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The Achievement of Shihmen Reservoir and its Catchments Management Project

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Abstract

On Aug. 23rd, 2004, Typhoon Aere caused great devastation across Shihmen reservoir, including damaged facilities, the massive amount of sediment siltation and 18 days water supply outage. Hence, in order to maintain operation and extended service life of Shihmen reservoir, Water Resources Agency (WRA) carried out “Shihmen Reservoir and its Catchments Management Project” from 2006 to 2017. This project focus on watershed conservation, desilting tunnel intake, multilevel intake and building Jhongjhuang artificial lake. With these measures, it’s able to confirm operation and water supply of Shihmen reservoir when turbidity muddy flow occurs during typhoon landing, and it’s also the first iconic case of reservoir improvement in Taiwan.

Keywords: reservoir improvement, Shihmen reservoir, Jhongjhuang artificial lake, water supply, multilevel intake

1 Project overview

1.1 Background

In Aug. 2004, Typhoon Aere hit northern Taiwan and rained 967 mm in the watershed of Shihmen reservoir for 2 days. It caused a serious landslide, erosion at upstream of Shihmen reservoir, simultaneously, the massive amount of sediment siltation flooded into the watershed in few hours as well as increasing turbidity to 10 thousands of degrees, far exceeding the purification capacity of the water plant. This situation forced the government to stop water supply in the Taoyuan area for 18 days. Besides, the quantity of final reservoir siltation statistics is up to 27.88 million tons in this single event, about 1/10 of design storage capacity. In order to confirm operation, upstream conservation and water storage of Shihmen reservoir, the executive Yuan budgeted 25 billions of NTD to carry out "Shihmen Reservoir and its Catchments Management Project" since 2006.

1.2 Project framework

The short-term goal of this project focuses on stable water supply during typhoon hitting in 2006, and long-term goals are extension service life and reduce the risk of water shortage. To solve these problems, there have two main works to do, (i) emergency water supply project and reservoir renewal improvement; (ii) watershed conservation and management. Watershed conservation and management is mainly

based on non-engineering measures such as strengthening watershed management, counseling residents and so on. In the other hand, because the water supply of Shihmen reservoir cannot be interrupted during engineering works, it has to plan in a new way when in the second part of works and makes this project become the first iconic case of reservoir improvement in Taiwan.

Emergency water supply project and reservoir renewal improvement include 12 subprojects executed by NRWRO, which is affiliated to WRA, MOEA and the authority of Shimen reservoir. In this project, the most significant subprojects about water supply and reservoir renewal improvement are (1) multilevel intake; (2) desilting tunnel intake and (3) Jhongjhuang artificial lake.

2 Project content and implementation achievement

2.1 Multilevel intake

Shihmen Reservoir was designed in 1955 and completed in 1964. The original design of intake is setting the position as low as possible to ensure enough water supply during drought seasons. Furthermore, the main water supply target of Shihmen Reservoir is agricultural water. The high turbidity water during typhoon seasons has relatively low impacts on agricultural water for further usage. However, as the water supply targets have changed over the past 50 years, 50% of current water supply targets are domestic and industrial water. When water becomes highly turbid from the low intake, the capacity of the water plant would be insufficient to process such water. Then, the supply of domestic water would be interrupted. Therefore, in order to improve the stability of Shihmen Reservoir's water supply, the top priority of this project is to append multilevel intakes to Shihmen Reservoir. When the density current flows into the reservoir during typhoon seasons, the turbidity of surface water is usually lower. The multilevel intakes can access to the surface clean water to maintain the stable supply of domestic and industrial water.

