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Current Issues and strategies of hydropower generation in the multi-sand river – A case study for the upstream of Wu-jie dam

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Abstract

The upstream catchment area of the Zhuo-shui river is fragile in geology to erosion and collapse. Lead to high concentration of sand in the stream. Taipower Company has Song-lin weir and Wu-jie dam under the Wu-she Reservoir in the Zhuo-shui river catchment, and the Wanta Power Plant and Song-lin branch power plant for power generation in series, diverting water to the Sun Moon Lake Reservoir via Wu-jie dam. In 1934, after the completion of Wu-jie dam, it was completely filled in 1935. In 2008, the typhoon of Sinlaku reduced the storage capacity of the Wu-she Reservoir.

After the completion of the Song-lin weir in 2012, a large amount of sediment was deposited in the downstream of the Wanta river. Song-lin weir faced difficulties in tailwater discharge, and sediments during siltation caused the difficulty of water intake and hydropower generation. The tailwater outlet channel of Song-lin branch power plant was located in the upper reaches of Chu-ping Canyon. The narrow river channel made the channel soil sand transport blocked, resulting in easy siltation at tail water outlet. The collapsing of the sand on the other side of the bank collapses into the river, which may endanger the discharge of power generation tail water. In addition, the clean tail water from the Song-lin branch power plant was sent to the Zhuo-shui river, which was mixed with the river mud and sand into turbid water, and then divert water into the Sun Moon Lake via Wu-jie dam causing siltation.

In series of dams for hydropower generation faces different soil sand problems. In addition to continuing to handle the dredging of the Wu-she Reservoir, the Taipower Company used hydraulic drainage to reduce the sedimentation of the downstream of the Song-lin weir. The Taipower Company has programming of retrofit the existing water diversion tunnel to remove sediment in the Wu-she reservoir. On the other hand, study on connecting the Wanta Power Plant power tail water to the Song-lin branch power plant water intake by Specific piping system. And think about feasibility of setting flood diversion tunnel in the Wanta river. The countermeasures for the water transmission of the Sun Moon Lake reservoir by the Song-lin branch power plant tail water dedicated special pipe are considered. Take the concept of overall watershed thinking to deal with the impact of sediment deposition on water intake of hydropower generation.

Keywords: Wanta river、Song-lin weir、Specific piping system、sediment deposition、hydropower generation

1 Introduction

The Wu-she Reservoir was completed in 1959. The early dam construction did not have a bottom outlet for hydraulic desilting. The watershed of Wu-she River generate a large amount of sediment and flow into the Wu-she Reservoir. The current sedimentation rate in 2018 is about 73%. The Wanta Power Plant of Taipower Company is located at the downstream of the Wu-she Reservoir, and the tail water of the power generation is discharged into the upstream of Song-lin weir. Song-lin weir is located about 2km downstream of the Wu-she Reservoir and has a dam height of 9m. It is a small adjustment pool type reservoir. The Song-lin branch power plant of Song-lin takes water from the Song-lin weir to generate electricity. The tail water of the power generation from the branch power plant of Song-lin is discharged into the Zhuo-shui River. Then, the main channel water is diverted from Wu-jie dam to the Sun Moon Lake Reservoir for subsequent use.

Song-lin

However, Wanta River flow into the Zhuo-shui River about 400 m downstream of the Song-lin Weir. Due to the fragile geology of the upstream catchment area, a large amount of sand and rock piled up in the river channel. According to the survey, from the 921 earthquake in 1999 to the end of 2012, Wanda river catchment still has 612.31 hectares of land collapsed, the total collapsed volume is about 12,656,585m^3, and the river channel sediment deposit is about 3,164,217 m^3.

