Operation and Water Management of Dam Cascade System

Exploitation et gestion de l'eau du système cascade de barrage

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Abstract. The Larona River Basin which covers an area of 2,477 km2, including the three cascading lakes: Matano, Mahalona and Towuti, is a strategic watershed which acts as the water resource for three hydropower plants that supply 420 Megawatt of electricity to power a nickel processing plant and its supporting facilities and electricity need of the surrounding communities. The maximum and minimum operating levels of Lake Towuti are 319.6 meters (asl) and 317.45 meters (asl) respectively. The optimization of water resources management in the Larona Basin is important to fulfil the need to produce the energy sources. Weather Modification Technology in the form of cloud seeding is needed to produce rain which will increase the volume of water in the lake when the lake water level decreased. In the rainy season, spillway operations in all dams must be optimized because the water levels upstream and downstream are continuously monitored to prevent the impact of flooding in both areas.

Résumé. Le bassin de la rivière Larona, qui couvre une superficie de 2 477 km2, y compris les trois lacs en cascade, Matano, Mahalona et Towuti, est un bassin versant stratégique qui sert de ressource en eau à trois centrales hydroélectriques qui fournissent 420 mégawatts d'électricité pour alimenter une usine de traitement du nickel et ses installations de soutien ainsi que les besoins en électricité des collectivités environnantes. Les niveaux d'exploitation maximum et minimum du lac Towuti sont respectivement de 319,6 mètres (asl) et de 317,45 mètres (asl). L'optimisation de la gestion des ressources en eau dans le bassin de Larona est importante pour répondre à la nécessité de produire les sources d'énergie. La technologie de modification des conditions météorologiques sous forme d'ensemencement des nuages est nécessaire pour produire de la pluie afin d'augmenter les volumes d'eau dans les lacs si ces derniers ont diminué. Pendant la saison des pluies, l'exploitation de l'évacuateur dans tous les barrages doit être optimisée, car

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les niveaux d’eau en amont et en aval sont en permanence surveillés pour prévenir l’impact des inondations dans les deux zones.

1 Introduction

The Larona River Basin which cover an area of 2,477 km^2, including the three cascading lakes: Matano, Mahalona and Towuti, is a strategic watershed which acts as the water resource for three hydroelectric power plants which supply electricity needs for PT Vale Indonesia Tbk’s nickel mining operation and its surrounding areas 1. The total installed power for the hydropower plants is 420 MW, consisting of a 3 x 60 MW from Larona power plant, 2 x 65 MW from Balambano power plant and a 2 x 55 MW from Karebbe power plant, which all are in cascade systems.

The three hydropower plants operate by utilizing the water resources from the cascading Lakes in Larona River Basin channelled through Larona River to the plants’ turbines. The drop of the Lakes water volume will affect the optimal operation of the hydropower to efficiently support PT Vale Indonesia’s nickel ore smelting operations in Sorowako. Lower than average rainfall has significantly impacted the water level of Lake Matano and Towuti. Minimum elevation limit of Lake Towuti for optimal operation of the hydropower plants is 318.00 meters. Water level decrease in Lake Towuti will disrupt the capacity of the three hydropower plants to serve the need of nickel production processes. In turn, PT Vale Indonesia will need to operate alternative electricity sources, like diesel generators and other sources which drive greater costs.

Fig. 1. Larona Catchment Area.

Table 1. Larona Catchment Area.

Catchment Drainage Area (km^2)	
Lake Towuti outlet	2,447
Lake Towuti outlet to Batubesi Dam	29.9
Upper catchment to Batubesi	2,477
Batubesi to Bailey Bridge	90.3
Bailey Bridge to Balambano	182.4
Lower catchment to Balambano	272.7
Balambano to Karebbe	53.3
Lower catchment to Karebbe	326
Matano Lake	165.9
Mahalona Lake	23.6
Towuti Lake	562.2

