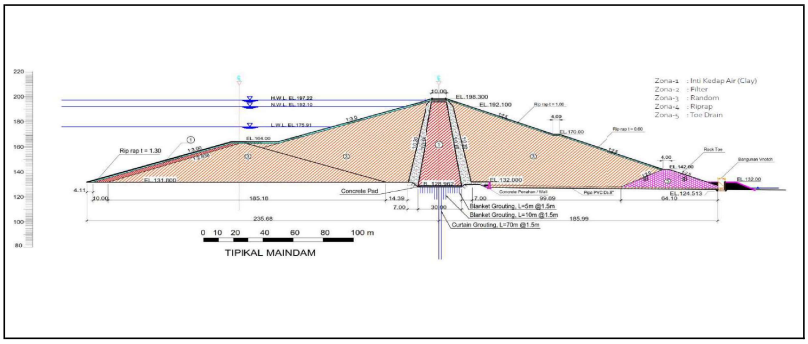
**Diversion**

| | | |
|---|---|---|
| Location | : | Right of river bank |
| Type | : | conduit |
| Length | : | 564.87 m |
| Dimensions | : | 2@ 3.2x3.2 m |
| U/S elevation | : | +178,85 m |
| D/S elevation | : | +162,85 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Mandalika (Tomm) |
| Rock/soil | : | Brecca, lava, tuf, sandstone – siltstone intercalation |
| Rock Class (CRIEPI) | : | D, CL, CM, CH |
| Main Dam Foundation | : | volcanic breccia |
| Spillway Foundation | : | volcanic breccia, tuffaceous sandstone, andesite lava |
| Diversion Foundation | : | volcanic breccia, tuffaceous sandstone, andesite lava |

| | | |
|---|---|---|
| Dam Name | : | Tukul |
| Province | : | Jawa Timur |
| Regency | : | Pacitan |
| Coordinate | : | 111°08'22" E<br>8° 03'26" S |




**Main Dam**

| | | |
|---|---|---|
| Type | : | Rock random zonal with central core |
| Height | : | 70.33 m |
| Elevation of crest | : | +198.30 m |
| Elevation base foundation | : | +127.96 m |
| Wide of crest | : | 10 m |
| Lenght of crest | : | 234 m |
| Upstream slope | : | 1 : 3.0 |
| Downstream slope | : | 1 : 2.5 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +192.10 m |
| Elv. of low water level (LWL) | : | +175.91 m |
| Elv. of flood water level Q1000 | : | +194.68 m |
| Elv. of flood water level QPMF | : | +196.82 m |
| Normal storage capacity | : | : 8.68 million m³ |
| Dead storage capacity | : | : 3.70 million m³ |
| Effective storage capacity | : | : 4.98 million m³ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | – |
| 10 year return period | : | – |
| 25 year old return period | : | – |
| 50 year return period | : | 278.82 m³/s |
| 100 year return period | : | – |
| 1000 year return period | : | 405.96 m³/s |
| PMF return period | : | 1081.79 m³/s |

**Intake**

| | | |
|---|---|---|
| Type | : | Incline tower |
| Discharge capacity | : | 3 m³/s |
| Intake inlet elevation | : | +175.9 m |
| Gate dimension | : | 2 x 2 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Side chanel, ogee |
| Length | : | 320.18 m |
| Wide threshold | : | 40 m |
| Crest threshold elevation | : | +192.1 m |
| Stilling Basin type | : | USBR Type II |

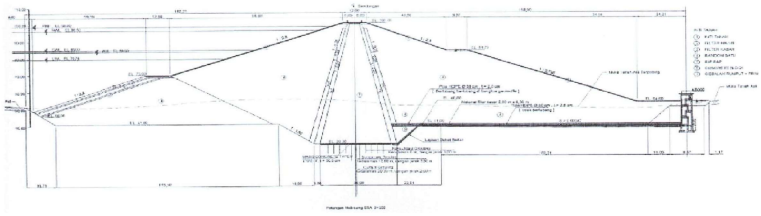
**Diversion**

| | | |
|---|---|---|
| Location | : | Left dam abutment |
| Type | : | Tunnel |
| Length | : | 283.71 m |
| Dimensions | : | ϕ 3.5 m |
| U/S elevation | : | + 138.90 m |
| D/S elevation | : | + 130.00 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Mandalika |
| Rock/soil | : | andesite, tuff. sandstone, v.breccia, claystone–siltstone |
| Rock Class (CRIEPI) | : | CL, CM, CH |
| Main Dam Foundation | : | andesite, sandstone, breccia, claystone–siltstone (alt), |
| Spillway Foundation | : | tuffaceous sandstone, volcanic breccia, claystone–siltstone |
| Diversion Foundation | : | tuffaceous sandstone, volcanic breccia, claystone–siltstone |

| | | |
|---|---|---|
| Dam Name | : | Way Apu |
| Province | : | Maluku Utara |
| Regency | : | Buru |
| Coordinate | : | 3° 33'11.82"S<br>126° 50'26.63"E |



**Main Dam**

| | | |
|---|---|---|
| Type | : | Zonal rockfill with verical core |
| Height | : | 72.0 m |
| Elevation of crest | : | +101.00 m |
| Elevation base foundation | : | + 29.0 m |
| Wide of crest | : | 12.0 m |
| Lenght of crest | : | 592.5 m |
| Upstream slope | : | 1:2.8 |
| Downstream slope | : | 1:2.5 |

**RESERVOIR**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +96.50 m |
| Elv. of low water level (LWL) | : | +79.75 m |
| Elv. of flood water level Q1000 | : | +97.37 m |
| Elv. of flood water level QPMF | : | +98.61 m |
| Normal storage capacity | : | 41.86 million $m^3$ |
| Dead storage capacity | : | 13.95 million $m^3$ |
| Effective storage capacity | : | 27.90 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | |
| 10 year return period | : | |
| 25 year old return period | : | 642 $m^3/s$ |
| 50 year return period | : | |
| 100 year return period | : | 891 $m^3/s$ |
| 1000 year return period | : | 1427 $m^3/s$ |
| PMF return period | : | 3248 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Drop intake |
| Inflow capacity | : | 24.5 $m^3/s$ |
| Intake inlet elevation | : | +79.75 m |
| Gate dimension | : | 5.0 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | combination of side channel & gated |
| Length | : | 316.5 m |
| Wide threshold | : | 75 m (side channel) |
| Crest threshold elevation | : | +96.5 m & +85.0 m |
| Stilling Basin type | : | |

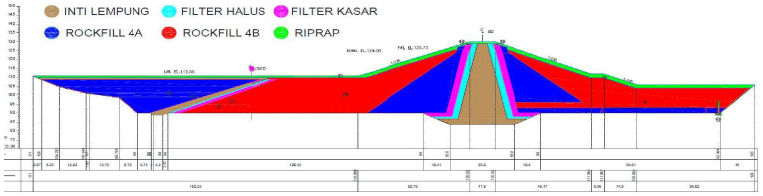
**Diversion**

| | | |
|---|---|---|
| Location | : | Right abutment |
| Type | : | Tunnel |
| Length | : | 415.0 m |
| Dimensions | : | |
| U/S elevation | : | |
| D/S elevation | : | |

**Geology**

| | | |
|---|---|---|
| Formation | : | Wahlua complex |
| Rock/soil | : | Alluvial, terrace, Metamorphic rock unit |
| Rock Class (CRIEPI) | : | D, CL, CM |
| Main Dam Foundation | : | Metamorphic rock unit |
| Spillway Foundation | : | Metamorphic rock unit |
| Diversion Foundation | : | Metamorphic rock unit |

| | | |
|---|---|---|
| Dam Name | : | Way Sekampung |
| Province | : | Lampung |
| Regency | : | Pringsewu |
| Coordinate | : | 5° 20'0.07"S<br>104° 55'6.05"E |




Zone 1 (Zona Inti) : Ukuran partikel maksimum 20 mm
Zone 2 (Filter Halus) : Pasir hasil dari aliran sungai way sekampung
Zone 3 (Filter Kasar) : Pasir campur kerikil hasil prosesing aliran sungai Way sekampung
Zone 4A (Rockfill) : Rockfill mak. size 50 cm hasil blasting dari galian spillway & quarry area genangan
Zone 4B (Rockfill) : Rockfill mak. size 100 cm hasil blasting batu galian spillway & quarry area genangan
Zone 5 (Rip-Rap) : Rockfill mak. size 100 cm hasil blasting batu quarry di area genangan

**Main Dam**

| | | |
|---|---|---|
| Type | : | Rock–filled dam with central core |
| Height | : | 47.0 m |
| Elevation of crest | : | +130.00 m |
| Elevation base foundation | : | +83.0 m |
| Wide of crest | : | 12.0 m |
| Lenght of crest | : | 256.0 m |
| Upstream slope | : | 1:2.75 |
| Downstream slope | : | 1:250 |

**Reservoir**

| | | |
|---|---|---|
| Elv. of normal water level (NWL) | : | +124.00 m |
| Elv. of low water level (LWL) | : | +112.00 m |
| Elv. of flood water level Q1000 | : | +125.70 m |
| Elv. of flood water level QPMF | : | +127.50 m |
| Normal storage capacity | : | 68.06 million $m^3$ |
| Dead storage capacity | : | 7.85 million $m^3$ |
| Effective storage capacity | : | 23.27 million $m^3$ |

**Hidrological Discharge**

| | | |
|---|---|---|
| 5 year return period | : | 90.56 $m^3/s$ |
| 10 year return period | : | 167.35 $m^3/s$ |
| 25 year old return period | : | 299.66 $m^3/s$ |
| 50 year return period | : | 420.83 $m^3/s$ |
| 100 year return period | : | 559.42 $m^3/s$ |
| 1000 year return period | : | 1153.82 $m^3/s$ |
| PMF return period | : | 3419.52 $m^3/s$ |

**Intake**

| | | |
|---|---|---|
| Type | : | Submarged intake |
| Height | : | 20.5 m |
| Intake inlet elevation | : | +109.0 m |
| Gate dimension | : | 7 x 7 m |

**Spillway**

| | | |
|---|---|---|
| Type | : | Combination of free overflow and gated |
| Length | : | 361.42 m |
| Wide threshold | : | 85.0 m |
| Crest threshold elevation | : | +124.0 m |
| Crest threshold gate | : | +116.0 m |

**Diversion**

| | | |
|---|---|---|
| Location | : | Right abutment |
| Type | : | Tunnel |
| Length | : | 341.0m & 379.9m |
| Dimensions | : | : 5.0m, 2 traces |
| U/S elevation | : | +92.00 m |
| D/S elevation | : | +91.00 m |

**Geology**

| | | |
|---|---|---|
| Formation | : | Lampung and Gunung Kasih |
| Rock/soil | : | Sandstone, conglomerate and schist |
| Rock Class (CRIEPI) | : | CL and CM |
| Main Dam Foundation | : | Sandstone, conglomerate and schist |
| Spillway Foundation | : | Sandstone and schist |
| Diversion Foundation | : | Sandstone and schist |

# *Attachment 2 Summary of Dam Issues*

# Dam Issues Arised at Construction Sites (1/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| 1 | Landslide/Slope Stability | 1 Bendo | Intake slope stability is doubtful | The stability of the foundation rocks and slopes around the intake building is doubtful. Carry out repair designs by strengthening the slopes, then develop technical justification for strengthening the slopes, which should be carried out before reservoir water floods the intake structure. The importance of detailed descriptions and drawings regarding methods (design) for strengthening and stabilizing slopes at intake building sites, including in situ tests that have been carried out to determine the technical parameters of the rock mass in analyzing its stability. | It is recommended that all cracks and rock cracks on the intake slopes and the platforms above should be covered with sealing grout, and adequate and permanent surface drainage should be arranged. |
| | | | Reservoir landslide potential | Potential for landslides on the hillside in the reservoir inundation area on the right and the upstream of spillway | To determine the geological conditions and technical parameter values on the slope, it is recommended to take samples and then carry out an analysis of the stability of the slope under normal water level conditions and the slope under saturated conditions.<br>In addition, because there has been a landslide with indications of colluvium deposits at the bottom, a back analysis should be carried out to obtain residual shear strength parameters to be used as input in analyzing slope stability under normal water level conditions.<br>If necessary, instruments can be installed, such as inclinometers and sliding stakes, to monitor movement in areas prone to landslides upstream of the spillway that have the potential for landslides. |
| | | 2 Budong Budong | Reservoir landslide potential | The potential for landslides in the reservoir inundation area needs to be considered and studied in more detail. | A study of the potential for landslides in the reservoir inundation area should be programmed to be carried out at the beginning of construction implementation later. Include this recommendation in the design report. |
| | | | Sliiding potential of spillway | At the top spillway there was a layer of sandstone located on siltstone with the depth same as chute direction | At the top spillway there was a layer of sandstone located on siltstone with the depth same as chute direction, |
| | | 3 Ciawi | Landslide on left slope of stilling basin | To handle landslides on the left slope of the stilling basin, sloping and strengthening the slope with soldier piles is currently being carried out. It should be noted that reservoir impounding will cause an increase pressure in both of dam slopes and abutment slopes. | a. For this reason, so that landslides do not occur again, it is important to ensure that the slope strengthening work has been completed before the initial filling process of the reservoir.<br>b. Ensure that areas with the potential for landslides have an adequate drainage system to direct surface flow. This reduces slope loads due to high groundwater levels, reducing landslide potential. Consider being equipped with instrumentation and including it in the Monitoring Instructions CHAPTER in the Dam OP Guidelines, including evaluation.<br>c. To release uplift, consider that downstream the spillway is equipped with a relief well which can also function as an observation well.<br><br>To monitor slope movement, consider adding inclinometer instruments and observation wells around the landslide location. |
| | | | Sliding potetial at reservoir | Potential for landslides at the dam location and reservoir basin, including on the left slope of the stilling basin, which has experienced landslides, | a. Slopes with potential landslides should be depicted on the dam and reservoir basin layout map, with each location numbered.<br>b. In the vicinity of these locations, intensive visual inspections and instrument monitoring should be carried out, with greater frequency, in conditions before and during the initial filling of the reservoir later. The need for intensive monitoring should be included in the OP Guidelines.<br>c. The existence of the potential for landslides should be included as an indication of danger in the RTD Document.<br>d. The monitoring plan to be carried out and the evaluation procedures should be included in the OP guidelines. |

# Dam Issues Arised at Construction Sites (2/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 4 Cipanas | Landslide during excavation at spillway | Sliding had occurred at the excavation of spillway. | The cross section that has been made should be equipped with a profile line of the detail spillway layout.<br><br>The stilling basin section, volcanic sandstone is poorly cemented, it is necessary to explain the strike/dip of the rock and evaluate the direction of the excavation to determine the possibility of sliding recurring.<br><br>In the saddle dam the installation other instruments should be considerate, for example V-notch, piezometer, etc. |
| | | 5 Gongseng | landslide potential at reservoir area | Based on the landslide potential and ground movement map, to the east of the dam location is an area with high landslide potential. Apart from that, based on the geomorphology, the reservoir has many separate hills, which indicates the potential for significant erosion on the reservoir slopes. Surface erosion will increase the supply of sedimentation in the reservoir. | a. Landslide-prone areas around dams and reservoir reservoirs should be mapped in detail.<br>b. The OP Guidelines should convey the need for intensive monitoring of landslide-prone areas during initial filling and when the dam is operational later.<br>c. If there are indications of landslides, anticipatory measures should be taken immediately. |
| | | 6 Jatigede | Slope Stability of Reservoir | The stability of the reservoir slope influences the stability of the anchoring system | For this reason, it is necessary to analyze the stability of the reservoir slope at the location where the anchor is planned to be installed.<br>a. The earthquake load used in the analysis should be adjusted to the earthquake return period used in the slope stability analysis of the dam body, which depends on the Dam Risk Class.<br>b. The analysis should consider the engineering geological conditions and the slope angle of the reservoir slope at the location where the anchor is planned to be installed. |
| | | 7 Jragung | many landsline of access road | There is around 18 sliding that found on the access road. | Water is the main triggering factor of landslides, especially at road access locations. So that the control of the water content, especially the fill material is very necessary. It is necessary to add drainage and compaction for filling location. While at cut locations that have vertical slope, reinforcement can be used with geogrids and rockbolts. |
| | | 8 Keureuto | landslide potential around the Apron spillway | There is a cliff above the Apron spillway in the form of mudstone that is easily slaking | considering the material in the form of mudstone which is sensitive to weather (easy slaking). It is necessary to do with anchor and short create as protection and reinforcement of the cliff |
| | | 9 Kuningan | landslide at surounding dam body and reservoir | At the location of the dam and reservoir, there were several landslides, as shown in the picture below. | Landslide 1 is still developing, cutting off the access road and almost hitting the facility building (UPB office) above it. The cause of the landslide should be immediately examined (measurement of the dimensions of the landslide arc, cross landslide, landslide mechanism, and back analysis), and a handling design should be planned.<br>Landslide 2 occurred on the access road to the dam body, and currently, a back analysis has been carried out, and treatment is planned by returning it to its natural slope condition. Because a landslide has occurred and is in critical condition, the drainage flow should be moved so that it does not re-enter the landslide area. Reinforcement structures should be added at appropriate placement locations (in the area of resistance moment).<br>On landslide 3, repairs have been made by building gabion structures. An analysis of the landslide that occurred should be provided (material, back analysis, residual shear strength, etc.) to ensure that the repairs carried out are appropriate.<br>Landslide 4 still needs to be measured and analyzed. An analysis should be immediately carried out, as in landslide 2, and a handling plan should be planned. |

# Dam Issues Arised at Construction Sites (3/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 10 Ladongi | Landslide at left side of spillway | It was reported that a landslide had occurred on the excavation slope on the left side of the spillway building | a. In documenting landslide incidents, photos of landslide conditions should be presented clearly, with recommendations for how to deal with landslides included. Make a cross-sectional image of the landslide, evaluate the mechanism of the landslide, where the sliding area is, and check the results of the landslide repair.<br>b. Considering that the landslide that occurred on the left slope of the spillway excavation during construction was quite large during the operation phase, it is necessary to carry out more careful monitoring of the results of the repair of the landslide and of the surrounding area, which has potential for landslides. Monitoring is carried out visually and using an inclinometer instrument; for this reason, it is recommended to install 2 inclinometer points, and this monitoring program is explained in the OP guidelines.<br>c. If there is no OW in this landslide area, an OW must also be installed to monitor mat fluctuations against potential landslide readings from the inclinometer.<br>d. Bearing in mind that the trend of the schistose slope of the schist rock on the left side of the spillway, which is sloping on the suitable collar where the landslide occurred during construction, is quite significant, leading to the current spillway structure, the left side of the spillway needs to be specifically monitored continuously.<br>e. Inspections are to be carried out around the dam and the Ladongi Dam reservoir to determine the possibility of other potential landslides. If there is, make a plan to overcome it. |
| | | 11 Lausimeme | Spillway landslide potential | At the spillway location there is a layer of rock that leads downstream | there needs to be treatment regarding the layer because it becomes a weak zone (needs rock bolt / anchor) or a statement needs to be made to anticipate if a crack occurs someday. No additional reinforcement structure is carried out so it is recommended that reinforcement in the form of an anchor be added. |
| | | | Lanslide potential of reservoir | In the reservoir there is also unconsolidated material that may landslide during impounding | special attention needs to be paid to the location of the reservoir with landslide potential. |
| | | 12 Logung | Reservoir landslide potential | There are 19 (nineteen) potential landslide points in the reservoir area | a. Greenbelt areas should be handled immediately, especially in locations that are still in a bare condition by planting trees and making terraces.<br>b. The coordinates regarding the locations of the avalanches have been presented in Appendix 4 so that they are complemented by an evaluation of the volume that has the potential to enter the reservoir, wave height, and its relation to dam safety (overtopping).<br>c. This landslide potential should be included in the OP guidelines so that routine monitoring and maintenance efforts can be carried out as well as possible.<br>d. Considering that the location of the Logung Dam also has the potential for an earthquake with a moderate magnitude, if an earthquake occurs, special inspections can be carried out immediately, including inspections on all the slopes of the reservoir inundation. |
| | | 13 Manikin | Exotic block sliding | Based on geology map there a exotic block of sandstone at left abutment | The sandstone on the left abutment needs a further study, if it is an exotic block floating on the Bobonaro Mudstone, at the time of impounding there is the potential for the rock to slip. |
| | | 14 Meninting | Sliding potential at left abutment | In the excavation upstream of the left abutment of the dam there no slope protection. | it can be seen that the excavation cliffs are prone to sliding and no protection has been carried out for these cliffs. Zones that are prone to landslides should be a concern and protection should be immediately carried out to anticipate landslides that can disrupt the implementation of dam construction. |
| | | | Landslide at reservoir/quary | Landslide occur during exploitation of random material | The work prosedure should be made before excavationa and it not recommended to excavate from the bottom part of quarry area |

# Dam Issues Arised at Construction Sites (4/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 15 Napun Gete | lanslide monitoring above spillway | During construction, a landslide of slopes above the spillway building was handled with a retaining wall structure. | Details of the construction of the retaining wall structure that has been made following the As Build Drawings should be conveyed.<br>To evaluate the effectiveness of the treatment results, after the treatment has been carried out, a visual inspection and routine monitoring of the possibility of deformation should be carried out, including through several shear stakes placed on the ground at the landslide site and points determined at the top of the retaining wall.<br>A high groundwater table on a slope can trigger another landslide. To anticipate this, it is better to observe the performance of the drainage system in locations with the potential for landslides.<br>The landslide handling work should be mentioned and described clearly in the History of Dam Development and Management. Visual inspection and monitoring activities at the slide site should be included in the OP Guidelines. |
| | | 16 Nipah | Sliding at reservoir | Several places at reservoir was experienced landslide. | |
| | | 17 Pamukkulu | slidding around the spillway cut slope | Strongly weathered rock and weathered residual soil are confirmed above the fresh bedrock. | The cut slope composed of residual soil of weathered rocks has collapsed on a small scale. In order to protect this slope, it is necessary to remake the cutting slope gentler or to provide slope protection works other than sodding or Geo-net which is proposed by site office because sliding occurred in the soil layer, not slope surface erosion. |
| | | 18 Randu Gunting | lanslide potential around fasility building | Slope stability analysis on the potential for landslides at the bottom beside the facility building. | Considering that reservoir inundation is affected by the rise and fall of the reservoir water level, which can reduce the strength of the rock on the surface, the input material parameters used should be reduced concerning the high water level considering this in the analysis of slope stability in critical conditions. |
| | | 19 Rotiklot | Landslide ever occurred on the downstream slope to the left of the dam. | Landslide ever occurred on the downstream slope to the left of the dam. | a. Currently, it is planned to install 1 inclinometer in this area. The need for instrumentation installation should be reviewed again.<br>b. Consider installing a piezometer and Observation Well (OW) to monitor groundwater flow behavior and pore water pressure.<br>c. It is necessary to evaluate the type, type of landslide that occurred and the condition of the geological layers and their repairs (bored piles and gabions) on the influence of the groundwater level originating from the reservoir so that the position and number of inclinometer points are optimal (perhaps more than one inclinometer point is needed). |
| | | 20 Sadawarna | Landslide potential near to deversion slope | In the diversion conduit canal area that has been completed, there are slopes with steep slopes and indications of potential for landslides. Based on the consultant's information, the type of soil in the location is black soil (soft clay). Reinforcement has been carried out with Temporary Steel Sheet Pile (TSSP) and slope protection with shotcrete. However, the SSP that has been installed is not capable enough to increase stability against avalanches. | a) Further evaluation should be carried out to determine the physical and mechanical properties of the soil on the slopes that have the potential for landslides. In this case, soil samples should be tested to determine mineral content and obtain valid shear strength parameter values<br>b) Bearing in mind that protection is only carried out with shotcrete, so there is fear of a recurrence of landslides, based on the test parameter values obtained in point a) above, a slope stability analysis should be carried out, then recommendations for strengthening or improving the soil needed to enhance slope stability should be made.<br>c) In areas with the potential for landslides, visual inspection and monitoring of instruments should be carried out intensively.<br>d) The landslide potential should be included as a hazard indication in the RTD Document. |
| | | | Landslide around stilling basin | landslide/slope failure occurred around the stilling basin after impounding | UPB and Consultants should carry out field inspections regarding landslide incidents which are included in the "Extraordinary" event category and identify the causal factors and types of landslides that occur. The landslide that occurred should also be depicted in geological cross-sections and longitudinal sections. |
| | | | Reservoir sliding | There was an landslide near the dam jetty. improvements were made by sloping and protecting the slope with plants. | In addition, the amount of mass entering the reservoir should also be taken into account because it will become part of the dead storage and can cause waves that can trigger overtopping. |

