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Operation Planning of Desilting Tunnel at Shihmen Reservoir in Taiwan

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Abstract

Shihmen Reservoir is the main water resources facility in northern part of Taiwan, which has the multiple functions of irrigation, power generation, water supply, flood control and tourism. Through 55 years of operation since 1964, the most challenging issue of the reservoir is its severe siltation. For instance, the capacity of the reservoir decreases from $3.09\times10^8 m^3$ to $2.01\times10^8 m^3$, directly resulting in the reduction of storage of water supply capability. Recently, the frequency of heavy rainfall has increased due to global climate change. Therefore, it has become imperative to develop effective measures to enhance desilting and flood-discharging capabilities of the reservoir.

Accordingly, a desilting tunnel is under construction, whose intake structure is situated at Amuping area, 7 km upstream from the dam. After completion, the tunnel (L=3702m) could carry silt as well as coarse and fine sand outward to the outlet structure. The tunnel is expected to deal with $6.4\times10^5 m^3$ silt per year and enhance 600cms flood-discharging capability as well. In order to achieve these goals, dredge boats should be arranged upstream at section 26 to 28, and the desilting tunnel will be operated in the beginning of the flood-discharge process during the typhoon period.

Keywords: Desilting Tunnel, Shihmen Reservoir

1 General introctions

1.1 Project background

For Shihmen Reservoir, the dam impounds the water from Dahan River with the catchment area of 763.4 km^2 (Figure 1). Due to the climate change in previous decade, extreme hydrological events happened frequently, large amount of sediment is flushed into the reservoir. According to the annual sedimentation survey, the reservoir has been silted after each typhoon event(Figure 2) and average of $3.42\times10^6 m^3$ silt move into the reservoir every year. The capacity of the water conservation decreases from $3.09\times10^8 m^3$ to $2.01\times10^8 m^3$, which means only 65% of its original storage volume is remained.

Considering the strategies used to reduce sediment delivery or prevent sediment deposition, hydraulic desilting has been proven to be the most effective and economical method. Therefore, Water Resources Agency (WRA) planned to build a desilting tunnel for the Shihmen Reservoir. The basic design has been completed in 2017 and it’s under construction now. The project is expected to be completed in 2022.