1.1 Overview water resources

1.1.1 Water availability

The current operation of Larona Hydroelectric Facilities relies on the active/live storage of Lake Towuti. The maximum and minimum operating levels of Lake Towuti are 319.6 meters (asl) and 317.45 meters (asl) respectively. Total active storage between these two elevations is 1,231,500 m^3. Currently, the operation average outflow from Lake Towuti to the power plants is 130.1 m^3/second which is resulting in a total annual outflow volume of 4,103,000 m^3. By comparing outflow volume with the live storage volume, it is obvious that the current storage has a limited ability to store water volumes from wet to dry seasons. Routing studies support this observation. During a dry season, the outflow drops by 100 m^3/second. The total available flow from Larona Basin in average is 138 m^3/second per year, of which 7.9 m3/s spilled from Batubesi Dam. An increase in available storage volume would increase the energy production by eliminating, or at least reducing, the spill. Thus, an increase of volume will expand the average rate of flow to the power plant by the ratio of spill to average flow (7.9/130.1) or 6.07%.

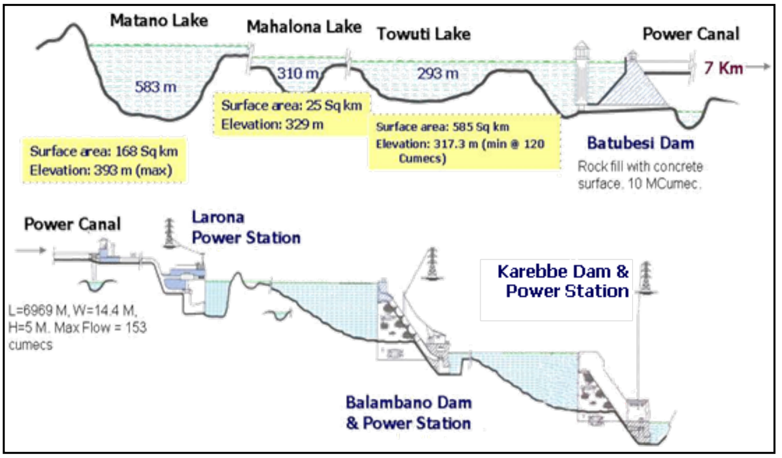

Fig. 2. Hydro Power Plant Cascade Systems.

1.1.2 Water management

There are 2 types of water management that are regulated in the Plan of Control (POC), namely:

- "Water Balance" where the output of Larona hydroelectric plant and the water debit of Patingko River is the same as the output of temporary Balambano hydroelectric plant.
- "Water Unbalance" where the output of Larona hydroelectric plant and the water debit of Patingko River is greater or less than the output of Balambano and Karebbe hydroelectric plants.

The water discharge of Larona hydroelectric plant is limited by a maximum canal capacity of 148 m^3/second which is equivalent to 1.22 MW at PLTA Larona, 0.76 MW at Balambano hydroelectric plant and 0.66 MW at Karebbe hydroelectric plant.

Calculation of the availability of electrical energy supply that can be distributed to the Process Plant department as user must adopt the water balance scenario (weekly forecast). If using the water unbalance scenario, water availability for Balambano hydroelectric plant can only last 8 hours from a maximum operating elevation of 166.00 m above sea level to a minimum operating elevation of 165.20 m.

Under certain conditions, power for nickel smelting can be obtained from another generator (Thermal Plant/Diesel Generator and Steam Turbine Generator) of 30 MW via the DC Link. And vice versa if the power requirements for smelting do not reach the maximum, then part of the Thermal Plant is positioned ready if needed at any time. This is applied when the availability of water in the 3 lakes is sufficient.