# Dam Issues Arised at Construction Sites (5/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 21 Sei Gong | Landslide on left bank of spillway | Landslide was observed at the left bank of spillway | |
| | | 22 Sindang Heula | Landslide potential | Rocks on the slope of left road towards the spillway bridge is tuff in a highly to moderately weathered condition and in some places has the potential for surface landslides (slope wash). On the cliff there is also a valley which during rainy times is traversed by quite heavy water. | Plants Wild shrubs on the slope are followed up by clearing them so as not to disturb the stability of the excavation slope. Upper part of the cliff slope is followed up with the creation of a drainage channel to direct the flow of rainwater so that it does not flow freely and trigger surface the occurrence of surface landslides. |
| | | 23 Sukamahi | Reservoir landslide potential | Reservoir will experience water level fluctuations, which have the potential to affect rock saturation on the reservoir slopes. | a. The infiltration capacity of rocks in the reservoir pool should be evaluated to determine the extent of saturation and compared with the slope level to determine the potential for landslides.<br>b. Zoning should be made to identify reservoir inundation slopes that have the potential to experience landslides, along with recommendations made to prevent such landslides.<br>c. It is necessary to inspect the reservoir banks to prevent landslides regularly. |
| | | 24 Temef | landslide of spillway bank | Landslide occur at the left and right bank of spillway, start form STA-300 to STA 50 then secant pile will be conducted up to 45 meter depth as well as to become a spillway wall. | The excavation of landslide should be adjusted to the field line (monolith). The excavation should be open in segment and the brake should be made for crack. For landslide treatment is suggested to use bore pile than secant pile. Model analyses should be adjusted to existing landslide. |
| | | 25 Teritip | Sliding at right abutment hills during impounding | During the initial impounding of the reservoir, the Teritip Dam experienced a landslide on the right abutement hill of the dam. The landslide that occurred is not known yet for its mechanism and genesis, and the rock on the right abutment is colluvium at the top and mudstone at the bottom. | a. if composed by colluvium, should be identified the existence of previous landslide patterns (bulging, slope wash, etc.) around the current avalanche<br>b. It should be determined in advance the type of landslide that occurred, including circular sliding, translations or a combination of both, because the handling of these types of landslide is different. this determination can be viewed from the type and pattern of rock layers around the landslide and the reconstruction of the landslide field that has been carried out<br>c. If there are many fault patterns at the dam site, it is possible that the type that occurs is a complex landslide. The potential type of complex landslide should be evaluated and identified again.<br>d. Because the landslide is likely to be influenced by groundwater conditions, an evaluation of groundwater conditions on the right abutment slope should be carried out. Plot the groundwater level in the cross section of the abutment hill that experienced a landslide.<br>e. related to the material parameters used in the analysis, if not all landslide material is stripped and still used, it should use the residual shear stress parameter that can be from the back analysis, instead of using the affective stress. |
| | | 26 Tiga Dihaji | Landslide potential on conglomerate | The excavation slopes downstream of the dam consist of loose conglomerate rock with the potential for landslides. | Handling potential landslides on the excavated slopes should be carried out, such as leveling the slopes, protecting the slope surface with shotcrete or geomat combined with hydroseeding, and installing weep holes and correct surface drainage design. |
| | | 27 Tiu Suntuk | Reservoir landslide potential | It should be noted that landslides on the slopes of the reservoir basin can endanger the dam safety. | To anticipate dangerous conditions, it is recommended as follows:<br>a. An inventory of potential landslide areas should be carried out on the slopes of the reservoir basin.<br>b. The landslide potential area should be depicted on the engineering geological map of the reservoir basin area at a scale of 1:5000.<br>c. On this map, each location with the potential for landslides should be numbered, along with the coordinates of the location, the direction of the landslide, and the potential volume of landslides that can enter the reservoir.<br>d. For each location of the area with the potential for landslides, a mitigation and handling plan should be prepared so that it does not impact the safety of the dam.<br>e. The potential for landslides on the left side of the spillway should be properly anticipated, for example by sloping the top of the slope or other protection. |

# Dam Issues Arised at Construction Sites (6/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 28 Tugu | Landslide at the right slope of spillway | Landslides ever occur on the slope on the right side of the spillway during construction. | It should be handled comprehensively and designed for long-term stability, including improvements to the surface system and its "sub-surface drainage" |
| | | 29 Way Sekampung | Sliding at outlet tunnel | The slope of the channel is dominated by alternation of sandstone tuff and conglomerate with moderate to strong weathering and CL class at the bottom. | Because rock conditions are weathered and are tuff sandstones which is sensitive to air, it has the potential for landslides. Protection of weathered rock is needed to keep contact rock and air.<br>Excavation slope foundation rock in the form of tuff containing a lot of pumice and volcanic glass that is easily weathered was followed up with spray concrete (shotcrete) or paranet sheets, while soil excavations are recommended to be reinforced with stone masonry.<br>The part of the slope that has no drainage is recommended to be made into a drainage channel. Drainage channels control the flow of rainwater so that it does not flow freely and trigger landslides. |
| | | | | | |
| 2 | Dam Material | 1 Ameroro | slurry clay for contact clay (no standard) | The consultant conveys that he will add slurry clay for connecting/adhesive material between rock foundation and clay core | using slurry clay is not yet in the standards/guidelines, it should reconsider using the slurry clay. |
| | | 2 Bagong | secant pile material should meet requirement | According to the design prepared by the Consultant, the secant pile will use plastic concrete with a strength of 2 Mpa. | a. Secant piles should be designed without reinforcement (plastic concrete), with a modulus of elasticity (E) value not exceeding 5 times the modulus of elasticity of the foundation.<br>b. Concrete quality of 2 MPa is considered too small; the quality of plastic concrete should refer to ICOLD Bulletin 129 (2005), with a maximum plastic concrete quality range of 3 MPa, as presented in Table 1.<br>c. Apart from taking into account the width of the intersection left - right laterally, it also sl should also take into account the width of the upstream-downstream intersection. The width of the upstream – downstream overlap should be 0.58 - 0.6 m.<br>d. Consultants should study the Wall Guidelines from the Dam Engineering Office. Before implementation in the field, mixture trials and tests should first be carried out in accordance with these guidelines. |
| | | 3 Bendo | density value of zone 3a & 3b (rock, is too high | For zone 3A, it was reported that, based on tests, the maximum relative density was 96.176%. This value is not reasonable because, generally, zone 3 material ranges from around 70%.<br>In the long term, due to the influence of rain, it is estimated that fine-grained material from Zone 3B will fall into Zone 3A | This value should be evaluated. If there is a change in the material during landfilling, a vibrating table test should be carried out following the material change so that the density test of the different materials is compared with the new vibrating table test results.<br>A slope stability analysis should be carried out with zone 3A conditions having the same parameters as zone 3B to evaluate the dam's safety in these conditions. |
| | | 4 Bener | Material gradation and Specification of Toe Slab | Gradation criteria of the toe slab material at uptream slope | Location 1B should be coarser than 1A and fly ash should be used for 1A. Gradation 3A to 3B should be coarser. considering the tonnage used and the number of passes required. Dams above 100 meters usually use a minimum tonnage of 15 tons and with a dynamic of 20 tons. |

# Dam Issues Arised at Construction Sites (7/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 5 Beringin Sila | some concrete strengh test result doesn't meet requirement | In the graph comparing the quality of concrete with curing and without curing, it shows that several test samples produce compressive strength values less than the technical specifications, namely K225. | a. Check the percentage difference in concrete quality from the two types of curing, then compare it with the requirements permitted in SNI 2847-2019 Requirements for Structural Concrete for Buildings.<br>b. Intensive visual inspections (with frequent meetings) should be carried out around the location of concrete structures whose sample test results need to meet the technical specifications.<br>c. To make it easier for OP officers to identify the location of concrete structures that need intensive monitoring, technical drawings should be made showing the area (elevation and STA) of samples with test results that do not meet technical specifications.<br>d. Point b and c above should be explained in the OP Guidelines and implemented in the field to monitor potential anomalies in the concrete structure.<br>e. It should be noted that based on SNI 2847-2019 Requirements for Structural Concrete for Buildings Table 19.3.2.1, concrete that is in contact with water and requires low permeability and durability, the minimum necessary concrete compressive strength is fc' 28 MPa. For that reason, the consultant should prepare recommendations for improvements needed to improve the quality of the concrete. |
| | | 6 Bintang Bano | some riprap is no interlocked | It was observed that the riprap on the dam body on the downstream slope did not interlock with each other | Rip-rap material that is too small does not interlock and/or does not meet standards should be repaired and replaced with material that meets specifications to avoid sliding. |
| | | 7 Budong Budong | insufficient potential of core material | Investigation of soil material for core is still very limited. | At the beginning of construction implementation, additional material investigation should be carried out. This core material investigation can be combined between testpit and hand drill. Include this recommendation in the technical specification report.<br>in the summary of soil test table, there is a description of the classification of the type of soil stated as clay, whereas in the USCS (unified soil classification system) classification is given the notation MH, fine-grained soil should be classified consistently in accordance with the notation according to USCS.<br>The difference between the natural water content (NWC) value and the optimum moisture content (OMC) value of the test results should be noted. If the NWC value is much higher than the OMC, a stock pile area will be needed to dry / reduce the water content in the soil. This drying will take a long time and will hinder the smooth implementation of the dam body embankment. This should be explained in the technical specification report and the method of dam construction. |
| | | | Using breccia for rock fill | The dam zone will use breccia for dan embanment that come from othe exavation area like spillway and tunnel. | The dam material is not recommended to use breccia (as rock fill) that had been identified has high abrasion (>40%). Using breccia as dam material will tend to soil random dam which related to dam design that should be changed too. |
| | | 8 Cipanas | Random material for spillway bacfill gradation | The backfill material used in the spillway is random material but the gradation of the material is not conveyed. | The gradation of the material should be conveyed to ensure that the material is free drain. Samples need to be taken from the installed material and not from the stockpile which may not have same gradation as the material installed on the spillway wall. |
| | | 9 Jlantah | Parameter of material | Random yang telah terpasan sekitar 2 jt m3 namun hanya ada 3 sample yang terambil | for material as much as 2 million m3 there should be 15-20 samples (for ramdom it should be 1 sample for 120,000 m3) to ensure the quallity of embankment |
| | | 10 Jragung | insufficient random material (resident rejection) | When design, borrow location in the Penawangan area is one of location that choosen be taken as dam random material, however location get rejection from citizen. Random material limitations overcome with looking for material that is still in development dam area, however there is about 150,000 m 2 only from requirement (5.5 milliont m 2) | Between Penawangan and Dam site there are random material potential which form of sandstone, siltstone and claystone, sandstone is the only material will be used for random materials. At the location, sorting must be strict and excavation may need more much time. Possible consideration is additional purchase from another place.<br>Dam Stability calculation should simulated again using new materials of sandstone. |

# Dam Issues Arised at Construction Sites (8/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 11 Karian | Wet core material (7-12% above OMC) | Material of zone 1 for core embankment has water contain 7-12% above OMC (wet core). The materials with high water content will be difficult to be compacted. | Construction method of wet core should be explained, especially compaction method at the site.<br>The consultant explained that compaction was carried out using sheep foot rollers. With a high-water content above OMC, usually there will be a lot of soil material attached to the legs of the sheep foot roller.<br>Consolidation in the wet core is usually relatively high (can reach 3% of the embankment height) and should be in the installation of instrumentation by considering the length of cable or tubing, etc. |
| | | 12 Kuwil | high ranged data of rock zone material | Various shear strength values were produced based on in situ direct shear tests carried out at 6 (six) points in the random rock zone (phi between 30° - 48°). Because the results were very varied and it was impossible to take an average value, the Consultant used a phi value of 39° (from the USBR graph) as an input parameter in the stability analysis, considering that the random material consisted of andesite rock. The consultant is also carrying out a MASW (Multichannel Analysis of Surface Waves) investigation to determine the density level of the dam body material zones. | a. Mapping of locations in random embankment zones, which have poor embankment quality, should be carried out to map weak areas of the dam. Regular monitoring should be carried out at the locations of found weak spots, either through visual inspection or monitoring surrounding instrumentation.<br>b. The need for routine monitoring should be included in the Operation and Maintenance Manual.<br>c. The results of the MASW and its evaluation should be presented in the embankment quality evaluation report. |
| | | 13 Lausimeme | Core material does not meet requirement | Based on the technical specifications, core material should passes the #200 sieve by 7% - 50%. Laboratory test results showed that more than 70% passed sieve #200. | These conditions indicate that the core material is not following the design assumptions. A gradation curve for the core zone material should be made according to the soil category. Furthermore, the gradation of filter material should be redesigned according to the base material. |
| | | 14 Leuwikeris | High OMC (47%) of core material/ difficulity of compaction | The material used for the core zone has a fairly high OMC value of around 46%, while in the field the natural water content is around 54%. This makes the material difficult to compact especially when working at night because the NWC of the material tends to increase in the afternoon. | Mr. Paulus commended:<br>The clay mineralogy need to be tested on clay of dam core.<br><br>Mr. Shimizu commended:<br>The core material used more like mud, necessary material blending with sand, for blending method ever done in Jatibarang (reference)<br><br>Mr. Bambang commended:<br>Pay attention to the settlement of the core material, because can happen internal sliding that can be observe by inclinometer tool |
| | | 15 Manikin | alluvium for fly ash | For the stone ash mixture used will use crushed riverdeposit | using riverdeposit is relatively in homogeneous so the parameters will be more difficult, using limestone will be better. In addition, using riverdeposit generally contains a lot of clay material, it is better to avoid clay as little as possible. |
| | | 16 Meninting | Quantity of core material | The consultant revealed that there were difficulties in finding core materials. The current problem is about zone 1 construction material (dam core material) where the remaining needs are still around 88 thousand m3 and only 5 thousand m3 is available, so that to meet the needs will be taken from 2 locations outside the reservoir where only 1 location can be utilized. | Considering the gradation of the core material mixture, it may increase the volume needed. Consultant convey that The Murpeji location can be taken as the core and the other one is the Mekarsari location which is still in process, looking at the Murpeji location reserves are not enough for the embankment to reach the crest dam plan. It should be ensured that the Mekarsari location can be freed when considering the impounding that will be carried out next month. In addition, the results of material properties testing need to be presented to ensure the quality of the embankment. |
| | | | Fine grained of random | based on visual inspectian random material is not uniform and contain may of fine grained material, it can be seen from presence of clumps of clay material | The gradation of random material shold be presented and ensure the random parameter from dam stability calculation |
| | | | Soil random | Random of meninting dam is tend to be soil random (semi impermeable material) which settlement and slope failure can occur. | Because it is a random zone of soil that is semi-impermeable, before testing, the sample should be consolidated first (for testing undrained). In the consolidation process, strain rate should be calculated based on consolidation time t50 or t90. |
| | | | Core quality | Meninting dam used the core meterial that tend to be wet and dry core | Meninting dam site tends to use wet core material, but there is also material that tends to be dry core. A detailed mapping of the location of the material placement should be carried out, where the location tends to be wet core and where the location tends to be dry core. |

# Dam Issues Arised at Construction Sites (9/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 17 Marangkayu | Dam embankment material (no impounding from completing construction) | Marangkayu Dam took a long time to complete impounding and is always in a dry condition. | The properties of the current embankment material should be checked again, whether there has been a change in moisture content or not. It is feared that if the water content decreases when it is inundated, the body of the dam becomes saturated and a sudden decrease occurs due to saturation which can cause internal cracks to occur. it is necessary to do a proctor to know the OMC value so that it can be compared whether there is a negative pore pressure value in the field |
| | | | Filter sample | At the sample filter location there is quite a lot of clay material | it is possible that the samples taken have been contaminated so the sampling procedure needs to be explained in detail. |
| | | | Counter weight condition | In the body of the dam there is zone 5 which is a counterweight derived from disposal material and placed downstream of the dam | the existence of this counterweight there is a possibility that the material closes the toe drain. A solution needs to be found on how to proceed given the need to know the phreatic conditions. |
| | | 18 Margatiga | Core material does not meet requirement | Some tests of water contain do not meet requirement. | The number and percentage of test results that do not meet the requirements should be mapped (station and elevation), even though improvements have been made so that they meet the requirements. These improvements allow for core homogeneity |
| | | 19 Pamukkulu | Termal craking posibility of concrete | At the design stage, the Pamukkulu Dam concrete membrane was designed using a single layer (single) reinforcement with a diameter of 22 mm with a spacing of 200 mm between the reinforcements. It may cause cracking in the concrete. | It should be noted that the reinforcement aims to anticipate the occurrence of cracks due to thermal cracking and scaling.<br>The Campos Novos Dam uses a reinforcement ratio of 0.3 – 0.6%, additional reinforcement to prevent scaling at the pressure (compressive stress).<br>Concrete structure that are experiencing compressive stress (compression), it is necessary to add two layers of reinforcement. |
| | | | Changing spicification of zone 2B material | According to the design on the upstream slope surface of the embankment zone 2B, before casting the concrete membrane is planned to be protected using CS2B (Cement Stabilized Zone 2B), with a thickness of 30 cm. The consultant suggested that zone 2B embankment protection be changed using shotcrete with a thickness of 10 cm | It should be noted that the protection upstream of zone 2B functions is a concrete membrane cushion. If the concrete membrane cushion is designed in the form of shotcrete, the shotcrete design needs to follow the criteria of the concrete membrane cushion. |
| | | 20 Sadawarna | Dam material parameter | The result of triaxial test of core material is high for CH class soil | Check the reasonableness of the core zone triaxial test results used for stability analysis. In order to reflect actual conditions, unreasonable test results should not be used in stress path depiction. Typically the value of the effective shear angle for the core zone with CH soil type is around 200 +/- 40. The results of all embankment material tests should be submitted in full with the parameters |
| | | 21 Semantok | Embankment doesn't meet requirement | During the stockpiling process, test samples produced a density that did not meet the density requirements according to the technical specifications. Even though at that location, the embankment is then unloaded, backfilled, and compacted until meets the technical specification requirements. | The location where samples that do not meet these requirements occur should be mapped to be able to mark the spot if one day there is an anomaly reading on the instrumentation which may be related to the condition. The mapping referred to point one should be carried out by confirming the location through STA., elevation and location plans. This information should be included in the OP's Manual to bring to the manager's attention at the time of the OP |
| | | | Different value of permeability of main cofferdam and dam embankment | In the zone 1 embankment permeability graph, the main cofferdam embankment has a lower permeability value (10-6 cm/sec) than the main dam embankment, even though the source of material and the technical specifications of the embankment are the same. | This condition should be explained in the report as a result of an analysis of the Quality Assurance of the embankment work. |
| | | 22 Sepaku Semoi | Difference modulus of dental concrete and rock foundation | Limestone at the site location has some crevices (hole) that cleaned and filled by concrete dental K225. There is possibility of differential settlement if modulus is difference between dental and the rock. | What needs to be considered is the potential for differential settlement if the dental modulus value of the concrete is significantly different from the modulus value of the surrounding rock |

# Dam Issues Arised at Construction Sites (10/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | | high pore water pressure at dam embankment | Based on the results of piezometer monitoring, the embankment has quite high water pore pressure, which indicates that the existing chimney drain has not been effective in dissipating the pore water pressure. This condition may cause slope failure of the dam.<br><br>Moreover, based on inclinometer pipe inspection, it is estimated that there has been internal movement in the pile which is suspected as a landslide. | consider to construct a horizontal drain or counterweight to speed up the pore water pressure dissipation of the dam and increase the stability of the dam slope. |
| | | 23 Sidan | Material of ashphalt concrete | Asphalt concrete porisity for dam core | Based on I-cold the required porosity for ashpalt concrete is not to exceed 3%, it is necessary to check porosity in the field (convert void ratio to porosity) |
| | | | Filter density | Zone 2 of an asphalt core dam serves as a support for the core zone, so it does not require the same relative density criteria as the filter in a clay core dam. | Recheck the density used in making the LSDS test sample, it should be adjusted to that actually implemented in the dam embankment. |
| | | | Random zone material (dam shoulder) | The ramdom material of shoulder zone at sidan dam tend to be soil random with USCS class as SM soil | Seeing that the physical condition of the random zone material tends to have a very small cohesion value and Atterberg test is also not possible, it should be used as 0 in the stability analysis. If the cohession of soil will be include in dam parameter, the proper laboratory test should be conducted such sampling procedure, sample preparation, the pressure of sigma 3 as large as the dam height, etc |
| | | 24 Sindang Heula | Weathering Riprap | Volcanic breccia has weathered and in some places are cracked Results visual observation, the weathered breccia occupy about 20 30 of the entire riprap rock. | Rocks damaged riprap rocks are followed up by replacing fresh rocks in the proposed 2023 program. Fresh rock in the proposed 2023 program |
| | | 25 Sukamahi | Piping potential at core material (high pore pressure) | In the piping potential analysis that has been carried out, it can be seen in the picture that high pore water pressure values (red) are produced in the core zone at the top of the dam and at the bottom. High pore water pressure at the top of the isolated dam is somewhat unnatural; | an explanation should be sought for this, and the results of running seepage analysis should be added to a legend to make evaluation easier. |
| | | 26 Tamblang | Quality of cental concrete as base aslpalt concrete (no reinforcement) | The zoning image of the Tamblang Dam describes dental concrete (gray color), which is informed that it is mass concrete without reinforcement with K-225 quality, and the foundation rock is andesite, which is relatively strong. | The actual concrete quality value in the field and the modulus of elasticity should be added to the section. To further calculate the force that occurs in the dental concrete due to the heap load on it. |
| | | | Settlement of asplat concrete | Based on the trial embankment results, the settlement of asphalt concrete after it has been compacted is 2.8-4.8 cm for layer 1 and 2.7-4.4 cm for layer 2. | It should be checked whether the settlement of asphalt concrete in layer one has stopped or is still decreasing. If the asphalt concrete in layer one can still experience a decrease, then the decrease in layer 2 can be cumulative in layers 1 and 2. This matter should be considered and confirmed again according to the conditions in the field when compaction is carried out |
| | | | high stress potential at contact of dental and aspalt concrete | The contact area between dental concrete and ACC (Asphalt Concrete Core) material has the potential to experience high-stress accumulation. | It has yet to be planned to install stress monitoring instrumentation at this location. As a future study, it should be in zones with the potential to experience high deformation and stress based on design calculations; installing instrumentation (total stress cell or earth pressure cell) is recommended. |
| | | | Piezometer reading of embankment | At the time of the first impounding, the foundation piezometer showed a good condition, in the center of the dam the location of the piezometer embankment was close together which seemed to indicate a condition that had a relationship. | special attention needs to be paid regarding to the condition |