With the consideration of geological condition, the characteristics of density current, reservoir's flood management operation, and the connection of downstream pipelines, the main engineering project is to construct three intakes in different height on the left dam abutment of Shihmen Reservoir: (1) upper water-intake: El.236m, (2) middle water-intake: El.228m, and (3) lower water-intake: El.220m(Figure.1). The purpose of the project is to improve the stability of intaking low turbidity water according to the water level and turbidity changes during typhoon seasons. The designed daily maximum water supply amount is 140 million tons, which could satisfy the water demand until 2026. The main challenge of this engineering project is completing multilevel intakes building in limited time while the reservoir keeps operating with the fluctuating water level. In 2009, the construction of upper and middle water-intakes and the system tests were successfully completed. The upper and middle water-intakes can fulfill the

function of water intake. However, the lower water-intake cannot be constructed until the water level is lower than El.218.5m. Such low water level means the reservoir is in the water shortage condition. With any water inflow to the reservoir, the water would be restored immediately, leading to short and temporary feasible construction time. We are still waiting for the adequate water level to finish the further work after the digging of low water-intake sloping surface and trash rack platform, slope protection, and tunnel drilling temporary protection.

The construction of multilevel water-intakes enables the stable water supply to domestic and industrial water in Taoyuan district during typhoon seasons. Since the start of multilevel water-intakes, the facilities have utilized for 2078 hours. Take Typhoon Aere as an example: one-day water outage caused 200 million NTD economic loss. The risk of more than 17 billion NTD economic loss has been prevented due to the construction of multilevel water-intakes.

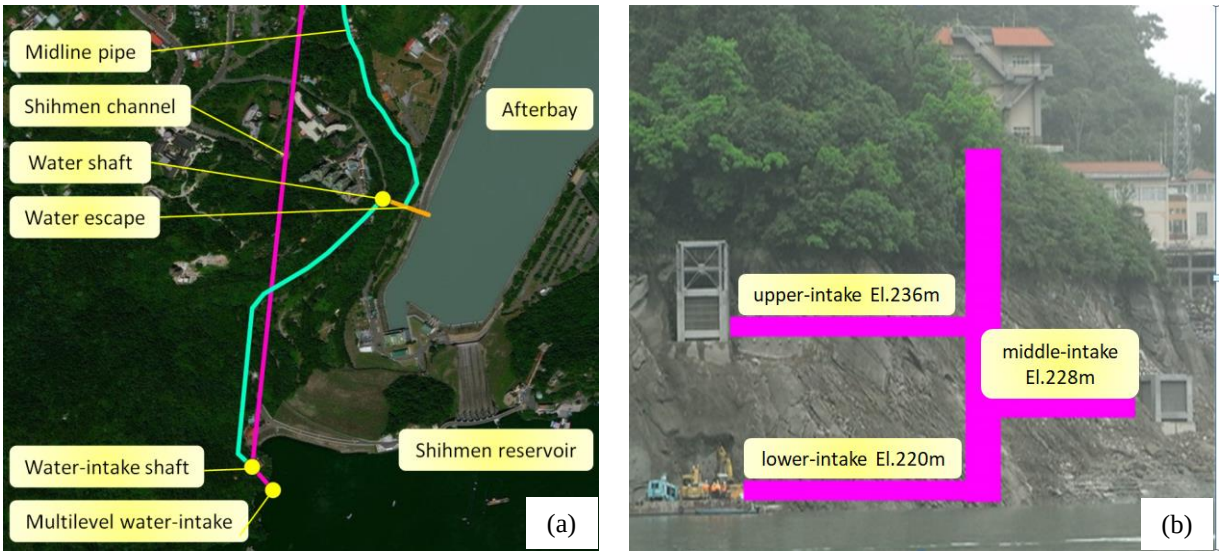


Figure. 1: Pictures of multilevel intake (a) position of multilevel intake system (b) simplified diagram of multilevel intake