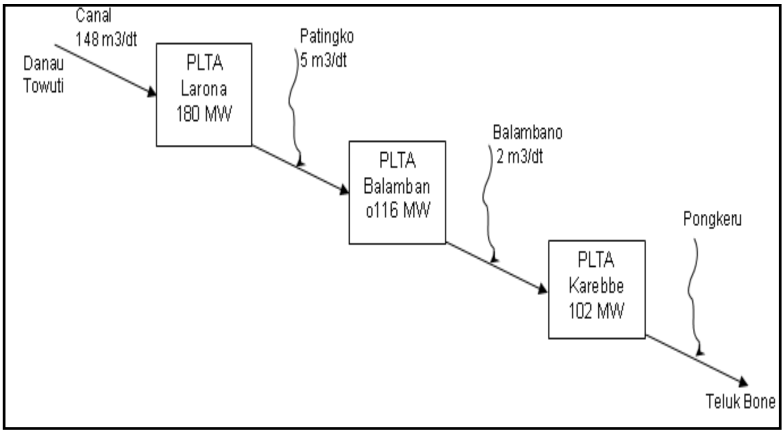

Fig. 3. Hydro Power Scheme Water Flow.

2 Maintenance of lake water level

Climatologically, based on rain-collecting data in the Larona Watershed, the peak of rainy season occurs in March-May while dry season occurs from August to October. Annual rainfall is concentrated around Lake Mahalona, while the lowest annual rainfall is in the southern part of Lake Towuti. Based on existing data that the annual rainfall spread has a high number around the area of Mahalona Lake which reaches 3,000 mm/year. Meanwhile, the lowest annual rainfall is in the southern part of Lake Towuti, about 2,600 mm/year. The areas around Lake Mahalona, the south eastern part of Lake Matano and the north western part of Lake Towuti have the most concentrations of rainfall. Referring to cloud presence data, cloud growth concentration also found in the upstream of Matano and around Lake Mahalona. To maintain the lake's water level so that the hydropower plant can operate optimally, the Company needs to utilize Weather Modification Technology (WMT) as an integrated part of water resources management. WMT is a human effort to modify the weather with a specific purpose through seeding clouds, to increase the intensity of rainfall in a specified area. Seedling materials are fired to the clouds through aircrafts or ground-based seeding facilities known as Ground-Based Generator (GBG).

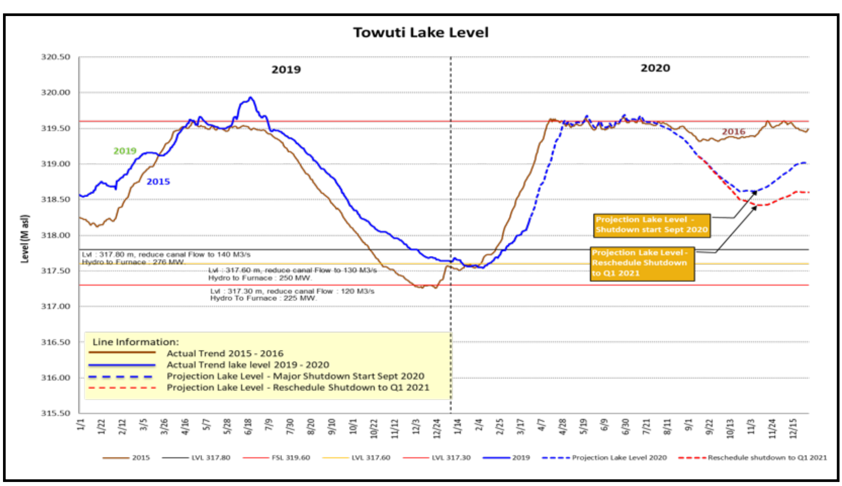

Fig. 4. Lake Level Inflow & Outflow Analysis.