# Dam Issues Arised at Construction Sites (11/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 27 Tanju | Weathered riprap | Around 39.11% of the riprap rock was semi-weathered, and 3.43% was weathered. | a. A re-examination of the current conditions regarding the status of the riprap stone should be carried out.<br>b. To ensure the condition and level of weathering of riprap, laboratory tests must be carried out with an adequate and statistically representative number of samples.<br>c. Laboratory tests for riprap stone materials at least include the following:<br>1. Absorption test<br>2. Specific gravity test<br>3. Test for immutability or durability<br>4. Uniaxial test<br>5. Slake durability test<br>6. Abrasion test<br>d. The cause of the relatively rapid weathering of the upstream slope riprap rock should be re-evaluated. For this reason, the results of laboratory tests for riprap during construction should be re-examined, whether it meets the technical specifications or whether the riprap installed needs to be better, not selective in selecting or sorting riprap.<br>e. Riprap stone material that is weathered should be replaced with stone material that has good quality and meets the requirements of riprap stone material.<br>f. For fresh and semi-decayed riprap material, the consultant should recommend the need for maintenance, inspection and or replacement of the riprap during future operations and maintenance. |
| | | 28 Tapin | Based on the current piezometer readings, pore water has yet to reach a steady state | Based on the current piezometer readings, the seepage condition or pore water pressure inside the dam's body has yet to reach a steady state. | The seepage condition or pore water pressure in the dam's body should be rechecked based on the results of the latest piezometer readings<br>Considering that the Tapin Dam has not yet reached a steady seepage condition even though it has been inundated for more than two years, a seepage analysis should be carried out using the permeability coefficient according to the built requirements to estimate the length of time to reach a steady seepage condition. |
| | | 29 Tiga Dihaji | Rock fill material criteria | Based on laboratory test results, it is planned that the rock material should have a compressive strength value at least 25 MPa. | Based on SNI 8062:2015, the compressive strength of rock for high dams is around 35 - 45 MPa. In principle, as far as possible, dam body material is taken from quarry areas located around or closest to the dam location. Suppose the stone material parameters from the quarry area do not meet SNI requirements. In that case, the supervision consultant should conduct a dam body stability analysis according to the stone material parameters to be used and ensure that the dam body stability safety factors meet SNI requirements. It should be noted that if the technical specifications for rock fill material are not met following SNI requirements, there is a possibility that the slope of the dam body will need to be leveled, which will result in an increase in the volume of the dam |
| | | | Material changing for the dam | Supervision consultant deigns to change the rock-fill material that will be used, from breccia to sedimentary rock and breccia (sandstone dominant). | The supervision consultant should review the previous technical specifications concerning changes to the rockfill material. If several things in the previous technical specifications are unusual or do not comply with NSPM/NSPK, the technical specifications should be corrected, based on the results of the trial embankment, the material parameters do not match the design, so design changes are required, then the technical specifications should be revised again according to the design changes |
| | | | Thick overburden of dam material & Dam design chan | The overburden produced in the two quarries reached 11 million m3 so that disposal was needed then consultan propose to utilize the overburden to be dam body zone. | The overburden is sandstone and claystone, The sandstone material to be used needs to ensure that the quary can be used or not. The claystone used has good value, but keep in mind that in the long run the claysotne is easily weathered, so it is not good for the long term. |

# Dam Issues Arised at Construction Sites (12/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 30 Tukul | high pore water pressure at dam embankment | Before impounding, the piezometer chart of the embankment installed at the lowest elevation shows a fairly high pore water pressure, which is almost the same as the embankment elevation. This shows that the soil water content is also quite high, when compacted around the piezometer area. | To ensure this, the consultant should re-evaluate the results of reading data for each installed piezometer based on material data (compact moisture content, OMC, plasticity index, material that passes sieve no. 200, and other properties indexes). Likewise with the results of other piles of piezometer readings) |
| | | | there has been a sattlement of >1% (compaction was not carried out properly) | In the Multi-Layer Settlement cross-section (MSL) shown there has been a sattlement of >1% which indicates the compaction process during construction was not carried out properly or related to geological conditions or the presence of faults. | The consultant should evaluate the compaction results of the dam embankment to determine the cause of the considerable decline. |
| | | 31 Way Apu | Difference modulus of groutcap and rock foundation | The current condition of the excavation for the foundation of the dam body in the field has been carried out with several grout cap castings, and grouting has been carried out at several locations. | a. As a later evaluation, the quality of grout cap concrete that is too different from the dam foundation could cause differential settlement of the surrounding foundation rocks. The quality of grout cap concrete should be adjusted to the strength of the dam foundation. In general, a grout cap with K-125 concrete is considered quite adequate.<br>b. It is feared that the surface of the grout cap, which appears smooth, is a weak area against reservoir water seepage due to its lack of strong adhesion to the resulting dam core zone material. Therefore it is recommended:<br>• Before being filled, the surface of the existing grout cap is made rough by "chipping" randomly and carefully.<br>• For further "concrete capping", the surface of the grout cap should be roughened before it dries by means of "brooming" in a direction parallel to the dam axle.<br>c. The grouting direction should cut the slope of the most dominant crack areas (discontinuity areas) after being evaluated using the "Schmidt net" to obtain effective grouting results. Likewise, with the direction of the check holes.<br>d. When selecting the maximum pressure at each stage of cement grouting injection, you should pay attention to the critical pressure seen in the water flow pattern graph obtained from the water pressure test.<br>e. At each stage of grouting injection, an evaluation should be carried out regarding the suitability between the amount of "grout take" and the physical-mechanical condition of the rock being grouted, including "core recovery" and its RQD. If there are zones that experience anomalies, re-grouting should be carried out.<br>f. Lugeon maps should be made on all the same cross sections at each investigation stage, pilot hole stage, primary and secondary grouting stages, tertiary stage and, if applicable, quaternary stage |

# Dam Issues Arised at Construction Sites (13/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | | Contact clay material | In carrying out contact clay embankment work | 1) Contact clay must be installed on all core zone foundation surfaces, including support slopes and concrete walls that meet the core zone embankment.<br>2) Contact clay should use a more plastic core clay material (higher IP) by eliminating coarse grains in the core material and keeping the water content slightly wetter than OMC conditions (around 5~ 10% above OMC).<br>3) A minimum of three layers of contact clay are applied with a thickness of about 10 cm for each layer, and each layer must be compacted well.<br>4) Before spreading contact clay, the foundation surface should first be cleaned of dirt, loose materials, etc., and then the foundation surface should be moistened.<br>5) When compacting contact clay on sloping areas (support slopes) and concrete spillway wall surfaces, you should pay attention to the following matters:<br>• The contact clay material is spread with a layer thickness of around ‡10 cm, with the surface of the layer made at an angle (around 1:6).<br>• Contact clay material is compacted with a stamper baby roller or other tool with the direction of compaction movement perpendicular to the support slope so that the pressure of the compactor tool is directed directly at the sloping foundation surface. After 3 layers of spreading and compacting the contact clay, the regular embankment of the core zone is spread and compacted, and so on. (See Guidelines for Implementing Embankment Dam Construction p.83).<br><br>6) To avoid errors in the implementation of contact clay compaction, an SOP for contact clay compaction must be created, and more intensive attention needs to be given to implementing the compaction |
| | | | | | |
| 3 | Dam Stability | 1 Bajulmati | Cross and long crack and settlement at Dam Crest | 1. Cross cracks with a width of 2 cm starting from the upstream side of the canstine to the pile wall of the abutment hill<br>2. Longitudinal cracks between drainage joints and asphalt pavement, with a crack length of ±10 m and a width of 1 cm.<br>3. a settlement in one of the points at upstream direction of dam | • Installation of monitoring instruments such as measuring dials to check whether the crack continues or has stabilized.<br>• Georadar testing to check the depth of the crack<br>• Installation of new shear stakes for the upstream side |
| | | 2 Bintang Bano | Craking on dam crest | There were cracks in the road at the top of the dam (settlement indication). | Regarding the presence of these cracks, it should pay attention to the following things:<br>• Crack locations should be depicted on the dam layout.<br>• An analysis should be carried out regarding the causes of cracks related to dimensions, geometry, crack patterns, and existing instrumentation readings. Then, what is the repair solution, and predict what will happen if the crack is not treated immediately. |

# Dam Issues Arised at Construction Sites (14/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 3 Budong Budong | high density parameter of design | The Parameter of input data of stability need to be considered properly. | a. parameter density of material core zone □=18.4 kN/m3 is considered too high and will be difficult to achieve in the field, should be corrected, for example to 17 kN/m3<br>b. Parameter internal friction angle of filter zone material and transition is used same value of 35°, while phi randon rock used a lower value of phi = 28°, the same as core zone phi = 28°.<br>• The phi (□) value of random rock is the same as the □ value of the core, this is unnatural, the parameters should be re-examined and corrected.<br>• Cohesion (c) and effective internal friction angle (□') in the core material are quite high. The effective inner shear angle value in this material can reach 28° but usually the cohesion value is close to zero. Recheck these values and attach the laboratory test results of soil shear strength.<br>c. The design parameters internal friction angle of filter and transition zone materials are determined based on assumptions. Laboratory tests should be conducted to ensure that the values of internal friction angle and other parameters that match the conditions of field and after compacting.<br>d. Design parameters used in the analysis of slope stability, will be used as technical specifications in the implementation of backfilling and compaction in the field, the value should not be taken too large so that it is difficult to achieve when implementation of compaction in the field.<br>e. Based on SNI 8064: 2016 static slope stability analysis method of embankment type dam, loading conditions that should reviewed on the analysis are:<br>• construction period condition<br>• lasting flow condition<br>• operational condition<br>• emergency condition<br>f. Calculation of pore pressure should refer to SNI8064: 2016 static slope stability analysis method of embankment type dam p.13-14. |
| | | 4 Gondang | conterweight additional | In order to improve stability, the Gondang Dam was modified with the addition of counterweights on the upstream and downstream slopes of the dam body. To strengthen the technical justification for the addition of the counterweight structure | A chronology should be prepared that explains the following:<br>a. The initial design of the Gondang Dam<br>b. The design changes made during the construction of the Gondang Dam.<br>c. The design of the Gondang Dam as a result of construction implementation and the problems that caused the need for counterweights.<br>d. The design of counterweights to handle post-construction problems. Counterweight design to handle post-construction problems.<br>In each of the above stages, a detailed description of the physical and mechanical properties of the embankment materials used, the results of instrumentation observations and visual inspection in the field, as well as the results of the stability analysis based on the shear strength parameters of the embankment and the results of the actual field inspection of the dam should be explained. |
| | | | Difirence specification of counterwright material | In the implementation of counterweight construction, there are differences between technical specifications and conditions in the field. | In principle, if the material in the field is difficult to find in accordance with the predetermined technical specifications, it can be tolerated as long as the Safety Factor value in the calculation of dam body stability can be met in accordance with SNI 8064: 2016 concerning Methods of static slope stability analysis of earth type dams.<br>In the counterweight construction implementation report, it should be ensured that the technical specifications and quality control methods of the counterweight construction implementation are available in the technical specification report. Furthermore, it should be ensured that the quality control results during the counterweight construction fulfill the technical specifications. |

# Dam Issues Arised at Construction Sites (15/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 5 Karian | High settlement potential | Camber height is planned 70 cm (1% of dam height), considering the core material is wet core, it may be 2-3% settlement. | Settlement should be calculated with modulus value of material at the site. |
| | | 6 Keureuto | Settlement of core embankment | In the multilayer settlement, the graph still looks down and still does not show that it is starting to flatten where it is located below, From the existing settlement results that the condition of the core material is still elastic and still continues to fall together, until now the potential for differential settlement is very small | the settlement condition of lowe part at the dam body needs to be explained by the consultant and the consultant should explain the thickness of the chamber to the total settlement after construction, the figure should be calculated before impounding. |
| | | 7 Kuningan | Bulging at dam surface | On the left side of the dam crest, it appears that the surface of the dam crest is bulging. | The history of cracks at the top of the dam should be checked, starting from the completion of construction until now.<br>Surface bubbling should be confirmed using the monitoring results of shear stakes and other instrumentation in the surrounding area.<br>The possible causes of surface bulging should be examined due to the shape of the dam's left support slope being too steep. |
| | | | high settlement from instrument reading | the parabolic settlement chart of multilayer settlement instrument, it appears that the largest settlement (deepest trough) is almost the same as the dam's left abutment. | • The graph should be equipped with multilayer settlement plotting on the cross-section of the dam body.<br>• The cause of the high settlement at the dam's left abutment should be evaluated, examining the possibility of the embankment slope being too steep.<br>• The amount of settlement should be calculated at the time of completion of construction until completion of consolidation to confirm the accuracy of the camber height that has been installed. |
| | | 8 Ladongi | Crack on construction joint of dam | The top of the dam, seen from the left support, looks good visually with a flat surface. However, on the upstream and downstream walls of the safety guard, there are transverse cracks in the construction joints. | a. Check whether the crack only occurs at the construction joint or continues from upstream to downstream of the dam.<br>b. Monitor crack progress by installing a crack meter on the crack. |
| | | | Crack on aspalt at dam crest | The asphalt pavement surface at the top of the dam looks cracked and wet; check whether this is due to swelling, shrinkage, or rain.. | Check whether the crack is deep enough and has a trend in a specific direction to conclude the cause and treatment |
| | | 9 Lausimeme | Sudden settlement of core embankment | From the settlement instrument readings and there is a large and sudden settlement even though the position is relatively at the top of embankment. | Technical judgement should be explained related to settlement condition at the top of embankment |

# Dam Issues Arised at Construction Sites (16/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 10 Marangkayu | Dam body inspection (deformation) | Based on dam body inspection there are several deformation indication. | a. It was reported that the crest surface of the dam was uneven or wavy. This may indicate that the subsidence of the foundation soil in the form of soft clay soil has continued until now. It is necessary to re-evaluate the settlement that has occurred in the foundation and body of the dam, both primary consolidation settlement (whether it has been completed or not) and secondary settlement, is this still ongoing?<br>b. Compare the results of measurements of the current topography of the body of the dam with the initial conditions, especially on the parts that are experiencing deformation.<br>c. The top of the dam should be compacted again. But before it is compacted, make sure that the settlement that occurs in the body of the dam has decreased.<br>d. Currently, the top of the dam has not been equipped with drainage channels. The consultant proposes to install a drainage channel at the crest edge of the dam. Make sure the drainage channel at the top of the dam can distribute water evenly and there is no concentration of flow in certain parts.<br>e. In the presentation of the technical discussion, it was reported that there was damage to the downstream slope of the dam. It is necessary to ensure that the damage that occurs on the downstream slope of the dam is in the form of cracks or surface erosion.<br>f. Due to the Covid-19 pandemic, KKB members and the Study Team for the Dam Engineering Center did not allow field inspections. For this reason, in the upcoming KKB discussion/assembly, the consultant should present videos and photos of field inspections and operational tests completely and clearly (one photo is made on one slide) so that the general conditions and detailed components can be seen: dams, auxiliary buildings, hydromechanical equipment. , reservoir, etc. Show the general condition of the dam and reservoir with drone video, including showing the location of the gas wells.<br>g. The position of the gas wells should be plotted on the reservoir inundation map. |
| | | 11 Meninting | Rapid drowdown | random material of meninting dam is tend to be soil random that has low permeability | Consideration should be given to the stability of the dam, especially under rapit drawdown conditions because the permeability of the random material is quite small. |
| | | 12 Napun Gete | landslide of dam slope stability mostly passes through zone 4 | The landslide field of dam slope stability mostly passes through zone 4. Therefore, rock types, gradations, and shear strength parameters need to be studied in more detail. | It is necessary to ensure that zone 4 is a rock-fill zone or random rock. |
| | | | Sudden settlement | The results of multilayer settlement readings show that there was a sudden decrease due to water saturation in the reservoir during impounding in August 2021 which could result in internal cracking. | An inspection should be carried out whether the dam body material includes collapsible soil. Collapsible soil is kind of soil that is very susceptible to collapse due to saturation. |
| | | 13 Paselloreng | settlement in the riprap (near the right abutment of upstream) | Visual observation showed there is a settlement in the riprap (near the right abutment of upstream) | |
| | | 14 Pidekso | Uplift potential | At the foundation of the dam body between sta 0+120 to 0+280 there is a concrete pad structure. Looking at the length of the concrete pad structure and the secant pile underneath, it is possible that there will be a large uplift potential in this zone later. | Regular monitoring of the zone should be carried out through instrumentation installed on the dam body.<br>The potential for uplift and accumulation of high pores water pressure in this area should also be included in the dam's OP guidelines (as suggested in discussion on August 31, 2021). |

# Dam Issues Arised at Construction Sites (17/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | | Crack along dam foundation | At the foundation of the dam body at STA 0+320 there is a closed fracture and a zig-zag grouting treatment was carried out. Zig-zag grouting treatment was carried out. | It should be ensured that appropriate treatment is taken to prevent seepage from occurring.<br>There is seepage at downstream of the dam at elevation +163 m, check the possible continuity of the fracture at the dam to the point where the seepage occurs.<br>To determine the effectiveness of handling and correlation of seepage downstream, measurement data of OW (Observation Well) 7 downstream of the fracture should also be presented, especially when the reservoir water level is already at MAN +185 m. |
| | | 15 Raknamo | wavy asphalt on dam crest and crack | Based on the inspection report in 2018, there were several deformation on the dam body.<br>• Wavy rip-rap, rip-rap locks are so lacking that there are many spaces.<br>• Uneven wavy asphalt at the dam crest<br>• There is a crack in the sidewalk ± 15 m to the left of the axis of the tunnel, with cracks upstream and downstream. | |
| | | 16 Randu Gunting | Vertical and horizontal movement of dam (high differrence) | Based on the measurements of the shear stakes, the vertical movement experienced the greatest decrease on the right, but the dominant horizontal direction moved downstream. | • The cause of the difference in the vertical and horizontal movements should be evaluated.<br>• It should also be compared with the results of the shear stakes' surface movement with the inclinometer's internal movement and the multilayer settlement.<br>• It must be ensured that all tools have been properly calibrated in carrying out shear stake measurements and that measurements are carried out in favorable weather. |
| | | 17 Rukoh | Broken Piezometer of embankman and dam foundation | There is a broken piezometer in PF-1 foundation and PE-1 and PE-2 in the embankment | At the location of the embankment as long as the data of PF-3 is still aligned, it can be represented by PF-3, for PE-1 and PE-2 as long as they can still describe the contour pattern, there is no need to replace them because drilling at that position is quite difficult considering that the rock is rockfil and at the embankment location will also drill rockifll and filter. At location PF-1, the replacement location should be brought closer to the filter. It would be better to add OSP there around the VWP instead of in the foundation and embankment |
| | | 18 Sei Gong | Surface erosional on dam body | Sei Gong dam has grass protection on the dam body, but in some places the grass has not covered the entire dam body. at STA1 + 50 there is surface erosion on the dam body because it has not been protected by grass. | |
| | | 19 Semantok | Uplift potential | the antural condition of dam foundation permeable | It is also necessary to take into calculation the potential stability of the dam based on the amount of uplift that occurs because there is the potential for uplift. |
| | | 20 Sepaku Semoi | Slidding during construction at dam embankment | December 20th, 2022, sliding occurs at embankment | The Dam Manager conveyed the chronology of the landslide starting from a small crack which gradually turned into an avalanche, then excavation was carried out as deep as four meters. Reconstruction of the landslide area should be carried out properly and ensure that backfilling does not result in another landslide. |
| | | 21 Sidan | Depth of D-Wall and Uplift potential | From the results of grouting that did not reach 2/3 H where it is still dominated by materials that have high lugeons, there is a possibility of seepage occurring around the D-wall. | From the pressure analysis, the uplift occurs in a fairly wide zone, from the uplist analysis, there is a large pressure at the end of the D-wall, there is a possibility that the D-wall is not deep enough. |
| | | | Dam deformation | There is considerable deformation in the shield zone as seen in the inclinometer readings and the possibility of pulling the asphalt concrete | it is necessary to reconsider whether the asphalt concrete is able to withstand the deformation that occurs, especially in the event of an earthquake. |
| | | 22 Sindang Heula | Settlement on the dam crest | From visual observations, several places at the crest of the dam, especially near the Box Instrumentation there is a slight settlement. | The settlement measured by the shear stakes (monument) is in the extra embankment, not in the dam body. |