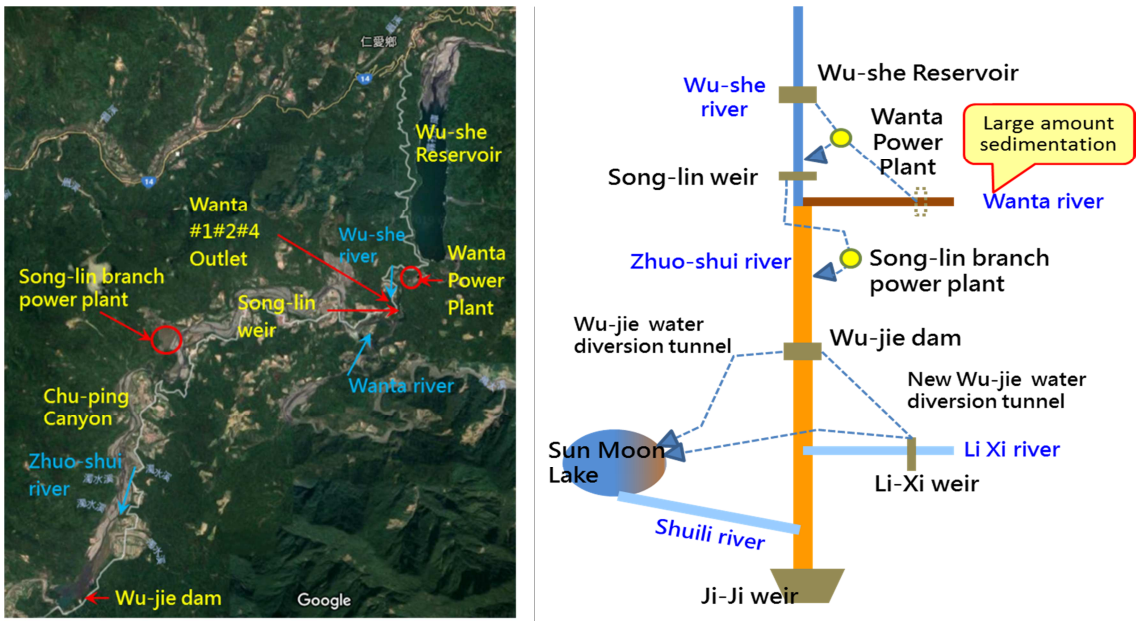

Figure 1: Schematic diagram of Hydraulic facilities location

2 Issues

2.1 Wu-she Reservoir

The Wu-she Reservoir has a designed storage capacity of 150 million cubic meters, and the annual average sedimentation rate is about 1.33 million cubic meters per year. After the Chi-Chi earthquake in 1999, the annual average sedimentation rate is increased to 3.25 million cubic meters per year. In recent years (2000~2016), the average annual sedimentation depth of reservoir bottom in front of the dam is about 0.88 m. Currently, the elevation of reservoir bottom is about EL.975, which is closed to the minimum operating water level, EL.978 m. However, the reservoir bottom is exceeded the power plant intake elevation of No. 1 and No. 2 and the intake elevation is EL.938.5. If the reservoir bottom in front of the power inlet is suddenly slippery, the sediment may block the water intake and induce a serious impact on the power generation of the Wu-she Reservoir. In addition, the sedimentation may cause the trash rack to be crushed and deformed. If the trash rack is crushed and broken, it will also affect power generation. 2.2 Song-lin weir

A large amount of sedimentation in the Wanda River have been piled up and accumulated in the downstream river, Zhuo-shui River. The river bed of Zhuo-shui River have been continuously raised to form a barrier lake at the downstream of Song-lin weir and affect the operation of the Song-lin weir for flood discharge and hydraulic desilting. After flood, the intake and the trash rack are silted in recent years. This condition force the operator to use manual removal for deposit sediment (Figure 2). However, this situation result in increased maintenance cost and decreased power generation efficiency of the branch power plant of Song-lin. In the future, if there is a typhoon or a large torrential rain, a large amount of sediment will move down to make the downstream river channel rise suddenly, the Song-lin weir may be cover by sand and gravel, and the branch power plant of Song-lin will face the situation of unable to take water for power generation.