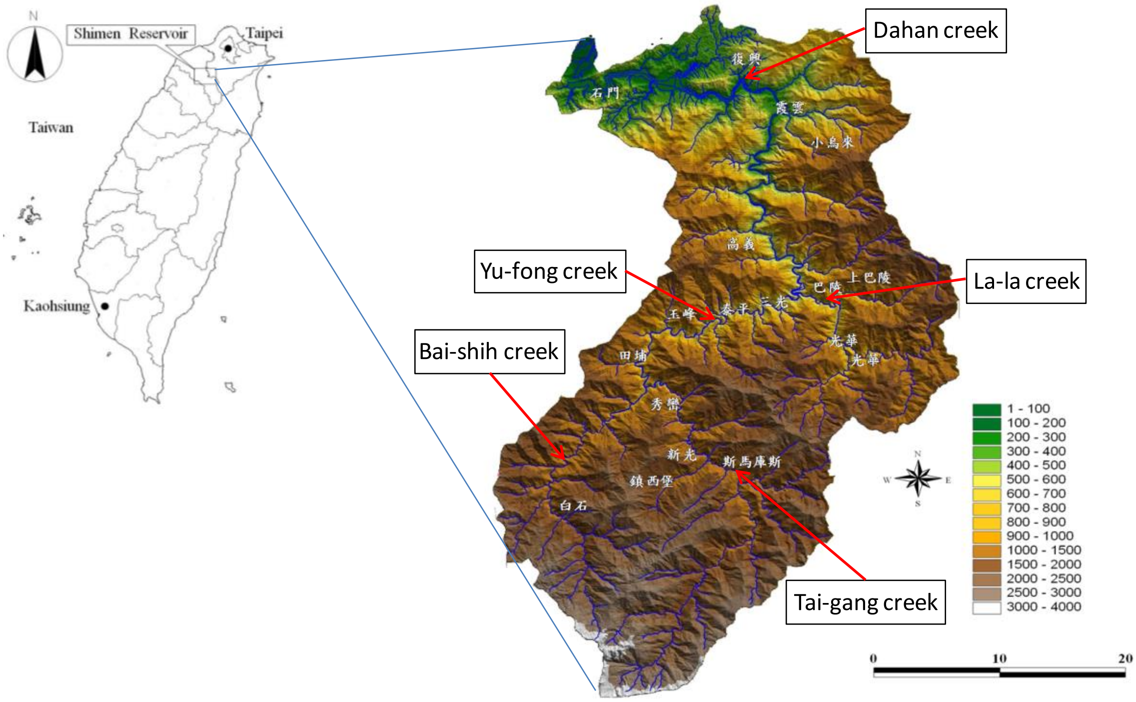

Figure 1: Location and catchment area of Shihmen Reservoir in Taiwan

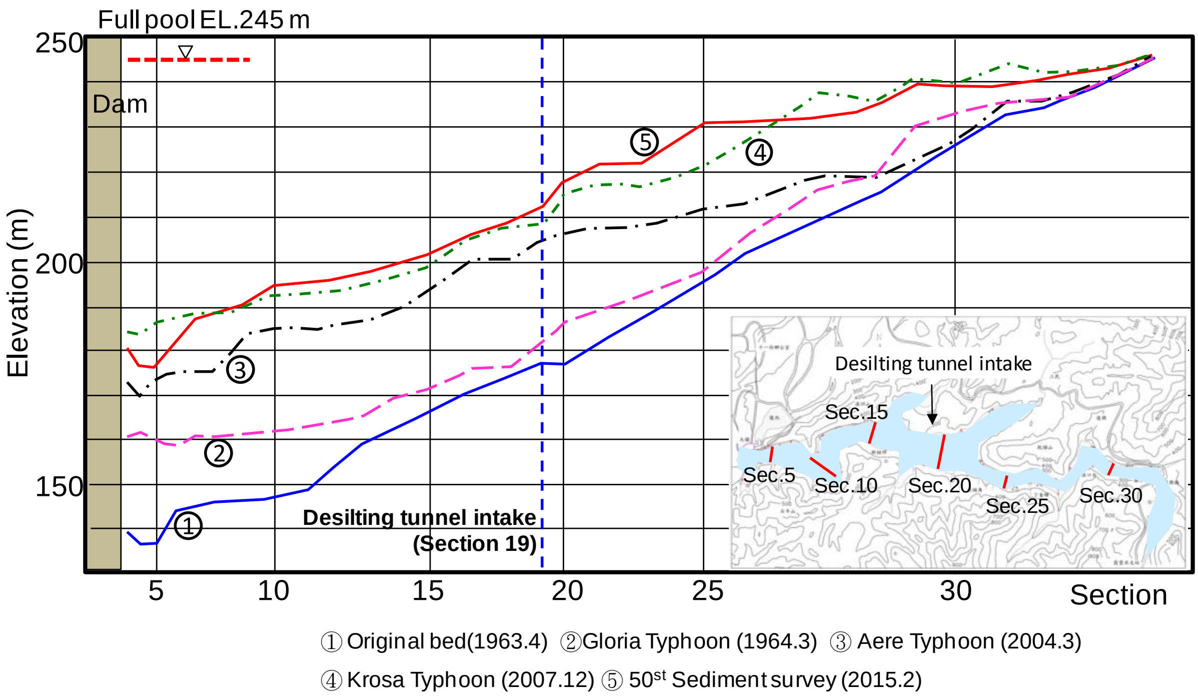

Figure 2: Sedimentation survey for the typhoon events

1.2 Objectives

Two major objectives arise from the desilting tunnel:

- To enhance the desilting capability and decrease sediment of the reservoir,
- To enhance the flood-discharging capability to ensure the safety while extreme hydrological events happened.