# Dam Issues Arised at Construction Sites (18/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 23 Sukamahi | High settlement reading | In th results of multilayer settlement readings, before the landslide occurred (29/10/2021), there was a decrease of 60 cm. After backfilling was carried out following a landslide (27/05/2022), an at 25/08/2022, the subsidence reached 25 cm. After that, a reading rose by 2 cm due to the difference in reading datum; until now, the decline that has occurred since 08/25/2022 is relatively flat, with the final point being around 2 cm deeper. | a. To be aware, in embankments of soft (wet) soil material, embankment settlement exceeding 1% is very likely to occur; only the extent to which this settlement can exceed the plastic limit of the embankment material requires a more detailed evaluation.<br>b. A deformation analysis should be carried out to determine the dam body's plastic and elastic limit values , then compared with the dam deformation instrumentation readings (multilayer settlement, inclinometer, and shear stakes). |
| | | 24 Tamblang | Safety factor of MDE analysis doesn't meet requirement | Based on the summary analysis results of dam slope stability under MDE conditions, the resulting safety factor does not meet the required safety factor, where FK = 0.40 (too small). The consultant has analyzed dynamic slope stability with time histories of earthquake acceleration, but the results still need to be evaluated. The vertical deformation occurs very small, but the horizontal deformation is relatively large. | The vertical deformation that arises should be assessed against the adequacy of the guard height, and the flat deformation results should be evaluated against the adequacy of the filter and transition zones in protecting the core zone if it experiences cracks. |
| | | | Craking on dam crest (aspalt road) | Peak Cracks Dam, Depth Up to > 5 cm in some parts, treatment is carried out with asphalt patching continually. | |
| | | | Dam Deformation | There is considerable deformation in the shield zone as seen in the inclinometer readings and the possibility of pulling the asphalt concrete | The inclinometer shows considerable deformation for a rockfill type dam, with considerable deformation is the asphalt core able to withstand the deformation of the rockfill. Check where the kick off of the inclinometer starts whether it is at elevation 168-171 where there is seepage. |
| | | 25 Teritip | Instrument settlement reading | The results of the slope settlement point monitoring readings at point SS-1 is decreased. | a. It should also be evaluated with the actual conditions in the field, as well as the correlation of the position of the CS-01 point which has decreased.<br>b. Graphic depiction of surface monuments should be drawn on the longitudinal cross section (as built drawing), so that the trend and tend of the decline (z direction) are visible. in the depiction there are 2 different scales, for example the longitudinal cross section in mater and the decline in mm or cm, the magnitude of the decline is depicted in a form that shows the magnitude and direction of the decline.<br>c. Results of the measurement of the X and Y directions are depicted in a drawing plan (lay out) and also in vector form. |
| | | | X-Y movement direction | On the crest settlement point graph, it appears that CS-01 (blue color) has decreased readings, and according to consultant information, there is indeed a movement in the X-Y direction at that point. | It should be confirmed with actual conditions in the field whether there is really a movement. |
| | | 26 Tukul | Immediate settlement | From the time- Settlement graph of the multi-layer sedimentation during impounding, there is a sudden settlement (immediate settlement) due to saturation, some of which are up to 10 cm in size. | The consultant should conduct a more in-depth study of this phenomenon (for example: is compaction carried out on the dry side, what type of soil is collapsible soil? Etc.). This decline can result in internal cracking, which develops into internal erosion. |
| | | | | | |
| 4 | Water Seepage / Spring on the Dam | 1 Ameroro | Water sepage on dam foundation | water sources found after excavation of foundations | Seepage handling is generally carried out by dewatering, while flowing well (spring/artisian) handling is carried out with concrete buis, based on monitoring of its head during the dry season and rainy season. |
| | | 2 Bendo | Seepage around the v notch | There are leaks around the V-notch and on the right abutment of the dam | it is necessary to conclude the condition of the seepage supported by data and add whether the seepage is a danger to the safety of the dam. |
| | | 3 Bener | Akuifer influence | During construction informed that there area akuifer at dam foundation of bener dam up to 2 m. | Recalculation of the seepage model is required because during construction there are aquifers up to 2 meters positive. if there are aquifers, consider to install piezometers. |

# Dam Issues Arised at Construction Sites (19/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 4 Cipanas | V-notch seepage before imponding (2 liter/second) | Before impounding, there was seepage at the v-notch with a discharge of 2 liters/sec. | It should be checked in the area whether there are springs and faults identified at the time of implementation. If there are seeps and faults from the geological conditions, separate measurements should be made.<br><br>The consultant still measures the V-notch reading, the spring is located at the top of the dam at the filter foundation |
| | | 5 Gongseng | seepage from lithology boundary (limestone and marl) | It was informed that there was spring seepage in the boundary area between the limestone and marl units on the left bank of the dam. However, seepage is only described as one point, not along the boundaries between rock units | Geological maps and cross-sections should be corrected according to conditions in the field. The seepage conditions and how to handle them should be explained in detail in the report description. |
| | | 6 Karalloe | Spring on the dam body | It is mentioned that the spring found downstream of the dam did not increase so no monitoring was done. | A comparison of the discharge from construction to post impounding should be presented at this time.<br>Based on consultan information that water seepage found downstream to the right of the dam above the sungi trough has a discharge of about 1 l/s and did not increase during construction, so that after being buried by zone 3c embankment material during construction until post impounding.<br>This seepage also flows on the surface and merges with the water whose volume is recorded at the V-notch. The volume recorded at the v-notch in the dry season is about 7.5 l/s and in the dry season 40-50 l/s. |
| | | 7 Keureuto | Seepage at the chute floor of spillway | Based on the results of visual observations in the field, seepage occurs on the spillway launcher's floor and the spillway's side walls. Based on evaluation from consultants, the emergence of seepage is caused by an aquifer/spring in the foundation of the spillway building based on the results of a geoelectric survey. | On this matter, it should be:<br>1. Consider creating a geological mapping structure 3D in the area below the spillway;<br>2. Make a situation map of the seepage points that occur, complete with documentation, then take measurements that include the coordinates of the points and their elevation. This needs to be done to investigate the relationship with the reservoir water level when filling the reservoir and when monitoring the amount of seepage that occurs;<br>3. make a plating of the seepage exit location into the geological map of the dam. Based on the geological map, evaluate the causes of seepage related to geological conditions.<br>4. Periodically measure and monitor seepage discharge from springs during construction until the initial filling of the reservoir and so on. The measured seepage discharge data should be made in graphical form and correlated with rainfall data and reservoir water level rise data during the initial filling of the reservoir and beyond.<br>5. Analyse and evaluate the seepage discharge by comparing the seepage discharge measured during construction with the initial filling of the reservoir. The seepage analysis carried out should be able to confirm the lift pressure acting on the spillway floor and walls.<br>6. One problem is the design of the exhaust system at the bottom of the plate and the back of the side walls. Generally, the drainage network system is below slab concrete and drainage behind the side walls is designed with water holes. Still, in the Keureuto Dam, drainage under the slab is only provided by one channel in the middle of the 30 m wide slab, and there is no drainage system behind the side walls. The consultant should be able to provide additional discharge pipes.<br>7. The consultant should create a sub-drainage system under the spillway slab to overcome the up-lift problem in the spillway launch channel. This system should be integrated with the drainage system behind the spillway wall, including filling the space outside the spillway wall in the form of backfill, free-draining material. The drainage system (sub-drain and backfill behind the spillway wall) is very important to support the |

# Dam Issues Arised at Construction Sites (20/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 8 Leuwikeris | Seepage from left and right abutment | There is seepage on left and right abutment, concrete pad is made on lower part of the abutment for withhold seepage. | Mr. Paulus commended:<br>The seepage at the abutment can be reduced by:<br>a. Wall<br>b. Grouting manset (manchette)<br>c. Secant pile<br>Need is known how much runoff occurred on shortcrete because found a number of carbonation<br><br>Mr. Shimizu commended:<br>Compaction cannot be done optimally if foundation is wet, in the field already there is a number of Installed well release, necessary check effectiveness from the release well<br>For controlling the water on foundation can be done with making a pit on base Foundation and pump it then lowering the water level. If the embankment already done, the well can be fill with bentonite or cement (base on well diameter) |
| | | 9 Logung | Seepage at left dam abutment | On the downstream left abutment there is seepage from the spring that flows down the downstream slope of the left side. This flow has been directed so as not to damage the downstream side of the dam body. | The existing channel needs to be improved so that the directional flow is not wild. A small V-notch should be constructed to measure seepage discharge periodically as with other seepage streams. |
| | | 10 Napun Gete | Seepage at the downstream of dam | It was reported that seepage or leakage occurred at several points in the downstream dam during field inspections in 2022. | Routine monitoring of seepage or leak should be carried out. It is necessary to evaluate whether seepage originates from the body of the dam or the foundation rock by looking at the history of seepage during construction.<br>At points that experience seepage or leakage, a cross-section should be made for further analysis of the creep length and the amount of uplift at the leak points in the downstream part of the dam body.<br>Suppose the analysis results in a high uplift potential at the location of the leak. In that case, the Consultant should also recommend treatment, for example, by adding a counterweight to the downstream part of the dam body. |
| | | | High discharge | In the graph of the readings of the seepage at the foot of the dam, it can be seen that the seepage is quite high at the foot of the dam on the right side, but the reservoir water level does not show an increase. It was stated that at the time of construction, there were several spring points both upstream and downstream of the dam on the right side. | a. It should be checked again whether the seepage reading is high enough influenced by the presence of these springs.<br>b. The results of the seepage discharge readings should be compared with the pore water pressure contour, to find out whether the dam is in a steady seepage condition or not.<br>c. Every time you measure the seepage discharge that passes through the v-notch building, you should also check for the presence of soil particles in the dam embankment material in the water that comes out, especially in the seepage to the right of the dam. |
| | | 11 Nipah | Water pressure on OW has higher elevation than ground surface | Point OW-3 has a water table elevation tends to be higher level than ground surface. | |
| | | 12 Paselloreng | Scouring and seepage at spillway | At the connection of the left wall and the spillway floor, seepage and scour were found at the elevation touching the appron (elv 46.00 m) seepage was seen especially after rain, this scour eroded the the surface of the left spillway wall. | |
| | | 13 Pidekso | difference seepage from v-notch reading | It was explained that v-notch readings are only affected by rainwater, and when it is not raining the v-notch is dry. However, at v-notch 3 there are seepage discharge results even when there is no rain (April - June 2021). | The origin of the seepage water should be explained, including whether it is also influenced by foundation seepage, or whether there are springs during construction that come out at the current v-notch. This condition needs to be correlated with the foundation piezometer readings, to determine the pore water pressure at the time of construction completion prior to inundation. |

# Dam Issues Arised at Construction Sites (21/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 14 Raknamo | Seepage on the abutment and toe drain | There is seepage/water springs in the right abutment. Seepage in the to drain is located on MD 20 when there is no rain seepage decreases, at the location of the seepage source located above the tunnel, at the time of the implementation process only covered with concrete so that after completion of the backfill construction and rain occurs | |
| | | 15 Randu Gunting | Seepage on the slope near to valve house | Monitoring of seepage discharge on the slope near the valve housing is done manually with a measuring cup. During monitoring, a blast of around 0.5 - 0.8 liters/second was obtained | a Parshall Flume meter should install to measure seepage at the location. |
| | | 16 Semantok | Reservoir leakage posibility | Previously, there had been seepage problems due to geological conditions of limestone in the existing dam reservoir where not far from the Semantok Dam location, namely the Bening or Widas Dam and the Pacal Dam. | It should be paid Attention to the possibility of a similar incident at the Semantok Dam due to the similarity of the geological conditions with the foundations of the Bening or Widas Dam and the Pacal Dam |
| | | | Seepage at the dam toe | the presence of seepage at the downstream toe of the dam (100 m along) | the consultand concoy that there possibly from the hill at the dam due to elevetion at the downstream dam is higher than tan toe dam elevation. Considering that the seepage area located around the conduit the asbuilt and geological condition should be checked |
| | | 17 Tamblang | Water leakage through dam body ( can reach 1 $m^3/s$) | Water leakage occurred on dam body at elevation 168 to 170 m and also on the dam toe. Discharge monitoring results at the toe of the dam once reached 1 m3/sec. | |
| | | | Dam body seepage | At the time of the addition of the D-wall and grouting in March 2024, there was a flood up to elevation +175 (above the location of the dam body seepage, 168-171) visually there were no visible leaks on the left and right of the dam, but the dam body was still there. | It is necessary to conduct a reservoir water level rise test to determine the locations where seepage occurs and the amount of discharge that occurs. |
| | | 18 Titab | Spring at the downstream of Dam | At the downstream of dam, spring water occur with pressure (artesian) | It recommend installing 2 or 3 pressure release wells around OW 5, with the same depth as OW 5. |
| | | | Seepage at dam toe | 4 seepage location was observed at the dam toe | It is necessary to investigate the electrical survey from the body of the dam (upstream) to the downstream to correlate the instrument readings with the presence of seepage in the dam. |
| | | 19 Tugu | seepage at foot of downstream slope | There is seepage water at the foot of the downstream slope located near the Irrigation House. The flow discharge during the rainy season is about 1.5 liter/s, during the dry season it becomes smaller at about 0.60 liter/s. Before impounding the seepage water at this location already existed during the rainy season, then decreased & dried up during the dry season. | |
| | | 20 Way Sekampung | Spring/seepage at right abutment | The seepage that occurs comes from springs that occurred during the tunnel excavation of the right abutment hill in 2017 to 2018. | The amount of discharge and its development have never been monitored. It is recommended that the quality and quantity of seepage discharge be monitored and its correlation with fluctuations in the reservoir water level be examined.<br>Spring seepage is conveyed by two pipes to the drainage channel. It is recommended that the V-Notch structure be constructed in accordance with SNI 8137:2015 regarding "Measurement of Discharge in Open Channels Using Upper Spillway Type Measuring Building". |
| | | | | | |
| 5 | Grouting | 1 Ameroro | Very deep grouting at abutment | The depth of curtain grouting appears to be uniform (same depth) from the riverbed to the abutment hill | the depth of curtain grouting is carried out by considering the height of the head (H) above it (generally = 2/3 – H), so that the grouting depth will be shallower in the abutment area |

# Dam Issues Arised at Construction Sites (22/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 2 Bener | no foundation grouting in placess | It was stated that the dam foundation is dominated by andesite breccia rock. Andesite breccia rock is thought to be impermeable and does not require foundation repairs with grouting. To determine this condition, a grouting trial has been carried out on the right abutment of the dam. The consultant determines the trial grouting location based on the results of drilling investigations during design and additional drilling investigations during construction, which are depicted in the geological longitudinal profile as presented in the following image. | a) The RQD value of the foundation rock should be explained to provide an overview of the geotechnical condition of the rock foundation.<br>b) If the foundation rock has many cracks, it is important to ascertain whether the cracks are connected from upstream to downstream of the dam.<br>c) When interpreting foundation rocks, it is important to stay within the depth of the drilling that has been carried out, the geological cross-sectional image above should be corrected and limited to the drilling depth limit.<br>d) The grouting criteria need to be determined first, taking into account the condition of the foundation rock mass based on the reference or NSPK regarding foundation repairs. |
| | | 3 Cipanas | posisibility of seepage between spillway and abutment | Curtain grouting has been carried out at the contact between spillway structure and hill abutment, but it seems that only protects the bottom of the foundation. | The curtain grouting design should be evaluated as possible the highest amount of water can reach the abutment and make sure that there no seepage through contact between spillway and hill. |
| | | 4 Gongseng | Ineffectiveness grouting indication from instrument | In the post-construction, pore water pressure contour image shows the phreatic water level on the dam's downstream side is higher than on the upstream side. Apart from that, seepage flows appear to have occurred on the downstream side of the dam. This indicates the ineffectiveness of grouting. | a. Landslide-prone areas around dams and reservoir reservoirs should be mapped in detail.<br>b. The OP Guidelines should convey the need for intensive monitoring of landslide-prone areas during initial filling and when the dam is operational later.<br>c. If there are indications of landslides, anticipatory measures should be taken immediately. |
| | | 5 Jlantah | Replaced grouting by cut-off wall | The consultant plans that the connection of cut-off wall will be conducted by curtain grouting (overlap of 2 meters on the left side of the riverbed) and a stepped structure will be made on the right side of the foundation. | The contact area between the curtain grouting structure and the diaphragm wall is a weak zone that can become a foundation seepage path. Therefore, the consultant should ensure that the overlap distance between the two structures on the right and left is sufficient.<br>To assess the effectiveness of the cut off wall to be implemented, the pumping well test can be used. The design of the pumping test is made in such a way that the position of the pumping well and the monitoring pipe can describe the depression cone needed to determine the effectiveness of the barrier wall. |
| | | | addditional monitoring for grouting dan D wall conection | The foundation improvement of Jlantah Dam using grouting and D-wall but there no detail about the conection of both method. | In addition to monitoring using a piezometer, the downstream should also be monitored using an OW to ensure the effectiveness of the D-wall connection and grouting. The depth of the OW should also be adjusted according to the height of the dam, because the dam height is about 70 m, there should be an OW of 45 m deep. |
| | | 6 Keureuto | Lugeon Value of Grouting | The consultant presented the Lugeon Map during the discussion before and after grouting work. The map shows that the Lugeon value of all grouting curtain areas before grouting is more than 20 Lu. However, the depth of the curtain grouting on the right edge is much shallower than on the left. | The dam builder, assisted by a consultant, should re-examine the adequacy of the arrangement of the curtain grouting installation area and prepare a grouting evaluation report containing samples taken, injection time, etc., as well as the Lugeon value, especially in areas where it is reported that there is still Lu>5. |

# Dam Issues Arised at Construction Sites (23/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 7 Kuningan | Ineffectiveness grouting indication from instrument | Based on the piezometer reading graph of the foundation at the deepest section, the piezometer readings upstream and downstream of the curtain grouting are almost the same, indicating no influence of the curtain grouting. | • Check the correctness of the reading and calculation data, especially the initial installation data.<br>• Check the geological conditions foundation to determine whether the presence of geological structures causes the condition in point (a). Likewise, check the dam's downstream side to see any wetting. The cause of this anomalous condition must be explained.<br>• The seepage path at the dam foundation should later be correlated with the OW (Observation Well) instrument downstream of the dam.<br>• If the correlation is less common, the accuracy of the foundation piezometer installation that has been carried out should be checked.<br>• The uplift potential in the dam foundation should be checked to ensure that the dam body is in a safe/stable condition from the potential uplift.<br>• The water level in the OW should be checked before the initial filling of the reservoir until now to determine the influence of the water level in the OW on fluctuations in the reservoir water level. |
| | | 8 Lausimeme | Insufficient groting at the dam | The CL-CM foundation rock class in the riverbed section is indicated as a continuous weak zone from upstream to downstream of the dam. The supervising consultant has grouted 15-25 m deep in the weak zone upstream of the core zone. The grouting depth considered is insufficient to cover the cracks in the weak zone completely, so it has the potential to become seepage when the reservoir is impounded and also has the potential for differential settlement. | The existence of weak zones should be investigated carefully. Check whether the weak zone is a fault or not.<br>weak zones or faults that are not too wide, can be improve by excavating weak zone material/squeeze material to a depth of 1.5 the width of the weak/fault zone, then backfilling with wedge-shaped concrete and combining it with grouting.<br>The downstream weak zone of the core zone should be excavated at least 1 m depth, then covered with a filter of sand and gravel (on top of the filter) to prevent the carrying of foundation material into the random zone.<br>The consultant should re-evaluate the strength of the grout cap in the weak zone to withstand the loading of the dam body and the water above it. If it does not meet, a repair design should be prepared.<br>A special report should be made regarding the existence of weak zones with their corrective/handling actions, including the Lugeon section, the pilot hole to the check hole at the weak zone. |
| | | | Rim grouting | From the grouting design that has been carried out, rim grouting on the spillway does not reach the abutment hill | rim grouting needs to add curtain grouting on the spillway rim to touch the natural hill. The obstacle is that there is already a building above it and the consultant has installed an observation well to see the potential side leakage that occurs. As a suggestion, grouting during construction will be easier than after impounding. |
| | | 9 Leuwikeris | The grouting carried out does not reach the appropriate depth in the body | At several part of grouting is very narrow, comparing to the height of dam | |
| | | | Fondation seepage of grouting and D-wall conection | Leuwikeris dam using grouting dan diafragm wall for foundaion improvement | There is potential seepage between the diaphragm wall and grouting, special monitoring and measurement of seepage should be carried out. If repairs are made, there must be a comparison between before and after the repair. |
| | | 10 Meninting | Rim grouting | Grouting that been carried out on the spillway building only up to the side of the spillway weir | The grouting should be extended to the right abutment hill, and the end part should be covered with curtain grouting to prevent side seepage around the spillway building. |
| | | 11 Rukoh | Grouting for Spillway | The end grouting of spillway is spillway wall | it needs to be confirmed whether any fan grouting is done after the spillway, looking at the drawings no fan grouting is carried out. |
| | | 12 Sidan | Consolidation grouting for tunnel floor | The consultant plans to strengthen consolidation grouting on the tunnel floor because the rock condition is sandy tuff with an NSPT value of around 15 - 17, and the tunnel crown is only strengthened with rock bolts and forepoling. | Considering that the tunnel floor has been equipped with a thicker concrete slab, and the tunnel crown is covered with a thinner concrete blanket. It is in a hanging position; the need for strengthening consolidation grouting on the tunnel crown should be re-evaluated. A special design is required for the tunnel portal, considering all loads, weakening, and protection from landslides above the portal. |

# Dam Issues Arised at Construction Sites (24/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 13 Tamblang | no grouting at river bed of dam foundation | The supervising consultant changed the initial design by not doing curtain grouting in the riverbed area because the foundation rock in the riverbed was andesite rock. Curtain grouting is still being carried out on the right and left abutments of the dam because the foundation is tuffaceous breccia | The technical justification for the initial design change regarding grouting should be detailed again, covering the condition of the andesite foundation, the results of trial grouting that has been carried out, the potential for uplift and seepage from the foundation, etc., to ensure that curtain grouting is not needed in the riverbed area and does not reduce the safety of the dam |
| | | 14 Tiu suntuk | only banket grouting on riverbet (no curtain groting) | Riverbed foundation is a location with a highest head, only blancket grouting was carried out and curtain grouting was not carried out. | Considering that the foundation is andesitic rock with small cracks which are feared to become seepage paths, the considerations for not carrying out curtain grouting on the riverbed foundation should be explained, supported by permeability test data, pumping tests, and documentation of cracks in the field. |
| | | | ineffective curtain grouting from piezometer reading | The piezometers showed the same response and pressure to the rise of the inundation water level in the upstream section (cofferdam). It is feared due to ineffective curtain grouting. | This condition is feared to result in a relatively high uplift on the downstream foundation of the dam, which will affect the stability of the dam. To anticipate, the initial impounding of the reservoir should be done in stages.<br>For the initial filling of the reservoir to be carried out in stages, facilities for removing water should be prepared to maintain and lower the water level of the reservoir in emergency conditions, and prepared operating procedures. |
| | | 15 Way Apu | Insufficient depth of groting at the dam | The grouting design in the dam body is designed with a depth of 20 - 30 m for curtain grouting for the Way Apu Dam height, which reaches 72 m. | Consider the design grouting depth taken as 2/3 Head of the reservoir based on the Grouting Guidelines for Dams. |
| | | | | | |
| 6 | Dam Foundation | 1 Ameroro | Step excavation of foundation | The excavation profile of the dam foundation site shows a relatively steep slope and it has potential to cause “arching” cracks in the embankment. | The technical considerations for determining/designing boundary or foundation excavation should be explained.<br><br>The dam foundation should be formed to make it easy to fill and compact and not cause arching and/or differential settlement of the embankment above it.<br><br>Monitoring should be carried out for the possibility of cracks in the embankment around the bulge area or at the top of the dam area |