2.2 Desilting tunnel intake

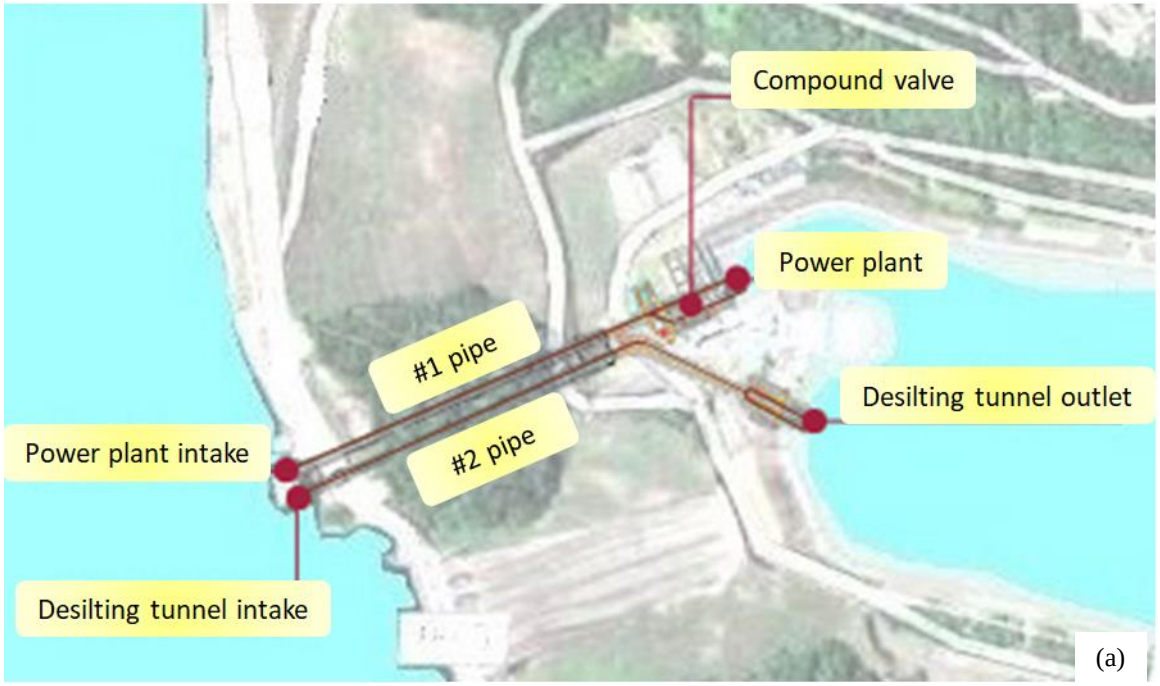
Although multilevel intake can obtain low turbidity water from the surface, according to the observation data from the previous typhoon events, without properly removing the density currents occurred during typhoon events the turbidity of surface water still increases dramatically. After applying the multilevel intake which solves the water supply issue, the next step is to increase the ability of discharging of sediment in order to get rid of density current. In this way, we can not only preserve the cleanness of surface water but preventing deposition of sediment inside the reservoir. However, applying modification on a currently working reservoir and keeping the safety of dam structure are extremely difficult. Taken considerations altogether, using one of the power steel pipes in Shihmen power plant as a desilting tunnel would be the optimum

solution.

The elevation of two power steel pipe is 173m which is the lowest intake except for permanent river outlet (PRO) at El.169m. Nevertheless, under constraints of power generator safety, the maximal flow rate of outflow during typhoon events is about only 53 cms. Bypassing the generators can increase the flow rate up to 300 cms and thus multiply the effectiveness of sediment-removal.

Desilting tunnel intake construction is the modification of the current power steel pipe in Shihmen power plant. The pipe is cut and redirect to after bay. The first-period construction began in December 2009 and ended in December 28th, 2012. To this point, the second power steel pipe has successfully converted into the desilting tunnel. The rate of sediment-removal is increased 35% comparing to the period without desilting tunnel during typhoon events.