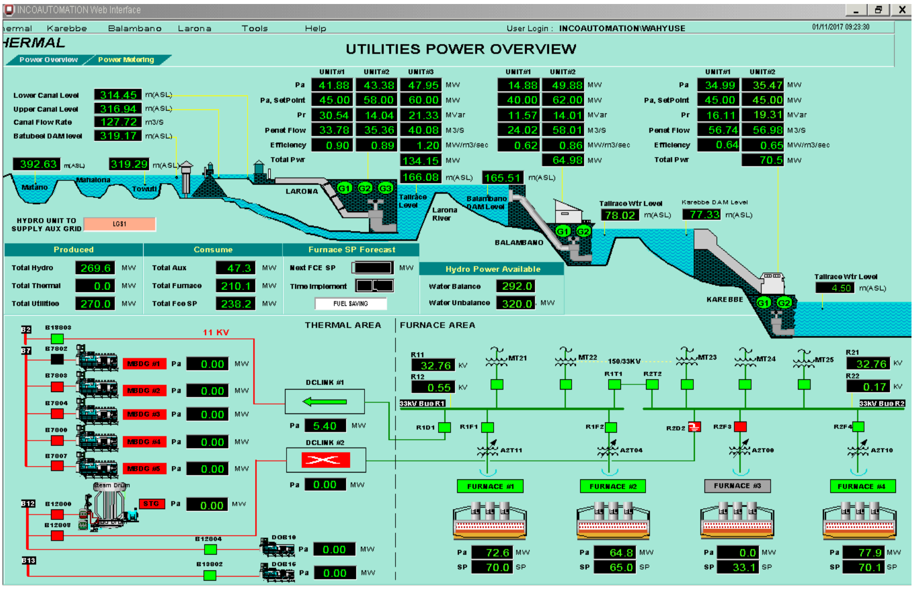

Fig. 5. Scheme of Power Plant.

2.1 Weather modification technology

Cloud seeding activities are usually carried out due to the predicted rainfall will be below normal for the next few months and will result in the number of inflows being below normal as well. When cloud seeding is carried out, inflow prediction is used with a probability of between 70% and 80% (below normal). From 2008 to 2010, cloud seeding operations have used a flare system to increase the water discharge in the lake. The material for the seedings is packaged in a sleeve like a firework and mounted on the wing of the plane. When the plane enters the cloud, the seed material is burned to allow the smoke enters the cloud. In 2015, seeding was also carried out from the ground using the GBG Tower (Ground Based Generator). Due to its static nature, GBG can only wait for the cloud and seed the cloud through the base close to the top of GBG tower, where the seedlings are released. To optimize the seeding material discharged from the top of GBG tower into the cloud, the tower must be placed in a relatively high area. By utilizing the air flow system, it is aimed that the released seedlings can be carried into the clouds.

2.1.1 Aircraft

The following is the cloud seeding process by aircraft:

- Seeding is carried out based on the potential cloud results from a weather study at the time of the briefing as well as cloud conditions from radar monitoring.
- Seeding is carried out on clouds that are predicted to have the potential to become rain (Cumullus; Cu), both inside the target area and outside the target area (upwind area). By considering the direction and speed of the wind, the seedlings are expected to enter the cloud and become rain in the target area.
- For Cumullus clouds that are outside the target area (upwind area), seeding is done by the jumping process method. Seedlings are carried out in the cloud base at a flying altitude of around 3,000-5,000 feet (when using hygroscopic flare seedlings) or in the ridge/cloud top area at an altitude of about 9,000-12,000 feet (when using

powder seed material) with the aim of accelerating the rain process before clouds move into the target area.

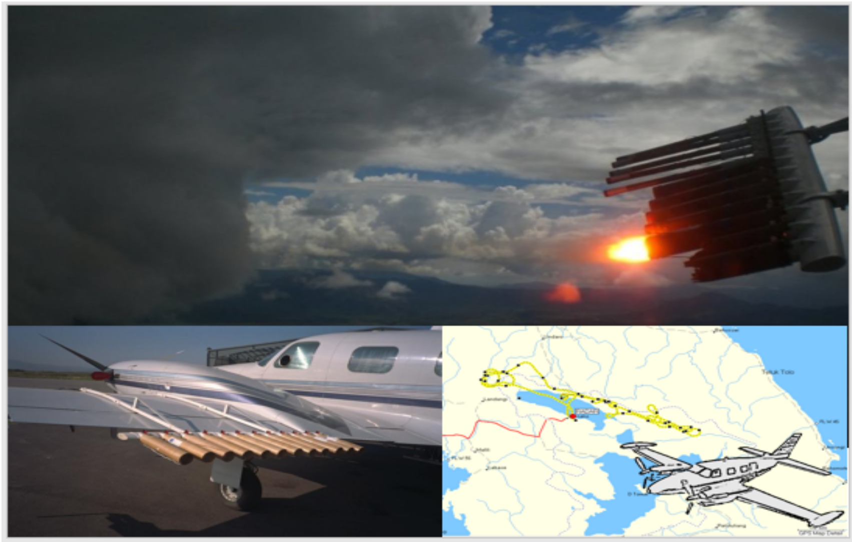

Fig. 6. Cloud Seeding by Aircraft.