Figure 2: Sedimentation problem of Song-lin weir

2.3 Downstream river of Song-lin weir

The huge amount of sediment accumulated in the Wanda River channel and its upstream catchment area will be moved down year by year. This upstream condition will induce the river bed elevation of tail water outlet of the branch power plant of Song-lin has been the same as the river channel. The tail water outlet area is the landslide and geostrophic sensitive area announced by the Central Geological Survey. Large-scale collapse may still occur. As long as the river channel bed is slightly higher, it will impact the tailwater discharge. Moreover, the narrow river channel of Chu-ping Canyon restricts sediment transportation, which will cause the crisis of branch power generation tail water of Song-lin to be discharged.

In addition, the clean tail water generated by the branch plant of Song-lin flows into the Zhuo-shui river, and it is mixed with the turbid water from Wanda River. Then, the mixed turbid water would be diverted into the Sun Moon Lake from Wu-jie dam, which indirectly causes the Sun Moon Lake sedimentation problem.

3 Strategies

3.1 Wu-she Reservoir

In order to deal with the sedimentation problem, Taipower Company continuously to implements excavation strategy and plans to modify diversion tunnel for pressure flushing in Wu-she reservoir. It was proposed to open a new pressure flushing tunnel at dam site Taking into account the problem of insufficient flood discharge capacity of the reservoir, it can achieve flood control safety and increase the outflow sediment quantity by new pressure flushing tunnel. The main conceptual works are shown in Figure 3. It is estimated that the annual sediment discharge is 750,000 m^3, the sediment discharge ratio is 34% of incoming total sediment yield, the reservoir life is extended for 21 years, and the total project cost is about 3.4 billion NTD.

The main purpose of this strategy is to use the hydraulic desilting to slow down the sedimentation problem and increase the reservoir life. The direct engineering benefits of this program are compared to mechanical dredging cost, and the results show that this is an economically viable development plan.