The desilting tunnel, which is a bypass tunnel of the reservoir, is expected to discharge $6.4 \times 10^5 m^3$ silt per year. Furthermore, the desilting tunnel is designed to provide another 600cms flood-discharging capability for Shihmen reservoir as well (Table 1).

Tab. 1: The comparison before and after the desilting tunnel completed

Item		*Now*	*After desilting tunnel completed*
Sediment discharge capacity	[10^3 m^3/yr]	2,070	2,710
Flood prevention capacity	[cms]	14,100	14,700

2 Strategies against sedimentation

A variety of sediment management techniques proposed by Kondolf et al. (2014) and a combination of several measures from the above categories is necessary to maintain reservoir capacity and achieve reservoir sustainability. In order to solve the problem of severe siltation at Shihmen Reservoir, WRA proposed an integrated desiltation strategies as shown in Figure 3.

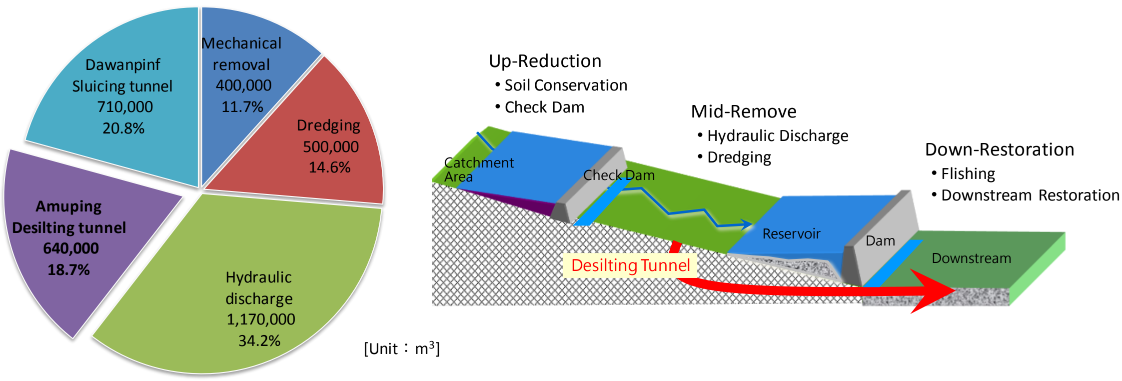

Figure 3: Integrated desiltation strategies for Shimen Reservoir

The desilting tunnel consists of the intake structure, adit, desilting tunnel, sifting facilities, outlet structure, and deposition pool. The intake structure is 80 m in length and is 7 km upstream far from the dam. The length of the desilting tunnel is about 3,702 m with a various slope from 10% to 2.863% (Figure 4). The typical cross section of the tunnel is 8 m in width and 7 m in height (Figure 5). For the requirement of maintenance and the usage during the construction period, an adit is designed for 306 m in length and connects to desilting tunnel.