2.1.2 Ground Base Generator

The static weather modification technology system or better known as Ground-Based Generator (GBG) is an on-surface, static medium or system to disperse seeding material into clouds which takes advantage of valley winds and slopes topography. GBG technology in cloud seeding can reduce our reliance to aircraft usage, the most expensive component in the weather modification operation.

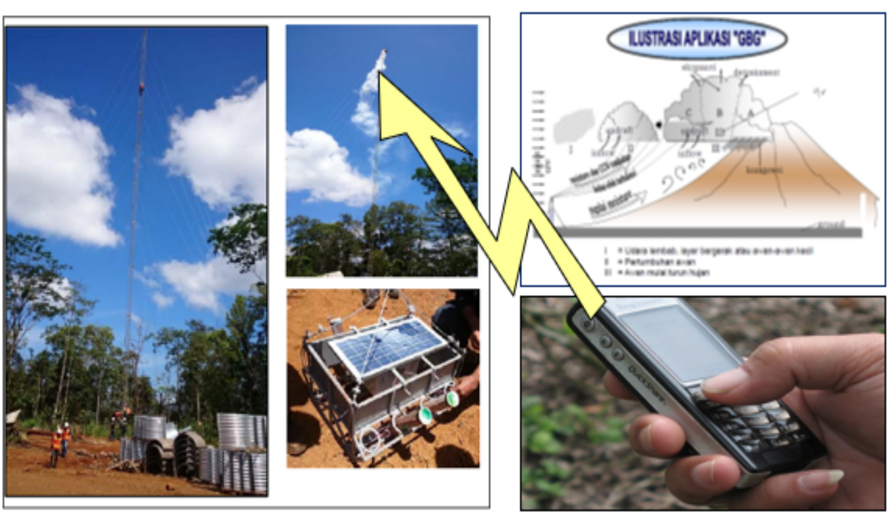

Fig. 7. Cloud Seeding by GBG tower.

3 Spill Outflow Procedure

The Standard Work Procedure is a guideline in carrying out the work of regulating the opening of the Petea Gate and setting the opening of Larona, Balambano and Karebbe spillway gates based on the level of Lake Matano, Lake Towuti and Larona-Balambano-Karebbe Dam by following the tide table, so that the work is done properly, safely and will not affect the community around Matano, Towuti and the area along the Larona river.

3.1 Technical Data

Petea Gate is a building specifically designed to pass and control the amount of water from Lake Matano that enters Lake Mahalona. The sluice gate is operated manually or by using a portable AC motor.

Petea Gate Technical Data

- Number of gates : 6 units
- Petea gate size : 4.0 x 2.4 meters/unit
- Maximum Opening : 4.0 meters
- Motor power supply : 220 Voltage and Frequency 50 Hz

Spillway is a building designed to drain water from a dam in the event of a flood or water level increases to a level above its threshold. This spillway is also a requirement for dam safety.

Larona Spillway Equipment Technical Data

- Type : Fixed wheel gates
- Number of Main Gate : 3 units
- Gate size : 3.86 x 3.27 m
- Drain size per unit : 80.5 x 3.89 x 3.50 m
- Bulkhead gate size : 3.18 x 3.15 m
- Top deck : @ El.322.0 m and Bottom Floor @ El. 294.00 m
- Opening 25% flow : 45 CMS
- Opening 50% flow : 88 CMS
- Opening 100% flow : 171 C MS
- Emergency Spillway Gate Dam : 3 X 20 M