# Dam Issues Arised at Construction Sites (25/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 2 Bagong | Colluvium foundation at right and left abutment | on the left abutment of the dam, there is a layer of colluvium and clay. The upper part is clay that used to be paddy fields and the lower part is colluvium deposits in the form of limestone mixed with clay. The size of the limestone is varies up to >4m in diameter.<br><br>At the right abutment of the dam, there are quite thick colluvial deposits, around 20m. The plan is that the colluvial deposits will not be completely excavated; seepage at the colluvial foundation will be controlled with a barrier wall in the form of a secant pile. | Because the secant pile has no strength and is in the colluvial layer where the colluvial layer still has the potential for movement, there is the potential for the secant pile to break. It is necessary to check the piping problem too.<br><br>The project should be aware of the risks involved.<br>Check for potential liquefaction in colluvial deposits. A low relative density value can be an indication of high liquefaction potential, so colluvial deposits are not suitable for use as a dam foundation or require special treatment, which is relatively high in cost.<br>The bearing capacity of colluvial foundations should be determined based on plate bearing tests in the field.<br><br>a. The dam abutment must be strong enough to withstand the pressure from the dam body and also other loads that will work, including earthquake and uplift loads. It is best if the spillway wall, which is the support of the dam body, is designed as a gravity structure that is strong and stable to withstand all the loads that will work.<br>b. Complete the design with stability analysis and detailed drawings.<br>c. The secant pile, which is planned with a depth of 10 m, the depth plan should be reviewed to ensure whether the secant pile has entered the watertight foundation layer. The ability of the pile and secant pile foundation must be proven to be able to support all loads, including lateral loads, which are supported by a fairly deep clamping effect. To make the stability calculation clearer, a 3-Dimensional analysis based on FEM should be used, which refers to various foundation materials, including colluvial, limestone, etc.<br>d. The image of the geological conditions at the dam abutment and spillway structure should be extended to a length of 2H (H = height of the dam) after the end of the dam axle so that the colluvial layer as a whole can be depicted. Along the colluvial layer below the MAB, secant piles should be equipped. |
| | | | Using coarse colluvial for dam foundation at left abutment | Based on drilling that had been conducted, the colluvium at luft abutment of Bagong dam can be separate to fine colluvium at upper part and coars coulluvium to lower part. Consultan planned to put dam foundation at coarse colluvium | SPT values up to 30-50. However, it should be noted that even though it has a high SPT value it is still part of the colluvial mass.<br>If the foundation is to be laid on coarse colluvial then some insitu tests need to be carried out on the weakest areas of the foundation. The current excavation has not yet reached the planned excavation limit (red line) so that the test cannot be carried out, then when it reaches the excavation, the test will be carried out and if the result is not achieved the requirement for foundation, it will continue until the rock foundation |
| | | | Left abutment foundation | After excavation to coarse grained colluvium, the condition of foundation is not as good as expected. | The consultan and owner decide to take foundation at the bedrock rock for filter and core of dam |
| | | 3 Bener | possibility of concrete slab crack below embankment & insufficient of concrete slab width | Concrete slabs can crack due to excessive deformation in the rock pile, as well as due to deformation of the concrete slab itself. The height of the dam influences the amount of settlement and deformation, the compressibility modulus of the rock pile and the shape of the valley, while long-term deformation occurs due to constant stress and is mostly due to the breaking of rock grains (which are of inadequate quality or have a flat shape). | When carrying out construction, attention should be paid to embankment materials with different parameters and sources, both from excavation and quarries:<br>- gradation of embankment material (adjust to the spec/gradation prepared based on embankment experiments),<br>- granular shape (avoid flat shapes),<br>- use fresh and hard rock (avoid using weathered or soft rock),<br>- use heavy vibrator rollers or impact compaction rollers, which are commonly used in high CFRD and optimum compaction layer thickness (stone size does not exceed 2/3 of the compaction layer thickness),<br>- Watering requirements during compaction (around 100~250 l/m3). |

# Dam Issues Arised at Construction Sites (26/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | | insufficient of concrete slab width | The width of the concrete slab is usually planned to be between 12 - 18 m, depending on the slip form and the capabilities of the casting equipment. Smaller/narrower slabs are usually used when there is a change in plinth geometry, foundation topography and near supports. Between the slab and the plinth and between the slab and the slab are connected by joints or connections, which can be perimeter joints, vertical joints (vertical expansion joints and vertical compression joints), and horizontal construction joints. The specifications for all types of joints must be detailed again because they need to be in accordance with the latest high CFRD requirements and require procurement time. | a. After completing the foundation excavation, the consultant should prepare a layout plan for the placement of the slab and its joints.<br>b. The consultant should prepare detailed drawings of the types of connections along with the type and specifications of the water stop/water barrier that will be used.<br>c. Height dams in the world, including the Bener Dam design, use multiple water stops/water barriers at the joint perimeter, namely at the bottom, middle, upper/external. The water stop can be damaged due to shifting, differences in settlement, opening of connections, high pressure etc. The project should be more careful in choosing the type, material and technical specifications of the water stop.<br>1) For the bottom water stop, you should use a type of metal, which can be copper (0.8 ~ 1.2mm thick) or stainless steel, which in the selection takes into consideration ease of work, water quality and cost.<br>2) For external water stops, you can consider using the Omega type. Currently, many CFRD dams in the world use Omega-type external water stops (Materon, 2006), which are more flexible, so they are more resistant to shifts, differences in settlement and opening of joints (see example below).<br>3) The connection between the water stop perimeter joint and the vertical joint is a point that is prone to leaks, so the installation and connection of the water stop at this point should be carried out more carefully.<br>4) Installation and connection of the water stop should be carried out by experienced experts/skilled personnel by following the manufacturer's instructions/manual. |
| | | 4 Budong Budong | Colluvium foundation at left abutment | The boundary of the foundation excavation on the left abutment of the dam is still on colluvium deposits. Colluvium deposits are generally unstable and not suitable to be used as foundations and abutment for rock filled dams. | The abutment should rest on a fairly hard rock foundation. The boundary line of the foundation excavation on the left abutment hill that still rests on the colluvium should be re-examined. |
| | | | Alluvium at dam shoulder & Dam toe | Zonal type dams with rockfill require good rock foundation.<br><br>the downstream toe of the dam is still resting on alluvial foundations with liquefaction potential. | The alluvial deposits to be used as the foundation of the dam shoulder, should be examined in detail for their stratigraphy and shear strength by large scale tests. It should be noted that in addition to being poor graded, the rock fragments in alluvial deposits are rounded so that their shear strength is usually low and they must be compacted first. An analysis of the liquefaction potential of the foundations should also be conducted. One of the data required in the liquefaction potential analysis is the relative density of the foundation material. It is recommended to conduct a relative density of the alluvial foundation material with a sufficient number of test specimens. If it is found that the alluvial layer has the potential for liquefaction, the alluvium layer should be excavated.<br><br>Dam Toe<br>• potentially liquefiable layers should be excavated<br>• the diaphragm wall should be shifted slightly downstream so that when the dam body foundation is excavated it is still filled with native soil with sufficient width to hold the diaphragm wall. |

# Dam Issues Arised at Construction Sites (27/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | | Alluvium foundation | Supervice Consultan desined to put dam foundation at alluvium deposite | a. Re- confirmation of thickness, by:<br>- Drilling through the underlying bedrock;<br>- Consider the need for a geoelectric survey; and<br>- If possible, conduct oblique drilling crossing from both sides (banks) of the river and sloping towards the river. This is also to determine/examine the geological structure (especially the presence or absence of fault structures) beneath the river.<br>b. If the alluvial layer is relatively thick and is planned to be used as a dam foundation, the type and arrangement of the material (stratigraphy and gradation), maximum grain size and type of material, and other aspects including roundness should be checked. |
| | | 5 Cipanas | Trush fault on dam Foundation | Geological profile shows that trust fault is found at the dam foundation | It should be explained that the existence of the fault regarding, outcrop at the field, brecciation zone, width of fracture etc. |
| | | 6 Gongseng | possibility difference modulus value of foundation and dental concrete | One of the foundation improvement carried out during construction is dental concrete on the weathered rock excavated. | Check the dental concrete design carried out in the field, whether it is close to the modulus of elasticity value of the surrounding rock, especially at foundation locations with large volumes of dental concrete.<br>If the elastic modulus values differ significantly, it is feared that differential settlement will occur, which could disrupt the stability of the dam. For this reason, the locations of dental concrete should be mapped, and then intensive monitoring of the pile and surrounding instruments should be carried out. This should be included in the OP Guidelines so that it is considered.<br>These conditions should be included as an indication of danger in the Emergency Action |
| | | 7 Jlantah | Permeable zone of dam foundation | The improvement of the Jlantah Dam foundation was originally designed using curtain grouting, but from the results of the grouting test in the riverbed section could not reach the required water impermeable value (Lugeon). The consultant proposes to replace the foundation repair method with cut off walls. | The consultant should examine the advantages and disadvantages of various alternative foundation repair methods, including: chemical grouting, upstream blanket, secant pile and diaphragm wall, etc.<br>From the study of the advantages and disadvantages of various alternative foundation improvement methods, the conclusions should be presented in a comparision matrix from the aspects of dam safety/success in achieving quality targets, effectiveness of foundation repair results, ease of implementation, time and cost, taking into account the geological conditions of the foundation, availability of tools, experience of personnel executor, etc. |
| | | | Difference modulus test result (from 2 tests) | The project has carried out an additional PMT (Pressure meter Test) test of 2 (two) test points on the dam foundation. The result of modulus elasticity values ranged from 509.10 to 1186.40 kg/cm2 which is much lower than the test results in 2021 of 11228.29 kg/cm2 | The difference results from 2021 should be re-evaluated, it could be that the difference occurs because of breccias have fragments and matrices where the strength of the matrices tends to be smaller than the fragments.<br>In determining the average value of the elastic modulus of the foundation, do not include data on the value of the elastic modulus from 11228.29 kg/cm2 because it possibility of the test being carried out is not representative due to disturb by the presence of boulder material. |
| | | | Overlaping diafragma and grouting | Dam foundation improvement was carried out by two methods, namely grouting and diaphragm wall. | At the design stage there was no recommendation to use a diaphragm wall. when construction at the riverbed location, grouting is not effective to do because the grouting test has been carried out with a distance of 25 cm and has not shown good grouting effectiveness. Consultan should make justification for it. |

# Dam Issues Arised at Construction Sites (28/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 8 Jragung | Coullvium deposite at dam foundation | On dam axis excavation (foundation of core material embankment) exists colluvium deposit at right abutment.<br>During foundation excavation in the axis of dam (core material), colluvium deposit found at right abutment of the dam. Colluvium material found at STA. 1+075 to Sta. 1+425 is feared become zone weak that effect to dam stability. Resent Condition has the grout-cap on, so at several location grout-cap lied on colluvium material.<br>Grouting has been carried out on layer of the colluvium. | From the results of some consideration on colluvium location will be carried out using CTB (Cement Treated Base) with mixture: Cement: 118 kg, Aggregate: 252 kg and Water: 100. On age 28 will produce K100-k125 values and control is carried out with modulus value so that no big difference to the foundation.<br>The CTB should compacted and the dental cement conducted on surface, because of there is a grout -cap , it is necessary to add contact grout then check holes should be carried out for grouting results.<br>Detailed geological mapping before grout-cap setting is really important to considerate location which necessary treatment is and what kind of treatment should be, especially on the colluvium that has been installed the grout-cap . |
| | | 9 Lausimeme | Water pressure and Foundation piezometer | At the time of installation of piezometer P2.0 there was water pressure up to 10 meters when installed | |
| | | 10 Manikin | Swelling pressure related to asphalt core | The fondation of dam has high sweeling potential and high swelling pressure | By using an asphalt core there is the potential for tearing of the core which is 75-100 cm thick. Given that the swelling pressure reaches 715 Kpa and the dam height is 50 m, there is the potential for uplift and if there is a repetition of this swelling it could tear the core. |
| | | | Foundation based on MASW | The dam foundation will be placed at a Vs = 500 value based on the MASW test results in the sense that there is an additional excavation of the core and filter 5 meters deep, which initially the foundation will be placed at elv.+103 and will be placed at elv + 93. | It is necessary to know the source of pressurized water because for future evaluation it will be difficult to evaluate. There may be pressurized groundwater below. Therefore it is necessary to install another piezometer in one hole, one piezometers in the weak zone and the other in the aquifer layer. In additional there incresing pressure of foundatoin during embankment that need technical justification about it |
| | | 11 Marangkayu | Dam foundation (efectiveness of vertical drain) | Improvement of Marangkayu dam foundation was carried out using a vertical drain | The consultant should compare the vertical drain effectiveness of the foundation before and after the vertical drain is installed. The geotechnical investigation (drilling) should be conducted immediately and also the current foundation parameters to calculate the stability of the dam. |
| | | 12 Meninting | Unconformity of foundation | The location between the laharic and volcanic breccia is a discontinuity zone | at least OSP should be installed at the boundary upstream and downstream of the foundation and embankment. In the random upstream section there is only one piezometer, it would be better if there are 2 to illustrate the pore pressure when drawdown (should be installed if possible before impounding) |
| | | 13 Paselloreng | Erosion at right abutment | There was scouring on the downstream surface of the right abutment, both at the top and foot, this location is very easily eroded by rain | |
| | | 14 Randu Gunting | Swelling potential | Randugunting Dam's foundation contains a claystone layer | The construction report should check whether a swelling potential test has been carried out on the claystone. If it doesn't exist, it should be done. |
| | | 15 Tiga Dihaji | Distribution of loose sand as foundation | The distribution of the loose sand layer downstream of the core zone is relatively wide. It is feared that seepage through the rockfill material could carry loose sand material, potentially causing sand boiling downstream of the dam. | To anticipate this condition, the contact area between the loose sand surface and the downstream rockfill base should be coated with a relatively thick transition zone. |
| | | | Loose zone at core | The loose sand layer under the core zone will be excavated and covered with K-175 Cyclops concrete | Cyclops concrete may be porous, so it has the potential to be a source of seepage. To anticipate this, cyclops concrete should be grouted until it meets the required Lugeon value. |
| | | | | | |
| 7 | Spillway Design / Condition | 1 Ameroro | ineffective stilling basin to reduce water velocity | At the location of the stilling basin, the stilling pool is too high then at downstream sp there is remaining energy, it visible at the same elevation of stilling floor | it is also necessary to add another reducer (groundsill). Groundsill must be integrated with the floor to be sturdy, it cannot just stick to it because it will not have a long life. Not only design issues but construction are also considered because some floors on the damper are already under construction.<br>There was a suggestion that by raising the stilling pond (5m), so another stilling pond would be needed because there would be another 5 meter waterfall. |

# Dam Issues Arised at Construction Sites (29/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 2 Bagong | Changing spillway design due to colluvium | In redesigning the spillway several things need to be considered | a. It should be supported by thorough technical analysis from hydraulic, seepage and structural aspects;<br>b. By using input parameters that are representative/according to real conditions in the field. Complete with detailed drawings of all construction in the area from the right abutment to the spillway.<br>c. Complete with detailed drawings and reinforcement drawings;<br>d. Also complete with detailed drawings of cross channel connections, types, specifications and methods of installing/connecting water stops;<br>e. Concrete that has the potential to experience erosion, abrasion or cavitation use a minimum concrete quality of f'c 30 MPa.<br>f. Under the spillway weir will be a secant pile and a bored pile. Make a drawing: plan longitudinal and cross sections of the placement of the piles.<br>g. The left spillway wall will be the support for the dam body. Make a detailed drawing of the part. If bored piles will support the wall, make a detailed drawing of the relationship between the wall and the bored pile. Make sure the wall structure and bored pile are stable against all loads that will work. |
| | | 3 Manikin | leakage potential of Morning glory elbow conection | The Connection of morning glory elbow tunnel and the transition tunnel (steel), it is prone to leaks or cracks due to vibrations from morning glory. | In the section should be given reinforcement for example by thickening the concrete wall or increasing the area of reinforcement, etc. The morning glory tunnel elbow should be extended downstream.<br>the junction between the concrete and steel tunnels should be calculated the dynamic load of the morning glory. |
| | | | purpose spillway channel to be open channel from conduit | Based on the design, some of the additional overflow channels are in the form of conduits or box culverts. The consultant proposes to change the channel type to open channel and the channel is designed to be longer. | Considering that the foundation rock is Bobonaro clay (Scaly Clay) and easily weathered, if it left open (exposed) for a long time, the potential for landslides on the slopes of the excavations can fall down to spillway thus disrupting the future operations and maintenance activities. For the reason, the spillway channel should still be designed in box culvert. |
| | | | Efectiveness of auxiliary spillway | The auxiliary spillway is function when Q1000 flooding return period | There is an option to remove the additional spillway, by increasing the height of the dam and main spillway. However, since excavation has been carried out at the location of the additional spillway at the initial construction, it will continue and simplify the building above it. |
| | | | Consider changing auxiliary spilway elevation | The additional spillway weir is located at elevation +149 m so that it will function in the event of a Q1000 flood. | Q1000 conditions will be very rare or may not work, so consider designing an additional spillway for the Q100. |
| | | 5 Rukoh | desain of slab drainage of spillway (insufficient drainage to downstream) | It was stated that under the building slab spillways Rukoh, the Rukoh Dam only there is a cross drain. This condition is deemed insufficient to drain water below the slab to flows downward and creates lifting pressure (uplift) under the slab still there. To resolve the issue, the consultant installed a drain pipe outside the side wall connecting to the cross drain. | Installing the drain pipe (drain pipe) requires wall excavation, so there is a considerable risk of foundation damage. To anticipate foundation damage, it should be very careful when installing drain pipes outside the side walls. Besides that, backfilling must be carried out adequately so that the stability of the foundation stays the same.<br>Consultants should create an as-built drawing from the sub-drain system under the spillway chute channel slab and then carry out a sub-drain repair design to overcome the uplift problem under the spillway chute channel slab to consult with the Dam Engineering Office and the Dam Safety Commission. |

# Dam Issues Arised at Construction Sites (30/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | | Spillway backfill material for drainage is not free drain material | The consultant said there was an installation plan for concrete cover on the gravel installed on the right and left sides of spillways. Besides that, it was also conveyed that the material backfill used on the right and left of the spillway is random soil whose surface is covered with gravel. | • It should be material backfill replaced with free-draining material (concrete aggregate gravel).<br>• Concrete cover is considered to be eliminated. Rainwater above concrete cover can slide downstream at high speed, causing destructive forces that disturb the original land on either side or downstream of the spillway. Rainwater and groundwater should be allowed to enter directly inside free draining material, which with its seepage speed be able to flow rainwater and groundwater to downstream spillways and dams safety.<br>• On top of the embankment, free-draining materials should be installed 1 m below the top of the spillways wall for the safety of officers if they are forced to walk at the top of free draining material. Besides that, this height difference is also useful for maintaining free draining material and rainwater splash do not run over the spillways walls enter the chute channel. |
| | | | Spillway capacity | Based on the SNI, spillway capacity should not less than 1/3 inflow | The spillway should not be smaller than 1/3 of the inflow (SNI) because it may endanger the safety of the dam, and if the existing condition is smaller than 1/3, it should be explained that the condition does not endanger the dam. |
| | | 6 Sidan | Changing stilling to sky jump type | To facilitate construction in the upstream part of the inlet, the slope of the tunnel channel was leveled, which increased the outlet elevation downstream, so it was planned to change the stilling energy type of the spillway building to a sky jump type, which is also equipped with a sub dam. | a. In spillway buildings with sky jump stilling energy, the water will fall into the plunge pool, not the stilling basin. The use of the term should be corrected.<br>b. The speed of water at the lip of a sky jump is generally very high, so there is the potential for scouring or abrasion to the concrete floor. To resist scouring or abrasion, this section should use high-quality concrete or be equipped with a steel liner.<br>c. Remember that the plunge pool will receive a water waterfall with high speed and energy. It should be ensured that the plunge pool foundation is hard rock or, if necessary, equipped with concrete reinforcement as a result of a comprehensive technical analysis.<br>d. It should be noted that the required dimensions of the plunge pool are that the upstream boundary should use a Q2th flood design, and the water jump extension should use a Q1000th or QPMF flood design so that the water plunge from the sky jump is in the plunge pool (upstream of the sub dam). Meanwhile, downstream of the sub-dam, a water jump must occur (hydraulic jump) so that the downstream flow is sub-critical. The bottom elevation of the stilling pool floor downstream of the sub-dam should be deeper than the riverbed elevation; the water jump downstream of the sub-dam should be below the downstream water level. Extra excavation of hard riverbed rock should be studied using adequate rock breaker tools.<br>e. In QPMF design floods, there is a sinking flow downstream of the sky jump; the backwater effect should be considered on the flow hydraulics and stability of the surrounding structures. The hydraulic behavior of the spillway building should be presented in technical drawings starting from the spillway apron building until it returns to the natural river to become the basis for the design and calculation of the concrete structure. |
| | | | Sub Dam additional at downstream of spillway | In changes to the design of the spillway building downstream, the plunge pool is planned to be equipped with a control weir structure (sub dam) with a height of around 11 m. It should be noted that water wave vibration modeling cannot be carried out in gravity-type dams. | a. The sub-dam to be built is quite high (11 m); failure of the sub-dam will trigger scouring of the spillway foundation. The sub-dam should be designed as a gravity concrete structure (like a gravity concrete dam or weir), safe against sliding, overturning, sinking, and seepage. In a gravity structure, bending moments cannot occur.<br>b. The thickness of the stilling pool floor should be ensured to be safe enough to withstand uplift, and, if necessary, additional anchor reinforcement obtained from the calculation notes should be added.<br>c. In analyzing the stability of a sub-dam, the water pressure from upstream should be considered to the deepest part of the sub-dam foundation or the overturning point. |