Finally, in order to restore the functionality of the second power generator. From July 31st, 2015, the first power steel pipe is divided into two outlets to supply water for both generators in Shihmen power plant(Figure.2). The reconstructed generator sets have been back online in August 13rd, 2015. From now on, the second generator can be used as a redundant backup of the first generator set keeping the ability to supply both power and water at any time.



(a)

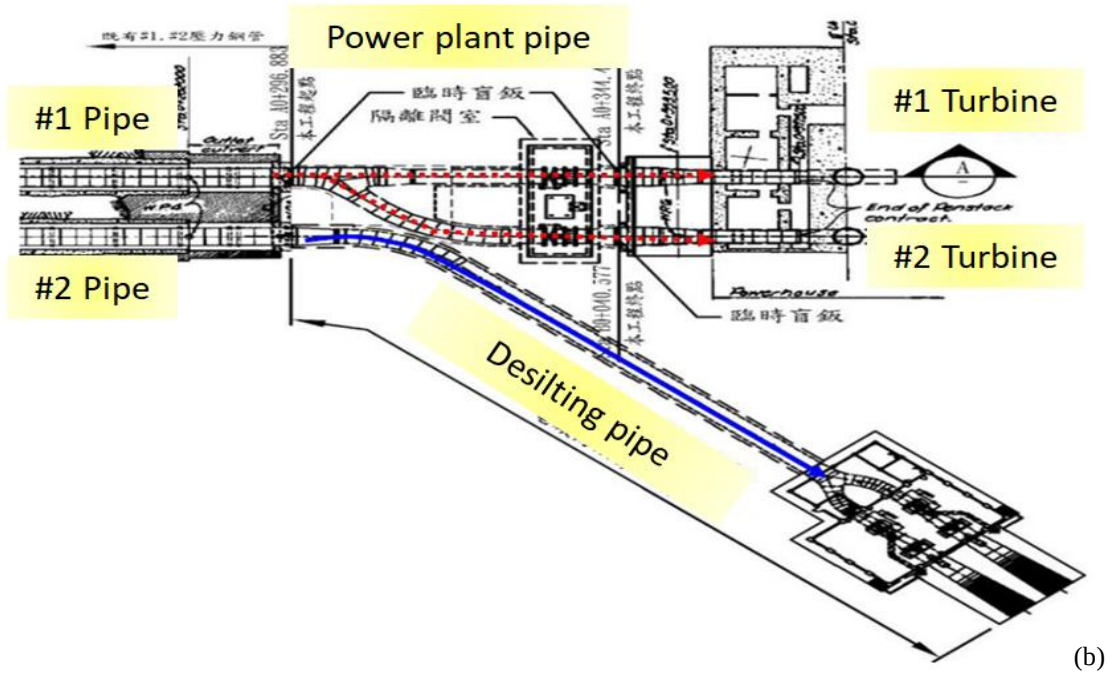


Figure. 2: Pictures of Desilting tunnel intake (a) position of desilting tunnel system (b) final design of desilting tunnel (including first and second-period construction)