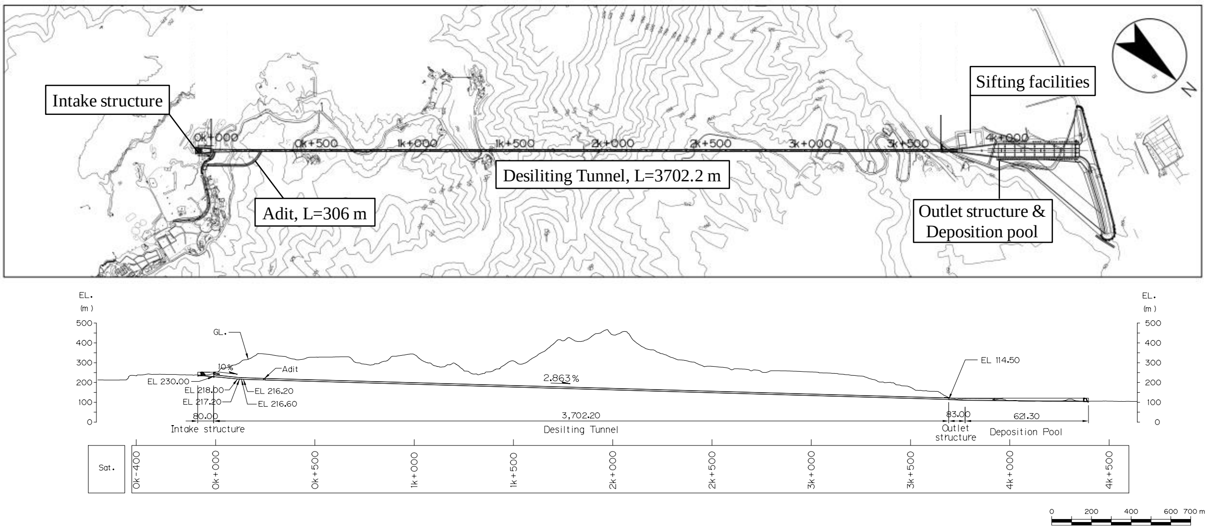

Figure 4: Plan view and profile of the desilting tunnel at Shihmen Reservoir

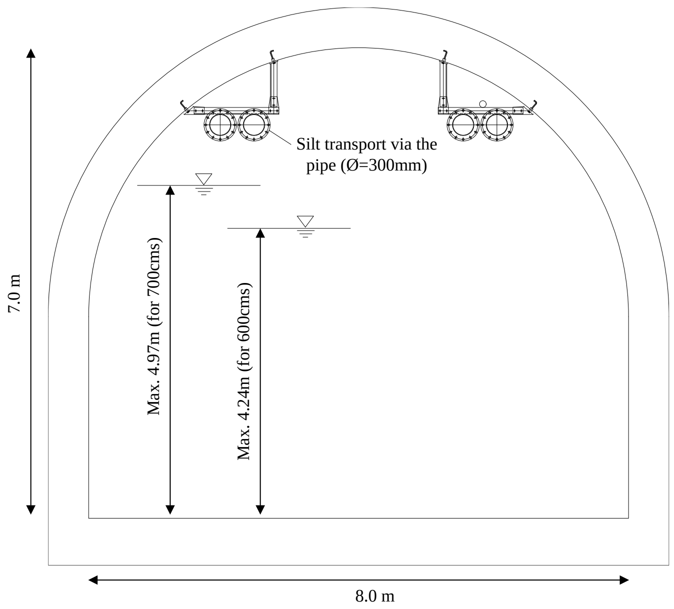

Figure 5: Typical cross section of the desilting tunnel

For the process of dealing with sediment, it is planned to dredge upstream, where the percentage of coarse sand (diameter≧0.1 mm) is over 50%. The silt will be transported via the pipe in the tunnel then be screened by sifting facilities at the exit of the tunnel. The coarse sand will be selected from the silt and be sold and reused. Besides, during the typhoon period, unnecessary water storage from the reservoir will be drained by the desilting tunnel, and the fine sand, which is stacked in the deposition pool, will be flushed toward downstream. Furthermore, the tunnel could be used as a temporary pass road and transport silt by trunk directly while drought period(Figure 6). Thus, the desilting tunnel not only solves the problem of sediment of the reservoir but also the problem of silt elimination.