# Dam Issues Arised at Construction Sites (31/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 7 Tanju | Crack at the spillway | There was a crack in the right wall of the spillway channel leading to the overflow building. | a. It is necessary to re-examine the cause of the crack, whether it is related to concrete joints, foundation conditions, or other reasons, so that the solution can overcome these causes.<br>b. The consultant should prepare detailed design drawings, technical specifications and methods for grouting and injection.<br>c. Dam managers should immediately plan to repair cracks in the guide walls of the spillways. |
| | | 8 Tapin | Crack at the top of spillway | At the confluence point between the top of the dam and the spillway, there is a crack in the transverse direction of the dam. The consultant reports that the crack depth is about 1 cm. | Based on the as-built drawing, the right slope of the foundation excavation is in contact with the spillway at a relatively steep angle. There may be a significant difference in settlement between the embankment and the concrete spillway structure. This location has the potential to experience arching. It should be noted that if the depth of the crack reaches the reservoir water level, reservoir water will flow into the damage, which can cause erosion in the core zone, which in turn can trigger a dam collapse. Intensified monitoring of the area should be carried out visually and on the results of instrument readings in the vicinity, including sliding pegs, piezometers and V-notch.<br>If a crack develops, the dam manager should immediately investigate to ensure the depth of the crack, including by conducting a test pit at the location where the crack is and non-destructive testing using geophysical tools if necessary. |
| | | | Many crack at threshold (mercu) | On the threshold surface of the spillway found many cracks. | A thorough crack survey should be carried out, and then a detailed technical drawing of the condition of the crack and a plan for handling it should be made. It is necessary to investigate whether these cracks are due to the concrete's shrinkage or structural cracks. As a reference, the Material Deficiency Identification module (June 2022) compiled by the Dam Engineering Center should be studied, which explains the crack survey method and examples of several types of crack-filling materials. |

# Dam Issues Arised at Construction Sites (32/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 9 Tiga Dihaji | Changing stilling design | The energy stilling design is planned to be revised using a ski jump type, and the surface elevation of the plunge pool floor will be raised to the height of the river bed. The foundation of the plunge pool is tuff which is relatively easily eroded by the flow of flood water. | The energy stilling design is planned to be revised using a ski jump type, and the surface elevation of the plunge pool floor will be raised to the height of the river bed. The foundation of the plunge pool is tuff which is relatively easily eroded by the flow of flood water.<br>The energy absorber must be able to reduce the energy of the water flow coming out of the spillway so that the speed becomes low enough not to cause damage, including erosion and scouring of the channel (bottom and slopes of the channel) downstream, at various variations in discharge up to the design discharge. The foundation of the plunge pool and also the bottom of the channel downstream of the plunge pool are tuff rock, which is relatively easily eroded by the flow of flood water.<br>Based on the water flow profile image below, in the Q100 flood discharge, there is no visible flow trajectory. The energy reducer does not show performance as a ski jump energy reducer but is more like a submerged bucket type (solid type) energy reducer. Maybe at small discharges (<Q50), it may function as an energy reducer for the ski jump or drop structure.<br>a. A plunge pool is required as a ski jump energy reducer. For this reason, building a ground sill at the downstream end of the plunge pool is best.<br>b. When preparing a ground sill design, the following things should be taken into account:<br>a. Ground sillmade high enough so that it is effective in helping reduce energy in the plunge pool,<br>b. When designing a ground sill, you should anticipate the possibility of future river bed degradation per KP-Irrigation of at least 2 m. The base of the ground sill should be lower than the estimated elevation of riverbed degradation.<br>c. As a submerged bucket energy reducer, it should be noted that the flow velocity downstream of the bucket is usually still quite high, especially if the tailwater elevation is low, so it can cause scour or trigger landslides on channel slopes. Consider installing |
| | | 10 Tugu | deformation on spillway between some blocks | In general, the structural condition of the Spillway channel is good, there has been horizontal deformation in some segments of the structure. This deformation can be seen in joints which are slightly open and shifted from one another. The section of the spillway channel that deformed, namely between Blocks SC15 & SC16, SC.17 dg SC18, SC.18 & SC19 and SC21 & SC22. From the results of measurements obtained the amount of deformation in the longitudinal direction of the spillway between 0.5 to 7 mm, and the deformation of the transverse direction of the overflow axle between 7 to 8.5 mm. | |
| | | | | | |
| 8 | Diversion leakage | 1 Bendo | Seepage around the tunnel | There is seepage at the joint structure inside the tunnel. In addition, there is also seepage at the tunnel crown. | |
| | | 2 Beringin Sila | Leakage water on diversion gate during dry test | The consultant explained that in July - August 2022, a dry test have been carried out on the diversion gate using filler to increase density. | It was conveyed that there were still leaks at several points from the dry test; the causes of these leaks should be analyzed, and recommendations for handling leakage should be proposed.<br>Before impounding, a wet test should be carried out, and a report on the damp test results should be submitted to the Dam Engineering Office |

# Dam Issues Arised at Construction Sites (33/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 3 Karalloe | Seepage in the tunnel | Informed that there has been seepage in the intake tunnel of 8.2 l/s. | The seepage should be observed more thoroughly to find the source of seepage. Do monitoring from existing instrumentation around seepage that occurs. If possible try to collect seepage flow and measure the discharge periodically.<br>Based on consultant information a v-notch was installed downstream of the intake tunnel to measure the spring seepage discharge through the foundation during construction and some other seepage. from the graph it can be seen that the seepage is almost the same and is not affected by fluctuations in the reservoir water level, so it can be concluded that the seepage occur from groundwater from the right hill, not from the reservoir. The total seepage until July 2023 is 7.58 l/s. |
| | | 4 Keureuto | Water leakage of Tunnel | Based on the results of visual field observations, There is some seepage in the tunnel, such as at the concrete lining area, segment interface, 1.5 m zone interface Cline, and on the base slab. | a. The consultant/contractor should carry out mapping along the tunnel using thermograph mapping.<br>b. Seepage in the tunnel should be repaired immediately to avoid more significant damage. The use of resin to repair seepage in tunnel segments is not recommended. Consider using XYPEC Grout (Crystalline Technology) in the Pandan Duri Dam or similar methods where the study results show an appropriate solution to the conditions faced. |
| | | | Leakage at tunnel | some seepage are appear beetwen conection of the tunnel | tunnels still has seepage which been repaired with Xypex Crystalline. Xypex crystalline is waterproofing material that can grow (expand), because there is drainage under the spillway it is feared that there will be a blockage so that uplift pressure can occur which can damage the spillway. The use of Xypex crystalline is not recommended for patching leaks on the spillway floor, because it is already installed it is necessary to consider installing instruments on the spillway to monitor the pressure below |
| | | 5 Kuwil | Leakage water in the tunnel | In the diversion tunnel, seepage was reported in several locations. However, at the Plenary Session, the consultant had not conducted a study regarding the source of the seepage. | It should be noted that seepage can increase due to pressure from the reservoir's water head after the reservoir is impounded. The cause of the seepage should be studied first, including the potential source from the water body (small lake) above it, and the seepage should be addressed before the initial impounding of the reservoir is carried out.<br>The consultant proposed treating seepage with chemical grouting. Before handling seepage, the location of the seepage should first be ascertained. If seepage occurs at the contraction joint, it should be ensured that the handling method used will not interfere with the function of the contraction joint as a controller for concrete swelling and shrinkage. |
| | | 6 Logung | Several seepage on conduit wall | Several seepage was found at the conduit wall and plugging | Re-injection is recommended to stop seepage. In the long term, periodic structural evaluation is required. |
| | | 7 Marangkayu | Leakage water at conduit | There is a leak in the conduit, but it cannot be inspected at this time because it is still waterlogged. | Considering that the conduit is located in soft soil, inspection should be carried out immediately to determine the deformation of the conduit. If the deformation occurs due to foundation settlement, the consultant needs to prepare a method of repairing the foundation, considering that there has been a dam backfill above the conduit. |

# Dam Issues Arised at Construction Sites (34/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 8 Napun Gete | Leakage in the wall of conduit | It was reported that there had been a leak in the diversion conduit, which has been handled. But it was informed that until now there are still leaks with a maximum debit ever measured of 7 liters/second. | Detailed pictures of the situation and engineering geological or geological conditions at the location and around the leak.<br>It should be explained in detail the condition of the leak, its location (plot on the transverse and longitudinal profit images), and the handling carried out to overcome the leak.<br>• It should be checked again, when and the cause of the leak. How it relate to engineering geological or geological conditions and the surrounding hydrogeological conditions.<br>• An analysis should be carried out on how the influence of the leak on the safety or stability of the dam along with the treatments that have or have been carried out as well as future management plans.<br>• There should be intensive monitoring of these leaks, including the quality and quantity of water. This should be listed in the OP's Guidelines.<br>• The condition of the leak should be included in the indication of potentially hazardous conditions in the RTD Document. |
| | | 9 Nipah | Seepage on the tunnel | Crack and seepage ware found on the tunnel wall that covered with calcium. | |
| | | 10 Paselloreng | Leakage on tunnel wall | Seepage and leakage along the tunnel were encountered. Seepage was encountered at every joint of the tunnel. The largest leakage was found at 3 points. | |
| | | 11 Rukoh | Crack and stalactization in tunnel | Based on the visual field observations, there are several cracks in the concrete wall lining at the joints of longitudinal segments of tunnels and the joints of the cross segments. | Consider mapping along the tunnel with thermograph mapping.<br>To avoid greater damage, cracks in the tunnel should be repaired immediately. The using of resin to repair cracks in tunnel segments is not recommended. Consider seepage by using XYPEC Grout (Crystalline Technology) that has been used at the Pandan Duri Dam or other similar methods that can be a solution to the specific conditions faced.<br>Stalactites were visible in the tunnel hanging from the tunnel ceiling. Even though the stalactites currently look small and few, should be paid attention to the process of calcification or lime leaching in the tunnel which needs to be monitored for its size and develop periodically. |
| | | 12 Semantok | D-wall and conduit conection | Diversion conduit is a weak section because it is surrounded by embankment. | The conduit location needs to be detailed, because the water that comes out around the conduit, The connection details between the conduit and D-wall/pile need to be re-evaluated. In addition, at the location there is stagnant water which is thought to come from the splash of the hollow cone valve, it is necessary to confirm the source of the water by drying inside the conduit. |

# Dam Issues Arised at Construction Sites (35/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 13 Tapin | Water leakage at the downstream of tunnel | There is a leakage in the conduit of downstream tunnel. The consultant reported that the leak was from the surrounding groundwater. Based on OW 3 and OW 4 readings near the conduit, the groundwater level around the conduit is quite high. | a. It should be studied whether or not there is a correlation between the leak and the reservoir water level fluctuations.<br>b. The rock stratigraphy should be described in sections from OW-1 to OW-4 to the conduit foundation.<br>c. Considering that OW-3 and OW-4 are on the left side of the conduit, the groundwater level elevation on the right side of the conduit should be estimated based on the readings of OW-3 and OW-4 so that the profile of the groundwater level through the conduit can be described.<br>d. The backfill material on the conduit is reported as random soil. In addition, the backfill area needs to be equipped with drainage channels. It is feared that surface water that seeps and is trapped in the backfill can cause the backfill material to become saturated with water, thereby reducing the material's shear strength. A drainage system should be planned on the left and right sides of the backfill area. With this drainage, it is expected that the water pressure to the seepage point on the conduit wall will decrease, thereby reducing the amount of seepage into the conduit. Also, consider using free drain material.<br>e. To evaluate the effect of the reservoir water level on leakage, it is advisable to measure the leakage discharge and correlate it with fluctuations in the reservoir water level. Necessary to measure the leakage discharge in the conduit should be stated in the OP's Guide.<br>f. The conduit contains hydromechanical equipment, so the leaks can disrupt operations and maintenance activities and potentially accelerate damage to hydromechanical equipment. Therefore, action should be programmed to deal with these leaks immediately. |
| | | | Calcite at the tunnel | In the plugging area and tunnel lining, calcite is formed. | a. Periodic measurements and monitoring of calcite volume or dimensions should be carried out. The results of measurements of the volume of calcite formed in the plugging should be separated from the results of measurements of the volume of calcite from the tunnel lining.<br>b. The calcite formation indicates the dissolution of lime cement from the tunnel concrete structure. The effect of dissolution on the quality of tunnel structure concrete should be evaluated.<br>c. The problem of carbonation (the occurrence of calcination processes) in the tunnel should be addressed immediately. Alternative treatments that can be considered include plugging the seepage cracks with crystal technology which has been applied to the Panglao Island Bypass |
| | | | | | |
| 9 | Spillway Foundation | 1 Bagong | Colluvium foundation | There were significant differences in the design and construction stages, especially the problem of the spillway foundation in the form of unstable colluvial deposits. The spillway is located on the right bank of the dam where hard rock is encountered at a depth of 15-30m. If the excavation is deepened, the cost and treatment will be greater. | Consider creating an inspection gallery at locations that are considered vulnerable and V-notch for foundation and embankment. For dam structures it is actually not preferred to use piles. consider morning glory as suggested by Mr. Ibnu. |

# Dam Issues Arised at Construction Sites (36/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | | Using borepile for spillway | The Bagong Dam spillway building is designed with a chute channel and two stilling basin. The foundation of the spillway building and the chute channel is a fairly thick colluvial layer at the top, then below is a relatively thin layer of limestone, and at the bottom is a layer of clay and sandstone.<br><br>To avoid thick colluvial excavations, the plan for the spillway building and the slide channel will be placed on the colluvial layer supported by rows of bored piles, which will be installed along the chute channel. Some bored piles are planned only to accept vertical loads, and others also accept lateral/horizontal loads by being installed deeper into the mudstone/sandstone layer. | a. Bored piles should be designed as a group of piles that work together so that they strengthen each other. Bored piles must be safe against all loads that will work, including own weight, maximum flood water load, uplift, soil and water pressure from the side, load horizontal direction earthquakes (Kh) and vertical direction earthquakes (Kv), etc.<br>b. So that the bored pile is able to withstand horizontal loads, the bored pile should be embedded and clamped in a hard foundation layer, namely clay or sandstone, with a clamp length that meets the requirements. When planning the depth of the bored pile, you should take into account the possibility of the existence/occurrence of a sinkhole because the foundation layer beneath the colluvial is reef limestone.<br>c. So that the bored pile can work as a group of piles, the chute channel should be designed as a rigid structure or monolith, where the left wall, floor and right wall of the channel are designed as one unit without contraction joints. Contraction joints, are only installed across the channel. Prepare a detailed drawing of the sliding channel reinforcement. |
| | | 2 Bajulmati | Settlement around spillway | Backfill settlement on the spillway slope abutment hill | Further study needed |
| | | 3 Cipanas | there a unconformity under stilling basin | Stilling basin lies on unconformity zone of volcanic rock | a detailed description of the unconformity zone should be explained along with any reinforcement have been applied |
| | | 4 Jragung | Colluvium foundation & landslide | Spillway there is some sliding so design changes and addition excavation. Above release channel there is a siding, it is necessary to clean up and provide drainage in which the channel discharge toward downstream/released into a stilling basin. | Because there is a shift in the release channel which is shifted to the right (away from the sliding), it is necessary to ensure in the new design that the axial of the spillway and river has curvature radius at least is 3r, where r is the width of the river. |
| | | 5 Keureuto | leakage at spillway | he spillway has been designed to withstand the water pressure of the reservoir there are many leakage at the spillway | considering that a lot of seepage occurs around the dam before impounding, it is necessary to consider the water coming from the abutment hill. |
| | | 6 Ladongi | Improvement of spillway foundation (residual soil foundation) | The spillway building in overcoming the potential for seepage because the identified soil class is residual soil | a. An inspection should be carried out to identify the possibility of seepage occurring around the spillway building foundation.<br>b. A thorough inspection of the source of the water seepage is necessary so that control can be carried out systematically.<br>c. The consultant should recommend dealing with seepage that occurs in coordination with the development work unit and UPB (Unit Pengelolaan Bendungan/ Dam Management Unit), especially regarding potential water sources around the spillway building foundation. |
| | | 7 Meninting | Foundation weakzone / laharic breccia | At the wall of spillway there is contact between laharic breccia and pyroclastic breccia | consideration can be given to installing an inclinometer to monitor shifts due to high water pressure on the wall spillways. |
| | | 8 Sepaku Semoi | alluvium deposite ot confluence of spillway and conduit | At the geological that Spillway and conduit confluence is lied on alluvium deposit. Alluvium is weak zone area that should be anticipated. | It should be conveyed the calculation notes and specifications selected for the design as well as the anticipation that will be carried out considering that the meeting area is included in the weak zone. |
| | | 9 Sidan | Foundation of spillway weir | The foundation of the spillway weir should rest on a foundation that can support the structure of the spillway weir above it as well as a waterfall that has quite a large amount of energy, considering that the foundation of the Sidan Dam spillway building is dominated by sandy tuff rock units at the top and volcanic breccia at the bottom. | a. Consideration should be given to deepening and widening the base of the saw spillway;<br>b. The design should be equipped with engineering analysis to ensure the spillway is safe from hydraulic, structural, and seepage aspects, including uplift.<br>c. It should be noted that sandy tuff rocks are prone to erosion; this should be considered when preparing the design and carrying out foundation excavations. If necessary, a tuff rock foundation reinforcement design can be considered.<br>d. It is feared that the contact area between the concrete structure and the foundation and the joints between the concrete structures may become areas of weakness. To minimize the potential for weakening, consider the sawmill concrete structure designed as a single unit (monolith). |

# Dam Issues Arised at Construction Sites (37/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 10 Temef | Swelling presssure of spillway floor | The swelling potential handling is planned to be carried out by thickening the spillway floor from 1.00 m to 2.50 m with anchor reinforcements as deep as 5.00 m and the distance between anchors is 4.00 m. | The depth of the anchor should be designed to reach the foundation layer which does not contain swelling clay. Seepage analysis ( flownet ) should be carried out on lasting flow conditions.<br>To handle seepage and reduce uplift, a subdrain should be planned under or next to the spillway building.<br>The installation of the anchors is carried out after the dental concrete has been made, then the anchors are connected to the reinforcement of the spillway floor construction |
| | | 11 Way Apu | Dispersive material spillway slope | The form of gully erosion on the right abutment slope above the spillway building indicates that the material tends to be dispersive in nature, easily eroded and prone to landslides. Apart from that, the excavation slope of the spillway building, which is quite high with quite large excavated material, can cause elastic rebound and the formation of sheet joints due to loss of load (distressing) of the embankment in front of it. | When excavating, it is necessary to pay attention to the following things:<br>a. Availability of an adequate drainage system, both surface drainage and internal drainage, with clear, directed outlets that reach the nearest water body.<br>b. There is a need for regular monitoring of the condition of excavation and drainage slopes to evaluate the function and effectiveness of the existing drainage system.<br>c. There is a design and slope strengthening method that is appropriate to the slope conditions to ensure long-term slope stability.<br>d. Along the top of the excavation slope for the spillway building, an interception drain should be made at the back so that surface flow from the slope above does not overflow onto the excavation slope and erodes the excavation bank.<br>e. The excavation design for the right side of the spillway building needs to be detailed (parameters, cross-section, slope stability) along with the handling that will be carried out.<br>f. All design recommendations for strengthening the slopes of spillway buildings should be carried out using engineering analysis to determine the safety factors as technical justification. |
| | | | | | |
| 10 | Fault Zone / Seismicity | 1 Ameroro | Influence Kendeng Fault to Gongseng dam | Based on the regional geological map, to the north of the dam location, there is a Kendeng thrust fault structure, which is quite large and long. | Evaluation should be carried out about the influence of regional faults on dam safety. |
| | | 2 Jatigede | Seismicity consideration in PLTS Instalation | Planning for floating solar power plants must also pay attention to seismic factors in Indonesia | a. Details of loading by earthquakes should refer to SNI 1726: 2019 concerning Procedures for Earthquake Resistance Planning for Building and Non-Building Structures, as well as SNI 8640: 2017 concerning Geotechnical design requirements in this case, especially for slope stability analysis and those related to earthquake loads for reservoirs.<br>b. At the planning stage, the spatial seismicity map should also be observed in preparing recommendations for locations for floating PLTS placement, and it is also necessary to add further studies regarding the potential for active faults around the location. |
| | | 3 Keureuto | Active fault | Location of Keureuto dam is very near to lhok Semawe fault with the distance around 10 km | Dynamic analysis related to faults needs to be considered due to dam site is located close to the active Sumatera fault and other faults. |
| | | 4 Kuwil | Influence Airmadidi Fault to Kuwil dam | Based on the latest 2021 active fault map submitted by the ESDM Geological Agency, the dam location is close to the active horizontal Airmadidi fault. | An analysis should be carried out regarding the influence of the active fault on dam safety (seismic hazard analysis). |
| | | 5 Lausimeme | Weakzone monitoring by Instrument instalation | pore water pressure in the weak zone | To monitor the pore water pressure in the weak zone, at least 2 (two) piezometers should also be installed in the downstream weak zone of the dam and located in line with the OW point downstream of the dam. Piezometer pipes that penetrate rock random zones should be protected with steel pipes. |
| | | | Seismic conductivity potential | Based on regional geology map, Lausimeme Dam located in fault zone and so reservoir area, the fault of reservoir area has potential to trigger Seismic conductivity | it recommended to carry out the impounding gradually |

# Dam Issues Arised at Construction Sites (38/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 6 Margatiga | Possibility of Reservoir Induced Seismicity | Based on the regional geological map, there is a fault at the dam site. Based on the results of geological mapping during construction, there were no indications of active faults at the dam site. Although the presence of active faults was not found. | One should be aware of the occurrence of reservoir-induced seismicity due to the presence of these faults during and after the initial imponding of the reservoir and during the operation and maintenance period by checking the lineaments that have seismic potential. |
| | | 7 Meninting | Dinamic analysis for active fault | On Lombok Island, an earthquake with a magnitude of 7 SR occurred. Based on the tectonic map and regional geological structure of Lombok and Sumbawa, the location of the Meninting Dam is 75.60 km from the Flores Back Arc Fault, 59.07 km from the Pasuruan-Bali-Lombok North Rise Fault, and 12.74 km from the Batujai Horizontal Fault. | Considering that the design of the Meninting Dam has a height of 74 m and a reservoir storage volume of 12 million m3, a dynamic analysis should be carried out to determine the level of stability of the dam against the influence of earthquake loads. |
| | | 8 Randu Gunting | Near to earthquake source (fault) | It was stated that the earthquake source closest to the Randugunting Dam was an inactive fault, so it did not affect the dam's stability. | • The classification of faults should be explained so that they are considered inactive faults.<br>• The possibility of reservoir-induced seismicity should be evaluated by continuous observation of the instrumentation.<br>• The magnitude of the acceleration caused by the Pati Fault has a PGA period value of 0.88 g. It should be checked again, considering the value is considered too large.<br>• To strengthen the analysis of geological structures, a joint investigation with a rosette diagram should be carried out to determine the direction of the main forces of the geological structure acting at the dam site. |
| | | 9 Sadawarna | there is a part of the Baribis fault structure indication | The geological cross-section of the dam is indicated that there is a part of the Baribis fault structure | a) Further investigation should be carried out regarding this part of the baribis fault and its influence on the safety of the Sadawarna Dam.<br>b) In identified locations as potentially affected by faults, intensive visual inspection and instrument monitoring should be carried out.<br>c) The potential effect of the fault on the dam's safety should be included as an indication of the hazard in the RTD Document. |
| | | 10 Tapin | Influence Meratus Fault to Tapin dam | In his presentation at the Plenary Session, the consultant said that, referring to the 2010 Indonesia Earthquake Map, there were no active faults around the Tapin Dam site. Based on the 2017 Indonesia Earthquake Map, there are 3 (three) significant active faults on the island of Kalimantan, namely the Meratus Fault (M 7.0; 0.2 mm/yr), Mangkalihat Fault (N 7.0; 0.5 mm /yr) and the Tarakan Fault (M 7.0;0.3 mm/yr). From the three faults, the Meratus Fault is located relatively close to the Tapin Dam location. | It should be checked and ascertained the distance between the active Meratus fault and the Tapin Dam location and evaluated for its effect on the dam's safety.<br>If the dam's location is close enough to the Meratus Fault, a comprehensive seismic study of the Tapin Dam should be carried out, including seismic hazard assessment, seismic hazard analysis and dynamic analysis. |
| | | 11 Tukul | Instrument instalation at fault zone & Monitoring | Based on the information provided by the Consultant, it is known from the indication of the dam structure that the fault is passed through is F1to F7, only F3 has Piezometer instrumentation installed.<br><br>Regarding the faults found, it is known that the main causes seepage and high pore water pressure. | Consider that in areas with indications of faults (F1-F7); a piezometer can be installed from upstream to downstream so that a thorough observation can be carried out.<br><br>consider installing a joint meter or crack meter in areas with indications of faults. |
| | | | | | |
| 11 | Dam Design | 1 Ameroro | Very slim core zone shape | In the dam zoning profile, the core zone looks too slender (slim). | To minimize the potential for arching in the core zone, the ratio between the widths of the bottom of the core zone to the head (at normal water level) is greater than 40%. |
| | | 2 Budong Budong | Dam zonal of rockfill | The zone 5 (rockfill) is not lied on stong foundation but on zone 4 random earth' | Zone 4 should be covered entirely by zone 5 and Rockfill embankments must have a harder foundation than the rockfill random embankmen. |
| | | 3 Jlantah | Dam design changing | There was a design change in the construction. During construction, zone 3a parameter was tested that has smaller parameters than the design then all zone 3a is replaced with zone 3b considering the availability of zone 3b is sufficient for use. | By replacing zone 3a with a coarser material there is a possibility that filter material will enter the random zone, if that happens it is necessary to do a piping test. |