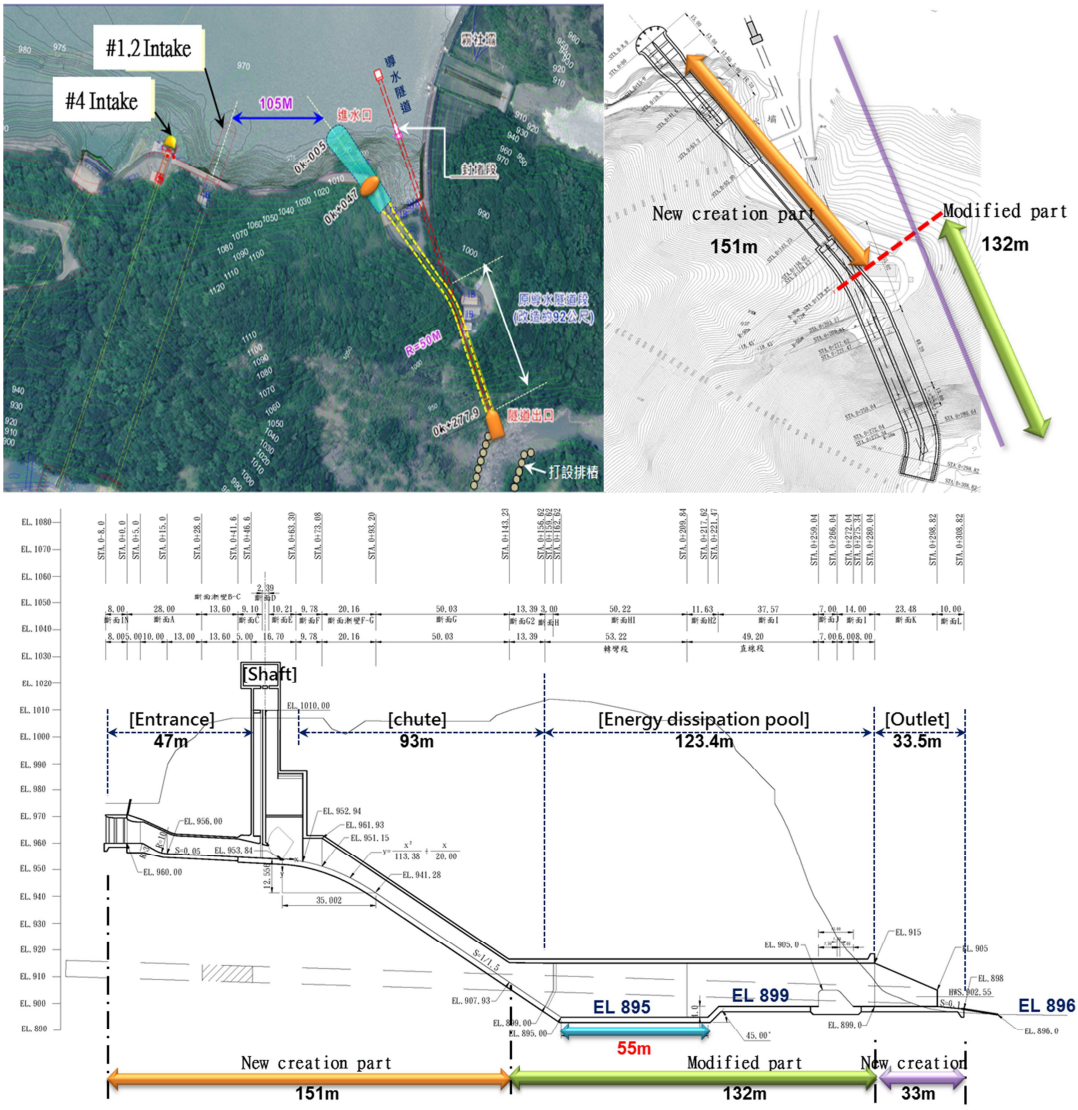

Figure 3: Water guiding tunnel reconstruction plan

3.2 Song-lin weir

A large amount of sedimentation continued to accumulate in the junction of Zhuo-shui River and Wanda River. In 2015, Taipower Company tried to use the mechanical excavation to treat the sediment deposite at the downstream of Song-lin weir. However, the sand deposition rate of Wanda River was greater than that of mechanical excavation. The effect of mechanical excavation was not as expected. Therefore, the hydraulic desilting is considered to discharge the sediment deposit during flood period to reduce the sedimentation elevation at the downstream of Song-lin weir. However, when the flood of Wanda river into the Zhuo-shui River, it will offset the kinetic energy of the water discharge to the downstream of Song-lin weir, and reduce the effectiveness of hydraulic desilting of Song-lin weir. How to

control or estimate the water volume of Wanda River has become a key issue for hydraulic desilting. Taipower Company studied the feasibility of adding a flood diversion tunnel from Wanda River to Zhuo-shui River. In addition, the feasibility of using a small hydropower unit to generate electricity by using the constant flow of Wanda River is also investigated. The preliminary concept is shown in Figure 4.

Considering the possibility that the Song-lin weir will be inundated due to downstream river bed rising in the future, ensure the water intake function and power generation, and reduce investment losses, the Taipower Company investigates the feasibility of the specific piping system of the Wanda Power Plant from the water intake to the branch power plant of Song-lin. Figure 5.