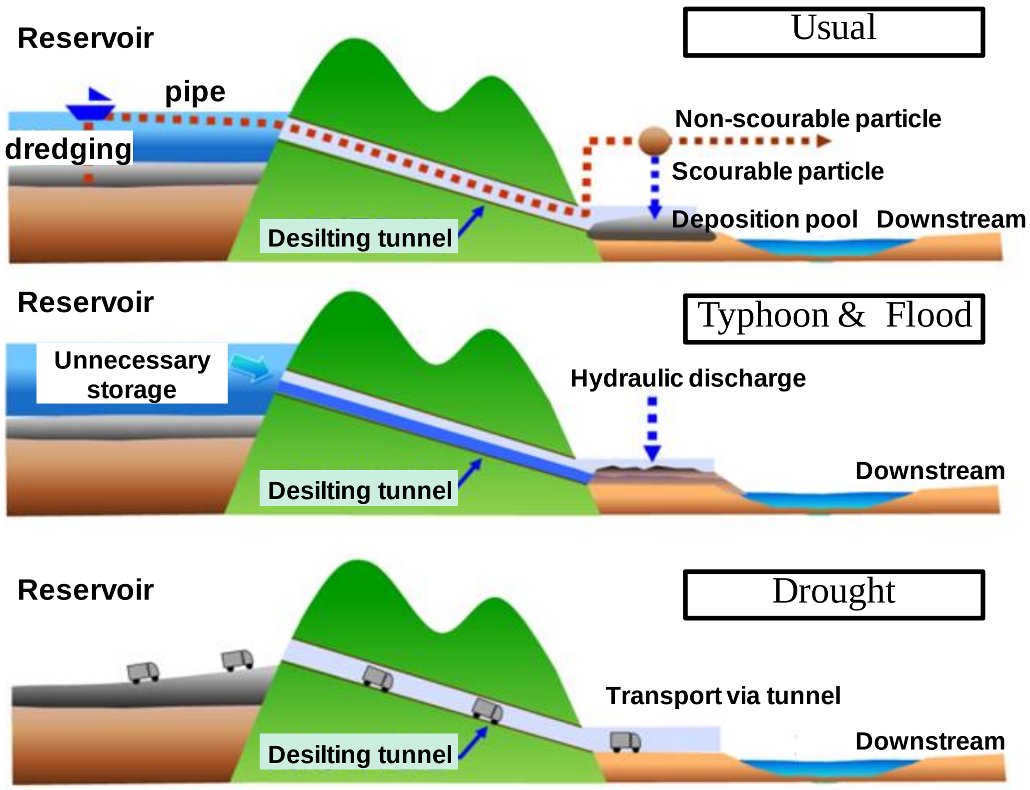

Figure 6: Multifunction of the desiltion tunnel at Shihmen Reservoir

3 Operation planning

3.1 Planning of dredging upstream

In order to achieve the goal of discharge $6.4 \times 10^5 m^3$ silt every year, it needs to arrange the dredging work and also consider about long-term water level, sediment data, typhoon data and discharge capacity of dredging boat. According to the water level during passed 10 years, the drough period is within February to June and the other is wet period. The water level, for Shihmen Reservoir, is higher than El.240m could expect over 200 days every year(Figure 7).

By the annul sedimentation survey, the elevation of river bed upstream (section 20 to 31) is between El.213m to El.243m. Assume that the dredging boats are arranged at section 26 to 28, and the minimum freeboard for the dredging work is 3.0m, so the boats can dredg wihle water level higher than El.233m at section 26 and El.237m at section 28.

According to the ‘‘Flexibility Assessment of Sediment Removal at Amuping Tunnel“ (Taiwan Construction Research Institute , 2014), the upper section we choose to dredg, the more coarse sand we can get from sediment. The percentages of coarse sand (diameter≧0.1 mm) are between 42.2% to 72.3% at section 26 to 28 (shown as Figure 8), so that the amount of coarse sand and fine sand can be calculated, and design the capacity of deposition pool as well.