# Dam Issues Arised at Construction Sites (39/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 4 Keureuto | Changing Rap-rap Thickness | The consultant stated that the total volume of riprap requirements (zone 5) of the Keureuto Dam amounted to 213,713.84 m3; meanwhile, material availability based on investigation results until May 2023 in the field is only 79,821,28 m3, so there is still a shortage of material availability. In connection with this, the consultant proposes to reduce riprap thickness in zone 5 from the original 2 m to 1 m. | a) Technical justification for reducing riprap thickness in zone 5 should be made, and prove with analysis should be proven that reducing the thickness will not reduce the stability value of the dam slope. The riprap rock parameters installed are the result of an independent laboratory report to be used as a reference.<br>b) A change design should be prepared along with a detailed change design drawing for reducing riprap thickness in zone 5. |
| | | | Horizontal Drain Function at Middle of Dam Body | There is a horizontal drain on the downstream slope of the dam for approximately 100 meters | The supervision consultant should prepare a technical justification regarding the horizontal drain placement and submit it to the Dam Engineering Office as a complement to the upcoming technical hearing. |
| | | 5 Leuwikeris | Design changing from rock filled to zoning | There is a design change from rockfilled to zoning, with random materials utilizing terrace and alluvial deposits at downstream of the main dam. | Mr. Paulus commended:<br>The random material will be used needs to be analyzed for stability again by adding brakes or making slope more gentle (a consequence of changing rockfill to random).<br><br>Mr. Shimizu commended:<br>Random material is more to sand and will be easily damaged when exposed to water, it is necessary to do a stability analysis.<br><br>Mr. Bambang commended:<br>Pay attention to the hydraulics of the intake because there are many bends in the pipe. It is necessary to look at Titab dam for the example where the intake exploded due to the large hydraulic pressure which resulted in an explosion in the intake tower. |
| | | 6 Marangkayu | Mapping of functioning Instrumentation | The embankment of Mearangkayu dam is already finish and dam never be impounded for drseveral years | The instrumentation that can still be used and those that cannot should be clarified, so that it can be concluded which parts need to be added to support the dam stability analysis. |
| | | 7 Rukoh | changing dam slope (become steeper) | The initial design slopes for the upstream and downstream slopes of the Rukoh Dam were 1:3.5 and 1:2.5. This is considered too sloping, considering that the Rukoh Dam type is a zonal rock filled with an impermeable core in the middle. Therefore, the consultant reviewed the enforcement of the dam body on the upstream side of 1:3.5, which becomes 1:2.75. | Consultant has tested the main embankment soil in Zone 3 with a value of phi=40°, then reduced to phi=36°. The embankment parameters should be equipped with a gradation curve and several field quality test parameters that need to be presented before deciding on the slope.<br>In determining of upstream and downstream slopes, it is necessary to consider analysing the full dynamic so that adjustments to the upstream and downstream slopes can be made optimally. |
| | | 8 Tamblang | dimentian of aspalt concrete (too thin) | The Tamblang Dam is a dam with an asphalt concrete core type with a relatively thin thickness of the core zone and has the exact (same) dimensions from the bottom to the top. With the presence of water load, more significant loading will come from upstream, so it is feared that it has the potential to cause the asphalt core to deform or bend downstream. | The consultant should carry out a deformation analysis with various loading combinations with representative parameters and describe the study results in 3 dimensions.<br>Based on the deformation analysis results, check the magnitude of the average and maximum shear stress, then compare it with the regular stress-strain graph of the triaxial test results for asphalt concrete core material. The values of the normal stresses, shear stresses, and strains (due to various load combinations) that occur must be less than the shear strength of the material obtained from the triaxial test results.<br>To prevent deformation of the asphalt concrete core, it is conveyed that there will be interlocking between the asphalt concrete core and the filter layer. A test fill has been carried out to see the deformation due to the compaction activity and obtained a deformation value of around 2 cm. The consultant should convey the results of the test fill that has been carried out along with the documentation. |
| | | 9 Tiga Dihaji | Cutting excavation | Cutting or excavating Siki Hill at the left abutment of the dam | Excavation should be no at same elevation of the top of the dam. The left support hill will be left at least 5 meters above the elevation of the dam top. This aims to anticipate whether, in the future, there will still be an increase in the crest of the dam due to climate change. |

# Dam Issues Arised at Construction Sites (40/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| 12 | Tunnel Collapse | 1 Bagong | Tunnel collapse at lithology boundary | Collapse in the tunnel due to lithology boundary and outflow of water. NATM needs to be considered because the tunnel shows that sortcrete at the middle to bottom part only. | In the tunneling process, consider using the NATM method with the main stages:<br>a. Excavation<br>b. Removing material<br>c. Steel support<br>d. Firtst Sortcrete<br>e. Rockbolt<br>f. Second Sortcrete |
| | | 2 Bener | weak zone claystone layer | On August 29, 2022, a collapse occurred in the tunnel work at sta. 0+518 to 0+525. The failure occurred in a claystone layer that was not previously identified during design. In previous identification, the tunnel was composed of andesite breccia, which had an RMR in the "Good" category and had a stand-up time of 20 days. Currently, support in the form of steel ribs has been installed in the landslide zone and mortar injection has been carried out from below, but the cavity from the collapse still needs to be completely filled. | a) RMR and stand-up time calculations should always be updated during tunnel excavation according to the condition of the rock being opened.<br>b) The failure zone of the claystone material at the top should be detailed to calculate the volume of mortar needed to fill the failure hole.<br>c) It should be ensured that the subsequent mortar injection can be carried out properly and is able to completely close and fill the cavity left by the claystone collapse so that it does not become a water trap zone when the reservoir is flooded, thereby preventing new collapses from occurring.<br>d) Consider the possibility of mortar injection being carried out from above so that filling is more optimal,<br>e) Consider conducting a geophysical investigation to determine the failure zone and the zone that has been successfully sealed with mortar. |
| | | 3 Jragung | Deformation on inlet and outlet of tunnel | Deformation locate at diversion tunnel, mainly at the outlet and inlet tunnel and also happen inside. Tunneling is still on going to finish 54 meters more. | In general, the deformation that occur at the inlet and outlet locations are almost the same, because of the thin layer of overburden. One treatment that can be done is to cut a thin layer of overburden to get 3D (overburden 3 times thicker than the diameter of the tunnel hole).<br>Suggestions from the supervising consultant would be to add reinforcement (poles) and add excavation at the bottom so that the hole diameter is relatively the same. |
| | | 4 Manikin | swelling material on tunnel (tunnel demage) | It was reported that one of the triggers for swelling in the rock that causes deformation in the tunnel is seepage/ground water in the tunnel. | Before carrying out repairs to the tunnel steel support, it is better to treat seepage/groundwater in the tunnel, for example by constructing a subdrain, dewatering (pumping), etc. e. To ensure the source of seepage, groundwater mapping in the tunnel rock should be carried out.<br>in order to ensure the groundwater configuration in the tunnel foundation rock, several observation wells (OW) should be installed along the tunnel. OW should be installed on the left / right side of the tunnel wall and reach the bottom of the tunnel. The OW should be used for monitoring the groundwater level around the tunnel and for dewatering. |
| | | 5 Tiga Dihaji | Diversion tunnel through loose material | It was also informed that the diversion tunnel structure would cut the loose sand layer. | It should be considered that for the downstream tunnel segment of the Dam axle that passes through the loose sand layer, a drainage pipe equipped with a filter/geotextile should be installed so that the saturation level of the sand layer below the downstream slope can be reduced to minimize the liquefaction potential. |

# Dam Issues Arised at Construction Sites (41/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 6 Way Apu | Tunnel collapse due to poor rock mass | Based on engineering geological mapping was carried out during the tunnel work, the resulting RMR value of rock along the tunnel building is in the RMR range < 40 (poor rock according to the Bieniawski classification). Based on this classification, the specifications of the support system in the tunnel have met the requirements, the distance between steel ribs between 0.6 - 1.0 meters, shotcrete layer thickness of 10 cm, and rockbolt depth of 4 - 5 m. According to information from the implementing contractor, the excavation method is blasting for zones with an RMR > 40 and uses mechanical excavation methods in zones tunnels with an RMR < 40. The collapse event is indicated due to poor steel rib installation along the 100 m to SR417. | a. It should be possible to explain in more detail the zones where blasting was excavated to identify the possibility of geological overbreak (GoB) occurring due to the influence of the blast.<br>b. Based on SNI 8460: 2017 Geotechnical Design Requirements, Sub Chapter 8.2.6 Portal and portal area requirements, Page: 144. It is said that the cover layer for the portal area and tunnel portal is at least 1-2D of the excavation diameter and rock arc effect.<br>c. Above the location where the GoB occurred, there is excavation work for the spillway building apron, and it only has an overburden distance of around 18 m, even though the planned diameter for the inlet tunnel is 9.70 m.<br>d. When handling tunnel landslides, consider stopping activities on the apron excavation to prevent landslides due to heavy equipment vibrations, considering that the rock is in poor condition. It is necessary to pay attention to the overburden layer in the tunnel, which, if referring to SNI 8460: 2017, is a minimum distance the tunnel is 19.4 - 20 m.<br>e. Basically, the calculation of the safety of the support system (steel ribs, shotcrete and rockbolt) during tunnel work is considered after all the components are installed in the tunnel structure because each support system component has its own stress value. Before continuing tunnel work, you should ensure the support system is completely installed in the tunnel structure. |
| | | | | | |
| 13 | Sedimentation | 1 Ciawi | rubbish acumulation on the trashrack | It was stated that at the Ciawi Dam, there had been a buildup of sediment and rubbish in the channel right upstream of the trashrack. | a. An inventory of waste accumulation points in the DTA should be carried out, which has the potential to enter river bodies. It is also recommended that upstream waste be collected at certain points before entering the reservoir area, for ease of management.<br>b. An evaluation of water pollution should be carried out based on the Decree of the Minister of Environment and Divinity Number SK.298/MenLHK/Setjen/PKL.1/6/2017, concerning determining the capacity to carry water pollution loads and allocation of water pollution loads for the Ciliwung River.<br>c. Based on data on potential waste input and evaluation of pollution, a control design should be created in collaboration with the LHK Service and Regional Government.<br>d. For the purposes of OP activities, the location of sediment and waste monitoring points should be planned on the reservoir perimeter. Likewise, access and storage locations need to be prepared regarding large rocks/boulders and logs that need to be cleared from the bottom of the reservoir in front of the inlet. Monitoring points and procedures should be included in the OP Guidelines.<br>e. The community participation approach, such as that carried out from DOISP Phase 2 funding which has been implemented at the Gintung Dam, should also be replicated at the Ciawi Dam, both in the DTA and around the dam and its reservoir in controlling waste and sediment. |
| | | 2 Logung | water hyacinths on reservoir | Several water hyacinths grow in reservoir puddles which indicate eutrophication in the reservoir. This eutrophication process can accelerate the silting of reservoirs due to the uncontrolled growth of water hyacinths. | a. The presence of water hyacinth should always be monitored and handled properly, and included in the routine maintenance of reservoir inundation in the OP guidelines.<br>b. Anticipation of the existence of water hyacinth and eutrophication is contested together with the local TKPSDA related to the causes and handling starting from the upstream watershed of the reservoir pond. |
| | | 3 Randu Gunting | high sedimentation | Based on sedimentation analysis using the USLE method, the Randugunting Reservoir has a total sedimentation rate of 1.70 tons/ha/year and is classified as a mild erosion class. | • the sedimentation analysis Should use the erosion map reference issued by BP DAS.<br>• It should also be equipped with a Randugunting Dam DAS / DTA map as a basis for sedimentation analysis.<br>• It was conveyed that no sedimentation test had been carried out, sediment sampling should be carried out at several points. |

# Dam Issues Arised at Construction Sites (42/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 4 Sukamahi | Clogging on the trashrack & Clogging on the trashrack | When operating the dam later, a big problem must be considered: mud, stone, and rubbish materials, which can clog and damage the trash rack so that the two channels are blocked (clogging). | a. When these two gates are closed, the hydraulic behaviour should be analysed, and the dam's stability (head load above normal water level and rapid drawdown) should be evaluated.<br>b. It is necessary to prepare steps that must be taken if a blockage occurs due to boulders and rubbish to maintain the continuity of the function of the dry dam as it should. This procedure should be included in the OP Guidelines.<br>c. Regarding these conditions, implementation references should be explained in the OP guidance document during the rainy and dry seasons regarding the cleaning of ring net barriers (if installed), stop log doors, maintenance of channels, etc. |
| | | | Trash and sediment problem | There will be problems with waste and sediment in the future. | The report should be accompanied by a document explaining the handling of waste and sediment in the reservoir, which will be cleaned periodically with a complete explanation regarding methods, transportation access and location of disposal areas that meet environmental requirements. |
| | | 5 Tugu | sedimentation reducing (sabo dam construction) | Reducing the rate of reservoir sedimentation to reach planned lifespan of dam. | To reduce the rate of reservoir sedimentation, integrated watershed conservation efforts should be carried out involving various related agencies and the community. Dam owners should carry out civil engineering efforts (construction of a sabo dam system) and other efforts to reduce the sedimentation rate of the reservoir so that the reservoir's lifespan is achieved according to plan. Should prepared the program |
| | | 6 Tukul | high sedimentation potential | Regarding the conservation of reservoir water resources, given the relatively high potential for sedimentation of reservoirs | a. Prepare a program for the construction of the Sabo dam system to reduce the discharge of sediment entering the reservoir;<br>b. Coordinate with related agencies to carry out integrated upstream watershed conservation by involving various related agencies and the community. |
| | | | | | |
| 14 | Flooding | 1 Bener | There is no analysis about flood control (one of Bener dam benefit) | One of the benefits of the Bener Dam is to control flooding in residential areas in the Purworejo area and the strategic YIA (Yogyakarta International Airport) area. To maximize the dam's ability to reduce flooding, the project plans to install gates on the spillway Bener Dam.<br>The consultant has carried out flood routing for the reservoir in conditions without gates and with gates but has yet to detail the benefits of reducing the extent of flooding that occurs downstream. | a) Flood routing should not only be done limited to reservoir routing but also river flood routing to determine the extent of flooding that occurs downstream so that we can know the comparison of flood reduction capabilities and the extent of flood inundation in downstream areas at various flood return periods, in conditions without dams, with dams (spillways without gates) and with dams equipped with gated spillways. The difference in flood area downstream of the dam, for example, for a 50-year return period, is a positive impact that needs to be socialized as a benefit of the Bener Dam as flood control.<br>b) Downstream flood control will be carried out by releasing reservoir water before the flood arrives (early release) to provide flood storage space in the reservoir.<br>I. Early release operations should refrain from interfering with the previously planned function of providing irrigation water and raw water.<br>II. In making an early release operational plan, the Reservoir Operation Pattern (POW) plan should be adjusted while maintaining the function of the reservoir in the context of providing water.<br>III. After the flood is over, efforts should be made to ensure that the reservoir is full again. The recovery time needed to refill the reservoir to the required elevation should be analyzed.<br>c) If the Bener Dam still cannot overcome the problem of flooding downstream, it could be considered to carry out flood control studies, for example, by using the polder method to protect priority areas that have the potential to be flooded (including YIA). |
| | | 2 Beringin Sila | Flash flooding potential | In point B.1 of the Minutes of the Technical Session, it was stated that there is potential flash flooding at the Beringin Sila Dam. | Consider studying the potential for flash flooding in the area around the dam. |
| | | 3 Jlantah | Large flooding historical | From the history around the jlantah dam, there have been large floods in August and September | these flood conditions should be included in the simulation during impounding if impounding will be carried out in rainy season |

# Dam Issues Arised at Construction Sites (43/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 4 Lolak | Flash flooding potential | Judging from the data recorded by the participants, there is the potential for a flash flood, which will cause the water level to rise rapidly. | 1. Should be able to use an early warning system as was done in previous studies to minimize the impact of flash floods.<br>2. Response to flooding if using the model will take time. The consultant should be able to provide clues that the DMU can hold to respond to future floods. |
| | | 5 Meninting | Flooding exceeds design plan for cofferdam | On June 17, 2022, at 15.35 WITA a flood occurred upstream of the Meninting Dam which caused water to overflow through the temporary cofferdam and flow into the main cofferdam and main dam work areas.<br>The flood water level that occurred was +168 m (equivalent to Q50 years based on measurements of the discharge downstream of the dam of 311 m3/s. | With the occurrence of flooding during construction that exceeds the design plan, the supervision consultant should be able to carry out a thorough evaluation of the hydrological and hydraulic calculations of all Meninting Dam design data (Temporary cofferdam, main cofferdam, circumvention canal, spillway canal, etc.). Evaluation is also carried out based on the design notes used in the calculations (e.g. taking the temporary cofferdam Qs year design, circumventing Q25 years, etc.). The results of this evaluation should be immediately submitted by the Consultant to BWS Nusa Tenggara I and the Dam Engineering Center |
| | | 6 Tugu | Flooding brings semdiment quickly | If there is a heavy rainfall in the reservoir watershed, the flood flow comes quickly to the reservoir, the reservoir water conditions are all becomes cloudy. This is a sign that the sediment entering the reservoir is quite large and will settle in the tapping tower area. | |
| | | | | | |
| 15 | V-notch | 1 Keureuto | V-notch Elevation is lower elevation than the river elevation | It was stated that there is a difference in elevation between the v-notch outlet and the river water level downstream of the spillway. The v-notch outlet is at +31 elevation, 5 m, while the river water level downstream of the spillway is +33,107 m (not including water storage height), so there will be concerns about backwater. In order to anticipate backwater, the consultant proposed to increase the v-notch elevation to 34,8 m and changed the v-notch design from a ground tank to an elevated one. | However, the plan to increase the v-notch elevation to 34.8 m is not recommended because the seepage water collection system (as in Figure 12 below) is not installed at Keureuto Dam.<br>Considering that the dam embankment work has already been carried out, it is impossible to change the v-notch design. Therefore, to overcome this problem, it is recommended:<br>a) So that the v-notch elevation is not increased and remains at the initial elevation and the v-notch design remains at the initial design, namely the ground tank;<br>b) Providing a measuring well tower to protect the flow of river water into the V-Notch<br>c) Added a drain pump that works automatically when the water level in the drain hole (downstream of the v-notch) reaches the setting position.<br>d) Pump capacity is regulated based on seepage discharge (checked through seepage water analysis including rainwater on downstream slopes)<br>e) The consultant immediately designed changes to the v-notch design and then submitted them to the Dam Engineering Office. |
| | | 2 Leukeris | The V-Notch position is lower elevation than the river elevation | The V-Notch position is at a lower elevation (elv. +71) than the river position (elv. +80). | Mr. Shimizu commended:<br>V-Notch got modified in 2 ways namely, 1) raise v-Notch position or 2) raise by tower/pipe for v-Notch, because the body dam already done maybe an alternative with a tower can done.<br><br>Mr. Bambang commended:<br>V-Notch necessary to be pumped, already lots a similar occurrence in several dam because v-Notch have to installed on right position |
| | | 3 Logung | water seepage and fooundation seepage in one v-notch | There are several springs on the foundation of the dam, but the seepage discharge and the spring enters into one in the v-notch | to determine the debit of seepage in the foundation, an evaluation of the fluctuation of the v-notch discharge should be carried out, especially during the dry season, the data recording the spring discharge in the dry season at the time of construction can be used to analyze how much seepage through the foundation, so that it can be estimated that the pure discharge fluctuations through the dam |