2.3 Jhongjhuang artificial lake

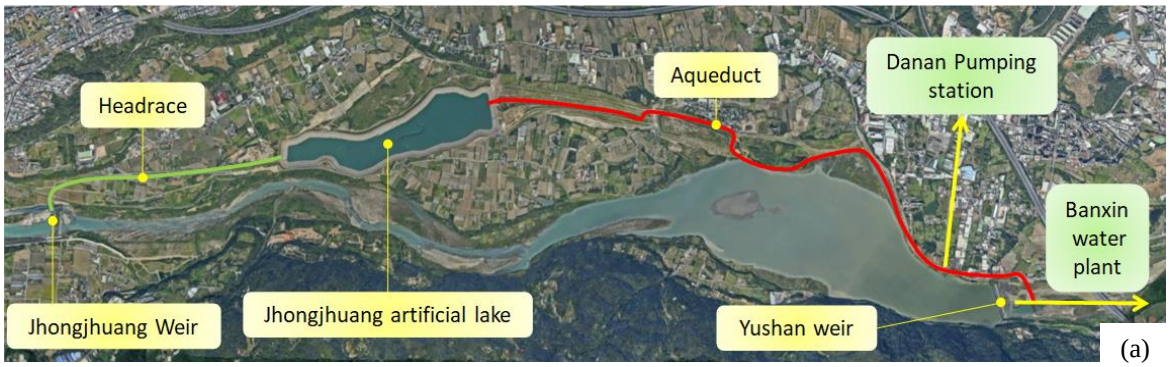
To thoroughly resolve the impacts of sediments on Shihmen reservoir during typhoon seasons, we must comprehensively consider the entire perspective of the water supply system in addition to Shihmen reservoir reconstruction works. Yuanshan weir located in Dahan river downstream 19km is responsible for water supply in Banxin and north Taoyuan districts. When Shihmen reservoir desilts during typhoon seasons (Figure.3(b)), the discharging density current flows into Yuanshan weir and causes the water suspension due to the increased water turbidity. To prevent the regional water supply from being affected by reservoir desilting, it is critical to look for the substitutional water source steadily supplying water with simultaneous desilting in Yuanshan weir and Shihmen reservoir.

The Northern Region Water Resources Office formerly planned to execute the project "Second Houchih" for Shihmen reservoir in order to utilize it as a redundant pool. However, after the consideration, the redundant water supply is not beneficial during typhoon seasons. Moreover, the problems of levying more private lands near the river course and connecting water pipelines to current systems still exist. Hence, we decided to discard the Second Houchih project.

After the investigation, there is a part of abandoned river course located in Yuanshan weir upstream close to Zhongliao island. The abandoned river course became a

wasteland and marsh due to little water inflow from Dahan river. Besides, owing to being left unused for a long time, it was illegally utilized by quarrying industry and the environment was severely damaged. If the abandoned river course could be reconstructed as an artificial lake, it is not only able to efficiently provide redundant water supply, but also improve the environment and be maintained by the government. Moreover, because the location is close to Yuanshan weir, the water pipelines have no issue connecting to Yuanshan weir. Therefore, this site was chosen to be developed into Jhongjuang artificial lake.

Jhongjuang artificial lake is the first high-turbidity redundant artificial lake. Located in the left bank of Dahan river and Shihmen reservoir Houchih downstream 12km (Figure.3(a)), Jhongjuang artificial lake diverts water from Dahan river through 1.7km water channel to the retention basin for water storage (Figure.3(c)). The former design of Jhongjuang weir is lying fixed weir. The weir height is 5m and the function of the weir is raising the water level for diversion. Yet, the severe water disaster caused by Typhoon Gloria in 1963 still haunts the local residents. The locals are worried about the former weir design and water channels would pose a threat to communities' safety. After the communication with the public, the fabridam was chosen as the design to resolve the doubts. The fabridam design is also able to increase the weir's flooding capacity and creates better ecosystems.




(b)


(c)

Figure. 3: Pictures of Jhongjhuang artificial lake (a) position of Jhongjhuang artificial lake (b) sand discharge from desilting tunnel outlet (c) Jhongjhuang weir

The artificial lake stores water in normal days and does not divert water during typhoons. When Shihmen reservoir desilts affecting Yuanshan weir's water supply due to high water turbidity, water from the artificial lake is transmitted to downstream water treatment plants through 4.8km water pipelines. Among all water treatment plants, the daily maximum water intake is 300 thousand tons for Danan water treatment plant and 500 thousand tons for Banxin water treatment plant. The effective capacity of the artificial lake is 5.05 million tons and it can be used as supplement water at least 7 days.