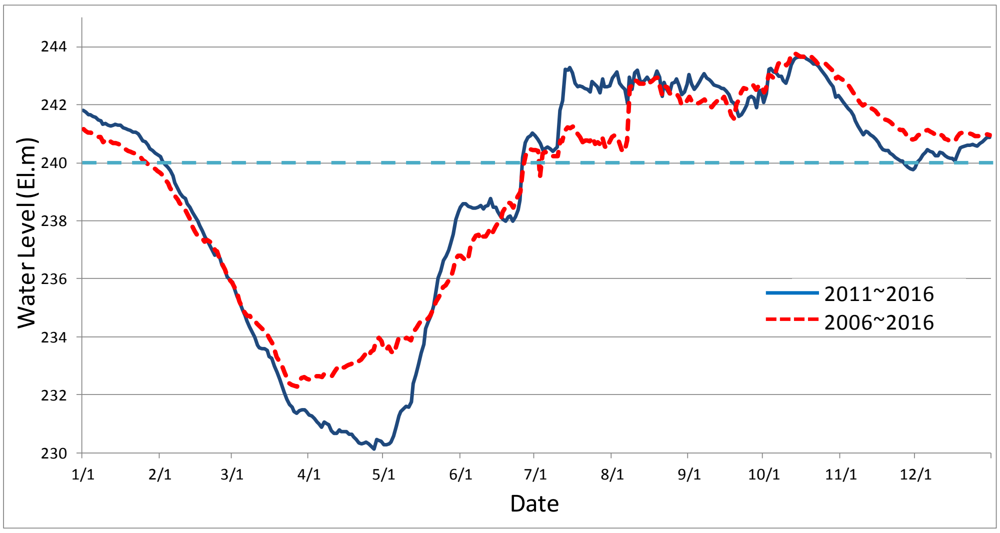

Figure 7: Water level of Shihmen Reservoir recently

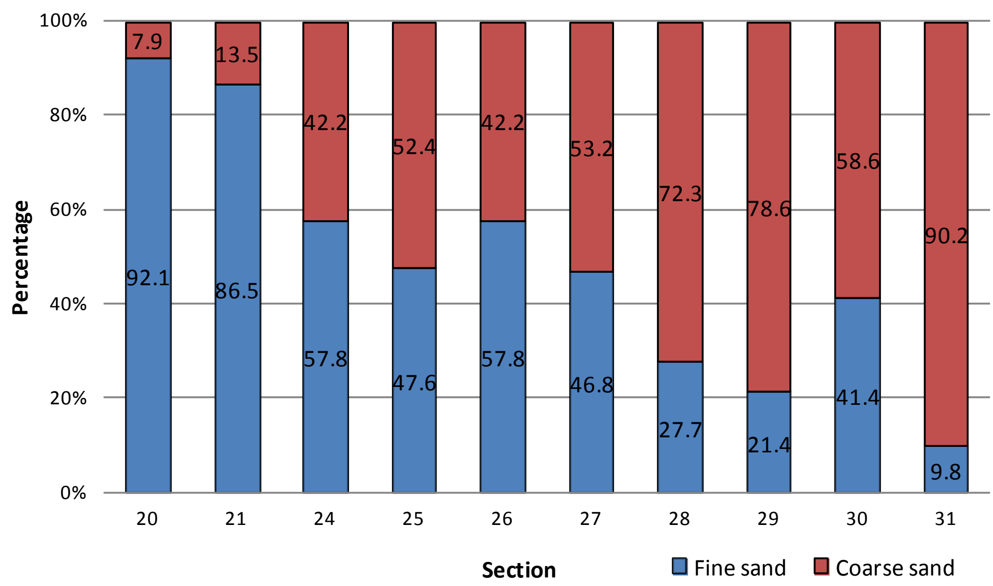

Figure 8: Percentages of coarse sand and fine sand at section 20 to 31 of Shihmen Reservoir

According to the annual dredging work for Shihmen Reservoir, it is estimated that the dredging capacity of each boat is 2,300 m^3 per day. Besides, the interval between each typhoon event is also a key factor. If two typhoon events are too close, then it will not have enough time to dredge and fill up the deposition pool. In contrast, if the interval of two typhoons is too long, then the fine sand will be no place to deposit because of the pool is fullfilled. Therefore, based on the typhoon events and also water level and sediment data, it is calaculated the amount of sediment discharge capacity for passed 10 years. The average of sediment discharge amount is about 6.7x$10^5$$m^3$ while two boats dredging at section 26 and 28, and the average amount can up to 7.4x$10^5$$m^3$ while two boats dredging at section 27 and 28. Both of these two arrangements can achieve our objective for discharge capacity.