# Dam Issues Arised at Construction Sites (44/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 4 Napun gete | disturbed due to backwater from the outlet building. | V-notch buildings are often disturbed due to backwater from the outlet building. | Recommendations should be made to deal with the backwater problem (for example installing a submersible pump with an automatic control switch) so that the seepage discharge that comes out of the v-notch building can always be properly measured.<br>It should explain how to calculate the safe limit for v-notch readings, by ensuring that the input data parameters used are appropriate. |
| | | 5 Rukoh | The V-Notch position is lower elevation than the river elevation | It was stated that there is a difference in elevation between v-notch outlets and river elevation at downstream, where v-notch outlets are at an elevation of 45 m, in comparison the river elevation is 58 m, so it is feared that backwater happens. In anticipation of this happening backwater, The consultant proposed increasing the elevation position of the v-notch and making design changes to make the v-notch become elevated to drain seepage water by gravity and add a barrier wall. | a. Adding a barrier wall is not recommended because it is feared that the water storage embankment will experience a saturated condition, which could reduce stability.<br>b. The v-notch design should follow the initial design with the following points in mind:<br>1) Elevation v-notch stays at the initial elevation, which is the elevation can measure seepage from the entire dam core embankment.<br>2) Providing measuring well towers to protect backwater from the river flow inward v-notch;<br>3) Install an automatic drain pump when the water level the drain hole (downstream v-notch) reach the setting position. The pump capacity must be adjusted depending on the expected seepage discharge and checked through analysis of seepage water, including rainwater on the downstream slopes.<br>c. To make it easier for officers to monitor and maintain buildings v-notch, they should explain monitoring and maintenance v-notch on the Rukoh Dam Operation and Maintenance Guidelines.<br>d. A safe building design for access and automatic pumping facilities should immediately be made and discussed with the Dam Engineering Center or KKB. |
| | | | | | |
| 16 | Reservoir | 1 Luewikeris | Water quality | one of the function of Leuwkeris dam is to provide raw water for Tasikmalaya regency | Additional sampling is needed near the waste management site at the upstream of the dam. and training is needed for OP officers to conduct routine water sampling. |
| | | 2 Logung | Environment regulation recommencation fo be applied | The Ministry of Environment and Forestry already has a standard for the quality status of lake ecosystems, which can be applied to dam reservoirs. | The status of Lake Ecosystem quality by the Ministry of Environment and Forestry was adopted from a PUSAIR study with several adjustments. This quality status can be used as a standard criterion for dam damage which includes the scope of the evaluation on the plains, riparian, and water bodies. The Directorate of Technical Development should strive for the Lake or Reservoir Ecosystem Quality Status to be used as a guideline for the management of reservoirs from an environmental standpoint. Before being used as an official guideline, consider that the consultant refers to the quality status standards of this lake ecosystem to assess the quality standard criteria for a dam or reservoir. |

# Dam Issues Arised at Construction Sites (45/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | 3 Jatigede | Location of Panel Instalation in reservoir | Planning solar panels in reservoir areas need to be considered based on several condition | a. The placement of solar panels should pay attention to reservoir operation patterns and water level fluctuations.<br>b. Solar panels should not be placed in reservoir areas where they turn into land when the water level is low. This is to avoid the solar panel system running aground when the reservoir water level recedes and the solar panels being washed away when the flood comes.<br>c. Solar panels and supporting equipment are not permitted to block water flow or cause significant backflow, which can disrupt the function of discharge buildings (spillway buildings, intake buildings, emergency release facilities, and bottom outlet facilities), etc.<br>d. The distance between solar panels and output buildings is not permitted to be less than 500 m, including overflow buildings, intake buildings, emergency release doors, early release doors, etc. Still, it must be equipped with trash booms as floating safety protection.<br>e. Solar panels and supporting equipment are not permitted to obstruct dam operation, maintenance, and monitoring activities, including dam inspection routes, reservoir inspection routes, bathymetric measurement routes, sediment dredging areas, especially in front of discharge buildings, etc.<br>f. When planning the placement of solar panels and mooring and anchoring, you should use the latest bathymetric data.<br>In planning the placement of solar panels at each water level, free space requirements must be met. |
| | | 4 Marangkayu | Reservoir water level impounds gas wells | To maintain the reservoir water level so as not to submerge the gas wells, an emergency spillway has been built in the conduit building. The capacity of the "emergency spillway" is only capable of flowing Q5 flood discharge. The consultant proposes to utilize the circumvention conduit as a whole (both conduit holes are not plugged) and be equipped with a door. However, at the Q10 flood discharge, the water level is quite critical or close to the level of oil and gas wells. This is of course still quite a risk of inundating oil and gas wells. | a. Considering that the emergency spillway function is not meant for emergencies, the naming of "emergency spillway" should be replaced.<br>b. The frequency of Q10 floods is very high and if the gas wells are submerged by reservoir water, the demand for compensation will be very high. The gas wells should be secured during the return period of a larger flood. Considering that the risk of the gas wells being inundated is very high, consider that the gas wells are secured at least until the Q100 flood.<br>c. Consider cutting or lowering some of the main spillway building crests. To obtain a large enough reservoir volume, consider the overflow building in combination with installing several doors.<br>d. The basis for determining flood return periods for securing oil and gas wells should consider the quality of existing rain data (level of data validity), the urgency of protected buildings or facilities, and the level of risk or consequences in the event of a failure.<br>e. The body of the Marangkayu Dam was built by the Provincial Government of East Kalimantan while the overflow building was built by the Central Government or BWS Kalimantan IV. It should be considered in the event of a disaster where the gas wells are flooded, who should be held responsible or pay compensation. |
| | | 5 Napun Gete | Rapid water rise of reservoir | During the initial filling of the reservoir, there has been a relatively rapid rise in the water level. Calculation of the reservoir water level during the initial filling of the reservoir is only done once a week. | Calibration should be carried out at the time of the sudden rise in the reservoir water level.<br>Description Fluctuations in the reservoir water level should be described with points per measurement date, so that it is known in more detail the points of the surge in the reservoir water level.<br>It is recommended that the measurement of the reservoir water level during the initial filling of the reservoir be carried out at least once per day for more detail, and in the event of rain and flooding, more intensive recording will be carried out (at least 3 times a day). |
| | | | | | |

# Dam Issues Arised at Construction Sites (46/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
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| 17 | Hidromechanical | 1 Rukoh | not be equipped with a bottom outlet. | In the design of the Rukoh Dam, it is not be equipped with a bottom outlet. After reviewing, the consultant considers that the bottom outlet is not required because the dead storage volume (±2 million m3) of Rukoh Dam is very small compared to its effective volume. When the normal water level conditions, the reservoir water can be released through a valve hollow jet at the downstream, and facilities have been designed for emergency release. | • The consultant should analyse whether the hollow jet valve downstream can release reservoir water from normal to low water level because it was worried that the hollow jet valve downstream could only lower the water level to an elevation intake, not low water level.<br>• Therefore, consider designing the bottom outlet required as emergency release to low water levels in order to regulate reservoir water levels, considering that Rukoh Dam has a reasonably large capacity (12570 million m3). Existence bottom outlet is also needed to remove mud and sediment at the bottom of the reservoir to improve the reservoir's storage capacity and support future dam operation and maintenance activities.<br>• Necessity bottom outlet Rukoh Dam should also be studied based on the risk during an emergency conition if an earthquake occurs, which requires a reduction in the reservoir water level in not too long, considering that the dam's height is 87 m with a quite large capacity and location of the Rukoh Dam is in a location with high seismicity. |
| | | 2 Keureuto | Displacement of Sluice Gate | Based on the certification drawing design, a sluice gate is planned to be installed upstream of the main plugging in the tunnel. However, the dimensions of the existing sluice gate are larger than the tunnel door. Supervision consultant plans to move the position of the sluice gate from initially in front of the main plugging to upstream of the tunnel. Because of sluice gate was moved to upstream of the tunnel, The supervision consultant proposed installing a butterfly valve upstream of the main plugging so that maintenance and repair activities are more accessible to carry out when problems occur between the main plugging and penstock regarding this matter. | Regarding the urgency of installing a sluice gate upstream of the tunnel and adding a butterfly valve upstream of the main plugging, it should consult with a hydromechanical expert from the Dam Engineering Center;<br>If it is decided to add a butterfly valve upstream of the main plugging, you should pay attention to the butterfly valve dimensions to match the tunnel dimensions. Apart from that, it is necessary to ensure that the procurement and installation of butterfly valves and actuators are within the target (end of December 2023). |
| | | | Raw Water Pipe Installation | In the initial design planning for the Keureuto Dam, there was a raw water pipe installation; however, in the design review, the raw water installation needed to be included. | a) The supervision consultant should make a chronology of the removal of raw water installations during the design review along with technical justification;<br>b) The Keureuto Dam is planned to have the benefit of providing 0.5 m of raw water3/second. In order to support the benefits of the dam, consider ensuring that the raw water pipe installation is still installed as in the initial planning design.<br>c) Apart from that, dam builders should be able to coordinate with the Directorate of Ground Water and Raw Water regarding the need for raw water utilization. |
| | | | Installation of Bottom Outlet | The installation of a bottom outlet has yet to be planned for the Keureuto Dam. Considering that the Keureuto Dam's capacity is relatively large, namely 215.94 million m3, a bottom outlet is significant for releasing water in emergencies (emergency release). | a. It is recommended that the dam be equipped with a bottom outlet to lower and empty the reservoir water level when an emergency occurs at the dam. The analysis results, which are complemented by determining the bottom outlet's dimensions and the decline's duration, should be submitted to the Dam Engineering Center.<br>b. The dimensions/capacity of the bottom outlet pipe should be determined based on considerations: reservoir water volume (in man), inflow discharge, duration of emptying/lowering the reservoir water level, and other doors/valves used to empty the reservoir water, such as intake doors.<br>c. The calculated inflow discharge is the discharge with a 50% probability of being met and then controlled with the flood discharge at a 10-year return period.<br>d. The duration of the reduction in reservoir water levels in emergency conditions should refer to the Criteria and Guideline for Evacuating Storage Reservoirs and Sizing Low-Level Outlet Work, USBR 1982.<br>e. A bottom outlet design should be prepared with an action plan for completing the work.<br>f. See the minutes of the Dam Safety Commission's discussion regarding suggestions and recommendations for the bottom outlet of the Keureuto Dam on August 27, 2020. |

# Dam Issues Arised at Construction Sites (47/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
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| | | 3 Temef | Early release pipe are too sharp and twisty. | Early release pipe are too sharp and twisty. | Early release pipe should be not installed sharply and twisty. Early release is recommended to use option 1 for those that take water directly from the turbine. It is recommended that if the turbine position is pulled to downstream then the pipe position is not mazy and the position is better. |
| | | | | | |
| 18 | Intake design/foundation | 1 Jragung | changing incline intake to tower intake | On intake location plan, there are 2 problems:<br>- sliding located at incline intake<br>- New shifting position for intake tower | The landslide around the intake will be covered/filled with material which then protected with riprap material.<br>There is no problem changing the intake to a tower because of tower is already on a good rock foundation. |
| | | 2 Leuwikeris | there is unstable potetial of intake foundation | Intake location will be planned to be shifted considering problem of stability on excavation slope. The shifting will be carry out between 2 tunnels, however there is indication that on intake foundation is present a lens weathered breccia. | Mr. Paulus commended:<br>The intake can be continue, it is necessary to check the existing intake holes. From the results of the drilling that has been carried out, there is a difference between the single and triple drilling, which requires confirmation drilling.<br>Mr. Shimizu commended:<br>In the intake, velocity of water inside pipe will very tight (not smooth), necessary to check the hydraulics condition. |
| | | 3 Marangkayu | Foundation of additional release channel | In 2020 there was a flood until the reservoir water elevation reached +106 m and in 2022 there was also a flood until the reservoir water elevation reached +107m. Because of the flooding, the realease chanel is currently being built | at the location of this realease chanel plan has a foundation in the form of soft soil with SPT values less than NSPT <10 to a depth of 14 m. It is recommended that piles be installed to a depth of more than 14 m. |
| | | 4 Rukoh | instrumentation for sliding monitoring at around intake | During construction several sliding occored around the intake | consider to install monitoring instruments such as inclinometer or surface monument. |
| | | 5 Temef | There was a shifting slope of pillar at bridge of spillway wall to intake tower | There was a shifting slope of pillar 5 (4.8o) to pillar 6 with a base elevation of +354 meter of the bridge where there is movement of landslides of steep cliffs with fractures and cracks. | Counter weight is recommended to balance pillars 5 so that it can be repaired or replaced with a new one. The slopes should be stabilized first, then the pillar is constructed.<br>It is recommended that the backfill is carried out immediately and pillar 5 can be excavated again under the foundation on the original soil. |
| | | | | | |
| 19 | Drilling on Dam Body | 1 Bendo | drilling on dam body to install piezometer | Currently, it is impossible to monitor the dam's horizontal deformation because all the inclinometer pipes are damaged. For this reason, BBWS Bengawan Solo proposed installing a new inclinometer pipe. | To avoid deep drilling, consider installing inclinometer pipes near the left and right abutment or in areas with geological structures and/or weak zones where the embankment height is less than the maximum height of the dam.<br>Drilling in the dam body poses a very high risk to the dam's safety. Before drilling for installation of the inclinometer and OSP is carried out, a Drilling Program Plan (P3) should be prepared. |

# Dam Issues Arised at Construction Sites (48/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
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| | | 3 Raknamo | drilling on dam body to install inclinometer | Drilling is planned to install an inclinometer pipe, because the existing inclinometer pipe has been damaged. | to anticipate potential damage so that it does not occur in the implementation of further drilling, it should be evaluated the cause of damage to the adrift inclinometer pipe, whether due to heavy equipment or because of the biggest decline that occurs in the elevation after the height of the damage while the telescopic distance provided is insufficient or because the inclinometer pipe is too thin, an earthquake occurs, the clamp is not deep enough, etc.<br>the urgency of drilling to install a new inclinometer pipe should be re-evaluated, for example because it is located in an earthquake-prone area, because the current inclinometer readings still show movement because it is necessary to monitor the safety of the dam in the 5-year major inspection activities later,<br>The urgency of drilling for the installation of the new instrument should be explained in the drilling guidelines report taking into account the suggestions. If it is considered not important, drilling for the installation of a new inclinometer can be considered not to be carried out. |
| | | 2 Rotiklot | drilling on dam body to install inclinometer | Inclinometer installation location is at the slope improvement that used gabions and bore piles | a. Determination of the inclinometer distance was not carried out based on the results of previous technical analysis. The installation distance for the inclinometer should be determined based on the calculation of embankment deformation from the measurement results of the previously installed inclinometer. Likewise, the position of the inclinometer point can be placed outside the landslide area based on the results of analysis of landslides that have previously occurred.<br>b. To design the installation of an inclinometer on a slope experiencing landslides, you should pay attention to the geological conditions on the slope. These geological conditions can be data during bore pile construction.<br>c. To see the adequacy of data in areas suspected of having potential for landslides, a clear layout of the placement of each type of instrument should be made, as well as a cross-section showing the relationship between the instruments and each other. |
| | | | drilling on dam body to install piezometer | There is a plan to install an Open Standpipe Piezometer (OSP) only in the filter zone. | a. Drilling in or through the sand filter layer is not recommended as it will interfere with the filter function.<br>b. In principle, the installation of instrumentation (piezometers) is placed in locations: the deepest cross sections, where special geological conditions (weak geological structures) are found, and other important locations. For this reason, in planning the installation of instrumentation points, you should previously study and consider the geological data of the foundation as well as the geotechnical data of the embankment material based on the drilling results that will be carried out later.<br>c. Considering that the OSP installation will be used to depict the phreatic line, the consultant should be able to explain the purpose of placing the piezometer in the free drain filter zone.<br>d. Installation of OSP should consider the permeability value (k) of each zone and the depiction of the phreatic line from OSP readings that are still functioning.<br>e. To make it easier to draw the phreatic line, consider placing an OSP in the core zone by considering the results of evaluating previous OSP readings.<br>f. The drilling depth for installing standpipe piezometers should be approximately 2 - 3 m below the estimated phreatic water level (except for short dams). For shallow drilling (<8 m), it is best to use a hand drill. |
| | | | | | |
| 20 | Penstock Pipe | 1 Karian | Difficulity of maintainence after impounding | The penstock pipe at the upstream main plugging is made of steel material | Considering that after plugging, the penstock pipe cannot be maintained and repaired if a leak occurs, the penstock pipe should be covered with concrete. Make sure the quality of the concrete used and the thickness of the concrete blanket is sufficient to prevent the penstock pipe from getting damp and rusting. |

# Dam Issues Arised at Construction Sites (49/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
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| | | 2 Keureuto | Shifting penstock location | The supervision consultant proposed shifting the penstock pipe downstream of the butterfly valve from the middle to the left side of the tunnel to provide an access road for OP activities. With this change, a part of the penstock pipe is slightly curved. It should be noted that bends in the penstock pipe have the potential to cause water hammer in the pipe, which can cause cavitation. | a. It is essential to re-examine the potential for cavitation in pipe sections that experience bends/changes in angle.<br>b. Pipes that experience bends should be strengthened, for example, by adding anchors to the pipe mounts, tightening the pipe mounts, covering the pipes with concrete, etc. |
| | | | | | |
| 21 | Liquefaction | 1 Kuwil | Liquefaction potential | The Kuwil Kawangkoan Dam has high earthquake potential, but the consultant needed to conduct a liquefaction potential study at the dam location. | The reasons for not completing a possible liquefaction study should be given. |
| | | 2 Tiga Dihaji | Liquefaction potential | One of the factors that triggers liquefaction in the loose sand layer is the condition of the groundwater level being high or saturated. | Consider installing a drainage gallery equipped with a filter on the loose sand foundation below the downstream slope to lower the groundwater level in the loose sand layer to minimize the potential for liquefaction in the loose sand layer. |
| | | | | | |
| 22 | Plugging of diversion | 1 Lolak | detail plugging implementation is required | The number of grouting points to be carried out in the plan for implementing contact grouting on plugging concrete has yet to be explained. Considering that there are many leaks in plugging due to sub-optimal grouting, | The plugging implementation plan should be accompanied by detailed planning design drawings, including the number and pattern of grouting points to be implemented. |
| | | 2 Manikin | Plugging and cooling methode | Recommendation of the plugging method in the inlet tunnel or at the bottom of the core zone | 1) The temperature of the mixing concrete should be kept no more than 200. For this, it can be done by lowering the temperature of the mixing water for concrete using ice flakes.<br>2) To avoid thermal cracks, restrictions should also be placed on the maximum temperature inside the concrete when the hydration reaction occurs. Usually the maximum temperature is limited to around 550.<br>3) Consider controlling the heat of hydration by a combination of pre-cooling and post-cooling.<br>4) Based on SNI 03-3976-1995 concerning Procedures for dosing, mixing, transporting and casting concrete, the casting of bulk concrete may not exceed 610 mm per stage. The plugging concrete casting method should refer to the SNI. In addition, because wet concrete needs to be vibrated, determining the height of the casting bed should also take into calculation the depth of the vibrator stick. |
| | | | | | |
| 23 | Cut-off wall / secant pile | 1 Bagong | possibility of insufficient length of spillway side | Under the control building/overflow weir, it is planned to install secant pile to cut off the flow of seepage on the colluvial foundation. | Seepage from the reservoir can flow through the foundation under the spillway building and can also pass through the foundation next to the spillway building. The barrier wall under the spillway should continue to the foundation/support next to the spillway building. |
| | | | | | |

# Dam Issues Arised at Construction Sites (50/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| 24 | Dam Impounding | 1 Lolak | staging impounding to monitor dam behavior | The initial impounding of the reservoir is planned to start on August 18, 2023, with a total time needed to reach the normal water level (NWL) of 72 days. Hydrological modeling is only limited to the location of the dam. | 1. In carrying out the initial impounding of the reservoir, it should wait to raise the reservoir water level to the MAN. Still, there should be a time lag after reaching the intake elevation (elevation +99 m) to monitor the behavior of the dam body for around 2 - 3 months before continuing to fill the water level to the MAN. This time lag determines the instrumentation response and tests the dam's hydromechanical equipment.<br>2. Hydrological modeling should be made from more than just the point where the dam is located. Hydrological modeling can be made up to the downstream of the dam, given the frequent occurrence of floods.<br>3. A control plan is needed as an anticipatory effort if things happen that are not planned during the initial filling of the reservoir, including the appointment of personnel responsible for the problem. |
| | | | | | |
| 25 | Anchoring Panel | 1 Jatigede | base anchor on soil | From the discussion regarding "Geotechnical Condition" it is known that the anchor concrete block foundation is in the form of silty clay to clayey silt-type soil based on those taken from 2 (two) drilling point locations, with N-SPT values ranging from 15 - 29. | a. Considering that there are up to 2000 anchor block points, the 2 (two) drilling points that have been carried out need to be more representative in describing the geotechnical condition of the anchor block foundation as a whole. The geotechnical investigation of anchor block foundations should be expanded so that it can represent actual conditions in the field.<br>b. In addition to the equipment and test implementation having to comply with standards, the SPT test to determine the bearing capacity of the foundation soil mass following actual conditions in the field should be carried out in situ. If it does not meet the standards, the N-SPT value should be corrected so that the value can be correlated with the existing empirical value.<br>c. Because it is related to "floating force", you should also know the value of the "tension strength" of the anchor block foundation in water-saturated conditions.<br>d. Considering that reservoir sediment is recent/too young sediment that is relatively unconsolidated and cemented, its designation as an anchor foundation deserves to be considered and reconsidered.<br>e. The concrete anchor beam's design needs to consider the potential for slipping on the soft and slippery reservoir bottom, and the anchor details still need to be equipped with a shear key as an anti-slide device.<br>f. Concerning the points above, it is recommended to review/re-examine the map/technical geological condition of the reservoir base basin. Drill data is only available for 2 (two) points, which is still far below the minimum percentage of the number of islands and the number of anchors to be installed. |
| | | | | | |
| 26 | Galery Inspection | 1 Tiga Dihaji | Gallery recommendation | Regarding the gallery structure below the dam core zone, there some recommendation. | a. Detailed drawings are prepared, including reinforcement structures, contraction joints, drainage systems (water storage pools, pumps, drain pipes, flow measuring instruments), instrument systems in the gallery, lighting systems, fresh air blower systems, etc.<br>b. Contraction joints should be equipped with double water stops; consider one water stop using a metal water stop with a high duration.<br>b. For access in and out of the gallery, it is best to create a gallery access at the bottom of the pedestal, which can also be used to place a drain pipe. |
| | | | | | |
| 27 | Water Treatment plan | 1 Sepaku Semoi | Water treatment location | K- Water planned to build WPT at left dam abutment | The location of WTP is located near the left abutment of the dam. Please consider the topography at the left abutment which is so thin and will affect the dam body if landslide occurred. |

# Dam Issues Arised at Construction Sites (51/51)

| No | General Dam Issues | Name of Dam | Main Issues | Issue Explanation | Suggestions |
|---|---|---|---|---|---|
| | | | WPT location at left abutment | K-water as provider for WPT is planning to built the WPT a t left of dam abutment | The Dam Engineering Center (BTB) recommends that the WTP be built on the second Alternative as shown in the figure, in addition the WTP needs to have a procedure for Emergency action plan specifically for the WTP. |
| | | | Slope excavation at left abutment for WTP | For WTP there several cutting slope to locate the WTP building, at location C-C' there is a fairly high excavation, in addition there is also an embankment afterwards | it is necessary to consider how the stability on the slope and its relation to the safety of the dam. It should be noted that the characteristics of clay silt are very destructive and also expansive. In addition, geological data should be available along the WPT line. |
| | | | Determination of WTP location at Dam downstream | Geological mapping at the time of construction showed that the left abutment of the sepaku semoi dam site is dominated by quartz sandstone with intercalation of claystone, shale, limestone and siltstone. The mudstones, shales and siltstones at the site show slaking characteristics | The dam safety commission agreed that the WTP should not be built on the left side of the dam and highly recommended downstream of the dam 100 m from the toe of the dam (option 2). |
| | | | | | |