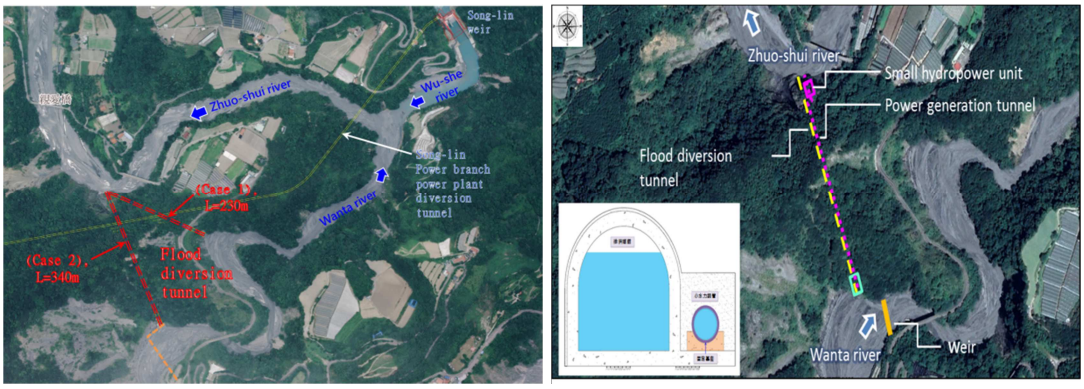

Figure 4: Schematic diagram of Flood diversion tunnel

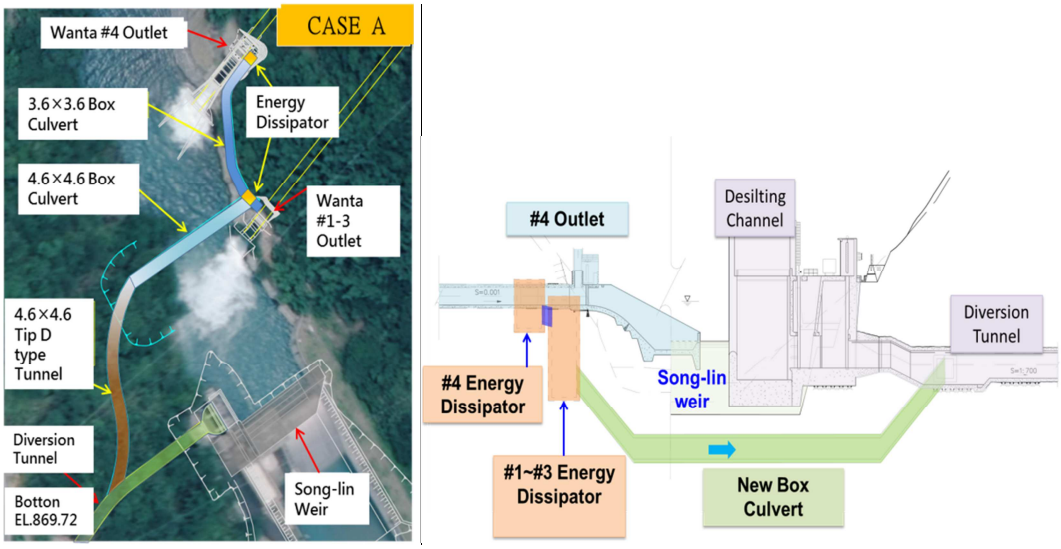

Figure 5: Schematic diagram of Specific piping system

Downstream river of Song-lin weir In response to the sedimentation of the tailwater channel of the branch power plant of Song-lin and the large-scale collapse potential on the opposite river channel , Taipower Company studied the feasibility of specific piping system from branch power plant of Song-lin to Wu-jie dam. Then, the water for power generation is no longer disturbed by the concentration of water

and sediment in the Zhuo-shui River. It can also generate electricity during periods of high river flow, except for the turbidity of the water. Operation time can also be extended to improve power generation efficiency, reduce the risk of turbine wear and reduce the sedimentation problem of Sun Moon Lake. The preliminary concept is shown in Figure 6.

Figure 6: Schematic diagram of specific piping system between branch power plant of Song-lin and Wu-jie dam

4 Conclusions

The multi-sand rivers make the cascade operation of the cascaded dams full of challenges, and the strategies for the sedimentation issue projects of different hydraulic facilities compete with each other. For example, plans to modify diversion tunnel for pressure flushing in Wu-she reservoir will aggravate the impact of downstream river channel sedimentation. The specific piping system of the water intake from Song-lin weir to Wu-jie dam may reduce the sediment deposit effect from the Wanda River.

Taipower company assess the risk of future power generation operations based on the characteristics of sediment characteristics, and continue to develop various improvement plans to enable power generation facilities such as the Zhuo-shui river from Wu-she Reservoir, Song-lin weir, Song-lin Branch, Wu-jie dam and Sun Moon Lake Reservoir. And consider the countermeasures in the basin as a whole to improve the efficiency of power generation, and strive to stabilize the power supply to ensure the sustainable use of water resources.

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