3.2 Planning of desilting and flood-discharge operation

Recently, WRA reconstruct the penstock of the existing power plant as a hydraulic sluicing pipe for Shihmen Reservoir and operate during typhoon period from 2013. The ratio of desilting is about 33%~37%. After the desilting tunnel is completed, the tunnel will be the first piority to drain with 600cms and flush the siltation in deposition pool during the typhoon period. As the inflow increasing, the spillway and drainage tunnel will be operated to the purpose of flood-discharge. The desilting penstock will be operated then and discharge high density currents with 300cms at the bottom of the reservoir. The flood-discharge and desilting plan is shown as Figure 9.

Moreover, the Zhongzhuang Reservoir, which is 10 km downstream from the Shihmen dam and completed in 2017, regarded as an auxiliary reservoir to serve as water supply while Shihmen Reservoir discharges sediment. The water storage of the reservoir is about 5.06x10^6 m^3 and could provide 6 days water-supply for Banqiao and Xinzhuang districts of the New Taipei City.

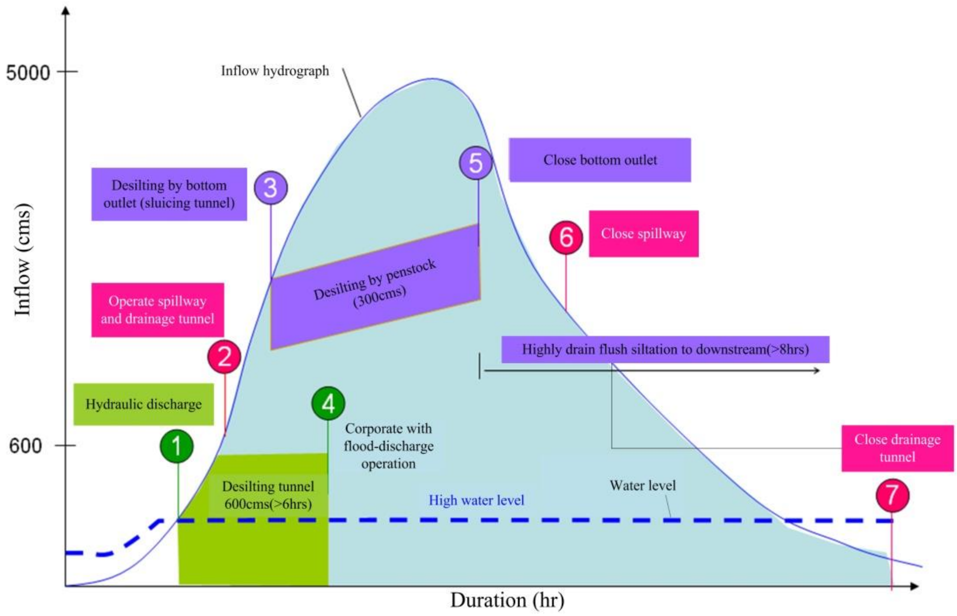

Figure 9: Flood-discharge and desilting operation of Shihmen Reservoir

3.3 Operation of deposition pool

According to the 1:40 scale model test, the deposition pool is designed with three open channels with 621 m in length and 20 m in width for each channel. The storage of deposition pool is 2x10^5 m^3 and some operation rules are as following:

- The elevation for siltation is El.114.5m and water level is El.116.0m, with 1.5m depth of water to avoid silt solidification.
- Three radial gates are closed while drought period and will be opened before the desilting process.
- The opening of the radial gates will be the same generally.
- The pool could be fulfilled rapidly by the dredging pipe from dam site or others.

4 Conclusions

Due to the climate change, extreme hydrology events have occurred frequently, large amount of sediment has been flushed into the Shihmen Reservoir. Taking effectiveness and economical efficiency into account, a desilting tunnel is under construction and is expected to deal with average 6.4×10^5 m^3 silt per year and provide 600 m^3/s flood-discharging capability.

In order to achieve the goals, it needs to take into consideration including long-term water level, sediment data, typhoon data and discharge capacity of dredging boat. Therefore, two dredging boats are needed and dredge at section 26 to 28. After the desilting tunnel is completed, the tunnel will be the first piority of the flood-discharge porcess and drain with 600cms and flush the siltation in deposition pool during the typhoon period.

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