The part-cut part-fill way was chosen to construct the artificial lake. The lake bottom elevation is EL.53m, the dike top elevation is EL.70.5m, water storage depth is 15m, water area is 41 ha, and the length of border dike is 3,600m. To ensure the border dike can functionally block and store water, the design of artificial lake refers to embankment dam specification. According to geological conditions, the sections are categorized into 3 types (Figure.4). The plastic concrete cut-off wall (A-A) was established under the central clay clog due to two reasons. Firstly, because the left side of border dike faces the flow of exterior groundwater, the wall must be built to get rid of questionable groundwater. Secondly, the wall is built to excavate and embank for artificial lake in the dry condition. The length of such kind of border dike is 2070m, accounting for 57% of total border dike length. The original soil of Zhongliao island was utilized for the right side of border dike (C-C). We used a fine shell layer for leak prevention and the cutoff wall was not established.

The border dike main body construction of artificial lake was completed on 2017 March. It started to divert water and test storing water in May and had first full water storage on June 18th, 2017.

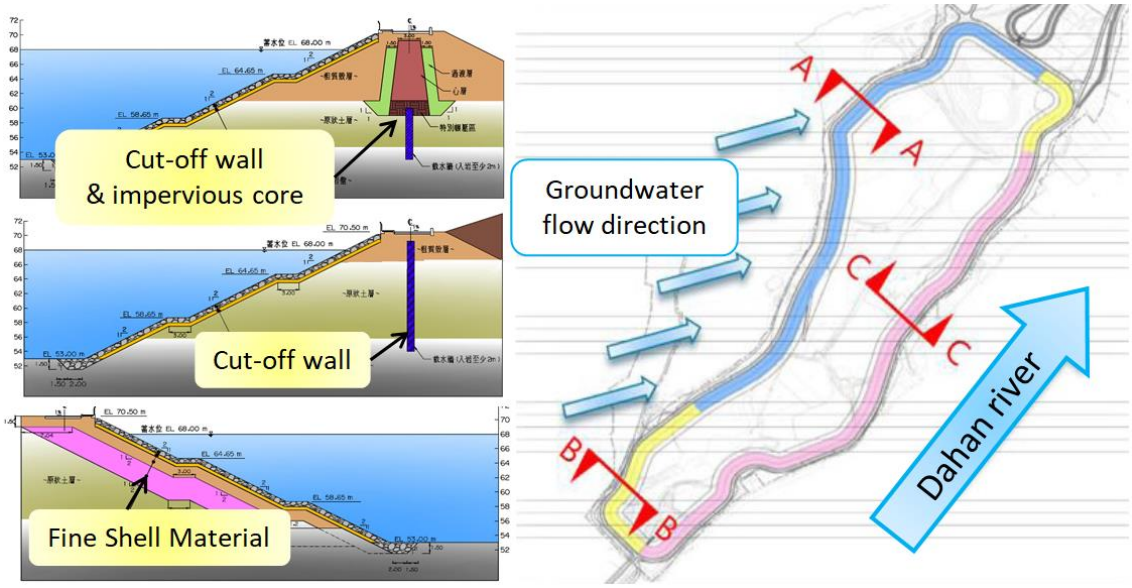


Figure. 4: Section types and layout of artificial lake dike

3 Conclusions

In the early stage of reservoir development and construction, Taiwan was limited by techniques and over-all situation. Taiwan received help from foreign groups for dam construction. Thus, the characteristics, such as frequent typhoons and fractal geological condition, were not well understood in the stage of design and planning during the construction processes. As a result, most reservoirs in Taiwan faces the challenges of high upstream erosion, high water turbidity, and silting issues. Shihmen reservoir is the first reservoir thoroughly redesigned and rebuilt during normal operation for silting management and sediment release control to improve the situation of high turbidity and silting issues caused by density flow in typhoon seasons, and, therefore, restoring the functionality of Shihmen reservoir. Furthermore, the power plant desilting project is the first project transforming electricity facilities into the desilting tunnel in Taiwan. The accumulated challenges and experiences of "Shihmen reservoir and its catchment area management project" can be considered as models for other reservoirs.

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