Balambano Spillway Equipment Technical Data

- Gate : 3 units
- Type : Radial gate
- Width : 8,000 mm
- Height : 15,076 mm
- Radius : 16,000 mm
- Hoisting Mechanism : Hydraulic
- Lifting Height : 150,924 m
- Opening / closing time: + 27 minutes

Karebbe Spillway Equipment Technical Data

- Type : Radial gate
- Clear width of opening : 8,000 mm
- Clear height of gate : 19,000 mm
- Radius : 22,000 mm
- Peak flow at PMF : 6,830 m^3 / sec at RWL 88.22 m
- Flow at FSL : 767 m^3 / sec at RWL 79.00 m
- Flow at DAM crest level : 843 m^3 / sec at level 79.50 m

3.2 Spillway Gate Operation

The operation of the spillway gates is carried out to lower the water level of Lake Towuti when it reaches 319.55 m above sea level which is usually occurs between June-September in the normal climate cycle.

On May 6, 2006, a maximum opening simulation of Larona spillway was carried out with a total flow of 513 m^3/second and 133 m^3/second from the turbine. Testing lasted for 3 hours. There is no significant effect due to this test except for a few trees growing in the middle of the river (under normal condition, the river is not watered continuously except by a small spring from the hill). The water that comes out of the Larona overflow channel will meet the water generated from the turbine at the tail race to continue to Balambano dam. At the time of the test, the 3 turbine generator units were still operating normally even though the tail race elevation was up about 50 cm.

The level of the tail race in normal operation is a maximum of 148 m3/s. When the test was carried out, the flow was about 651 m3/s. Brown water comes from Larona, while green water comes from turbines. The difference in the elevation of the tail race can be seen in the image marked with a circle. The water discharge of 646 m3/second from Larona is used to increase the elevation of Balambano Reservoir by reducing the water flow from Balambano to 380 m3/second. Another factor that is always considered in normal operation is the amount of additional flow from the Patingko River, which under normal conditions the averages is only 5 m3/second, but during heavy rain may reach 150 m3/second.

At the downstream part of PT Vale's Hydroelectric, tests have also been carried out to see the impact of inundation due to the opening of the spillway gate along the river route starting from the village of Karebbe-Wawonriu-Malili-Balantang. The test takes a reference to the total flow that comes out of Balambano Hydroelectric and the total flow from Balambano overflow. The results obtained, at a discharge of 500 m3/second, water has started to inundate the cacao trees planted along the river in several areas in Karebbe Village, with a height of about 30 cm. This is due to the additional water flow from Pongkeru River. In the rainy season, the water flow from Pongkeru River can cause the water level around the Karebbe Village suspension bridge to rise up to 30 cm even though the water flow from Balambano is normal without spilling (maximum 200 m3/second). This is also one of the concerns of the dam manager to continue to coordinate with the community through appointed representatives to inform the condition of Pongkeru River water discharge when spilling occurred. Under certain circumstances, the water discharge from Balambano spillway is reduced to lower the water level in Karebbe and Wawonriu Villages.

For the operational interests of PT Vale, the amount of water spill discharge is also conditioned along with the tide in order to secure the loading and unloading process at Port Balantang. If the ship is going to move from/to the Gulf of Bone, the water discharge from Karebbe Hydroelectric is limited to a maximum of 280 m3/second.

4 Early Warning System

Evacuation is carried out when there is a very strong suspicion that there is an emergency or there is a certainty of dam failure. In that case, an evacuation is decided and the warning system is activated by East Luwu Regency Government based on the report/notification from the Dam Management Unit, in this case Internal Emergency Action Plan (EAP) team coordinator and Head of East Luwu Regency Regional Disaster Management Agency.

Regional Disaster Management Agency that has been formed in East Luwu Regency Government helped by other agencies are parties involved in the evacuation process initiated from the planning until the implementation. On the other hand, the owner/operator of the dam during the emergency state, aside from helping the evacuation planning process, is also directly involved in reducing the damage at the dam.

The Larona River Dam is classified as a high hazard level and the owner has adopted a flood warning system as his responsibility for the safety of the community in the downstream part of the dam is engaged. Warning system can utilize the warning siren. If the siren can be heard, residents must follow the development of emergency through the radio that should broadcast the steps to be followed. The activation of warning system is done together between the local government and dam operator.

4.1 Warning System

4.1.1 Siren at The Location Of The Dam

A siren is installed on each location of the dam, on the Balambano and Karebbe Powerhouse. This siren sounds automatically when one of the spillway gates starts to operate.

4.1.2 Siren in Karebbe and Malili

Sirens in Karebbe and Malili are operated by Shift Coordinator/Supervisor in the upstream part of Larona Hydroelectric Power Plant Control Room, signifying the level 2 and level 3 notification.

4.2 Siren Code

Forms of the Siren Codes:

Table 2. Sirine Code.

LEVEL 1 Notification	There is no siren (only danger sign/alarm around Hydroelectric Power Plant location)
LEVEL 2 Notification	The sound of the siren is loud, halting, 1 second it sounds, another 5 seconds it ends, continuously for 9 (nine) minutes.
LEVEL 3 Notification	Loud sound uninterrupted for 2 (two) minutes.
Controlled condition	One loud and long sound for thirty (30) seconds.

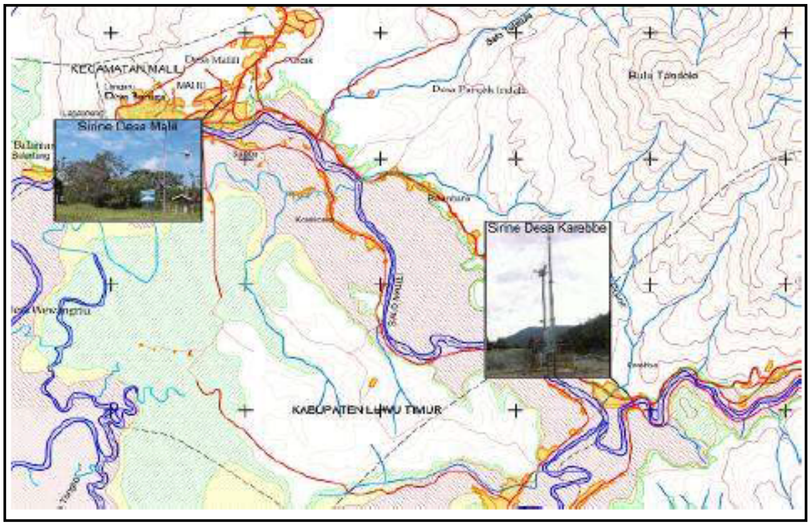

Fig. 8. Sirens Location.

Emergency state can occur on various conditions and sometime the danger level is hard to predict. Emergency state can occur both slowly or abruptly and very dangerous. For the safety of residents at the downstream part, an activity based on the development of emergency should be done.

5 Conclusion

The following are some important points can be concluded from the previous discussion:

- Weather modification with cloud seeding is useful at the end or beginning of the rainy season to meet the electricity supply of hydroelectric power that will be distributed to PT Vale's nickel processing plant. The energy needs of PT Vale and electricity for the community will always be fulfilled.
- The design spillway gate of the Larona, Balambano and Karebbe Hydroelectric Powerplant will be able to pass through a 1000 years flood cycle.
- Lake Matano water level can be controlled through the operation of Petea Gate and for Lake Towuti can be controlled through the operation of the spillway gate on a cascade system.
- Water river elevation on the downstream of the Hydroelectric will begin to rise about 30 cm when the total outflow reaches 500 m^3/second, at normal operations total outflow is about 200 m^3/second.
- Flood hazard warning systems have been established and socialized periodically and continuously.

This paper is dedicated to management of PT Vale Indonesia Tbk: Vinicius Mendes as Chief Operating Officer (COO), Abu Ashar as Director of Energy Environment, Pamrih Pammu as General Manager of Hydro Operation as our respectful counterpart in scientific discussions and the whole communities of Hydro operation of PT Vale, Sorowako, East Luwu, Indonesia.

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