CASE STUDY

BINGA, PHILIPPINES

Key project features

Name: Binga
Country: Philippines
Category: modify operating rule (focus or redistribute sediment); adaptive strategies
Reservoir volume (original): 95 Mm³
Installed capacity: 140 MW
Date of commissioning: 1960

Following commissioning in 1960, the Binga reservoir filled rapidly with sediment due to an underestimation of the sediment load and the absence of any sediment management strategy. When Binga hydropower plant was acquired by SN Aboitiz (SNAP) in 2008, it was not operational. Sediment management is crucial to maintaining the plant as a run-of-river project.

Binga hydropower plant, owned and operated by SN Aboitiz (SNAP) since 2008, is located in the upper reaches of the Agno river, on the island of Luzon in the northern Philippines. The plant was commissioned in 1960 with the purpose of generating electricity and providing flood control services.

Three dams in a cascade complex on the Agno river supply water to the 105 MW Ambuklao, the 140 MW Binga and the 345 MW San Roque hydropower plants. Binga dam, located 19 km downstream from Ambuklao, is a rock-fill dam with an inclined clay core. At a height of 107.4 m, the dam crest elevation is 586 masl, and the dam originally impounded a volume of 95 Mm³. The maximum and minimum operating levels of the reservoir are 575 and 566 masl respectively.

The spillway is located at the left abutment, while the intake is on the right side leading to the underground powerhouse through an 800 m headrace tunnel. The design spillway discharge for a return period of 10,000 years is 10,521 m³/s. A location map is shown in figure 1.

Following its refurbishment in 2013, the 140 MW Binga plant now hosts four Francis vertical shaft turbines of 35 MW each. The net head is 156 m and the design discharge is 25 m³/s. The average annual generation is 238.43 GWh.

Hydrology and sediment

The catchment tributary of the Binga dam comprises 936 km², of which 72 per cent is regulated by the Ambuklao dam upstream. Although the Ambuklao reservoir traps most of the sediment, the Binga tributaries, the Leboy, Adonot and Bisal Rivers, carry very high sediment loads. This is deposited in the upper section of the Binga delta, as shown by the white sediment deposits in figure 1.
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The Philippines is one of the countries most exposed to tropical storms. Approximately 20 cyclones and typhoons hit the country each year. They are concentrated in the months of June to September, but can occur throughout the year.

Due to its geographical location, the Philippines also suffers from high magnitude earthquakes. Since the middle of the 20th century, there have been eight earthquakes above 7 points in magnitude. In 1990, the island of Luzon experienced a 7.8 magnitude earthquake.

As shown in figure 2, the water inflow to the Binga reservoir has increased over the years, with the peak flow reaching up to 2,000 m³/s in 2017.

Sediment problems
Cyclones and typhoons cause major floods and landslides that increase water inflow and sediment load in the rivers. In combination with earthquakes, the sediment load in the rivers can be very high, and can contain heavy boulders that have the potential to seriously damage a power plant’s units. The annual observed sediment load through the turbines at Binga is 2.2 million tons, while at Ambuklao it is 4.5 million tons. Hard mineral concentration is not an issue because this represents just 10 per cent of the sediment load.

Based on a traditional approach, the Binga reservoir was designed without any sediment management strategy. In addition, the sedimentation rate was underestimated due to the limited sediment data available at the time. After commissioning in 1960, the Binga reservoir rapidly filled up with sediment as shown in the storage capacity-elevation curve displayed in figure 3. By 1986, the reservoir had lost 35 per cent of its original capacity. In 2015, the storage volume was just 21 Mm³, equivalent to 22 per cent of the original storage capacity.

In 2008, SNAP acquired both the Ambuklao and Binga power plants for USD 325 million. Both plants required major refurbishment due to the damaged hydro-mechanical equipment. The Binga power plant was not operational and the sediment deposits almost reached the intake level.

Due to the bathymetry of the Binga reservoir, the sediment has filled the dam and developed into a delta with a growing backwater effect, which could affect and bury the Ambuklao outlet. Figure 4 shows boulders and gravel in the backwater of the Binga reservoir.

An extreme precipitation event occurred in October 2009, following SNAP’s acquisition of the Ambuklao and Binga power plants. The peak inflow to the Binga reservoir reached 4,000 m³/s. Figure 5 shows the water inflow to the

Aerial view of Binga hydropower plant

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Ambuklao and Binga reservoirs due to the extreme flood.

This extreme flooding clogged up the waterways, and sediment deposits trapped in the Binga dam increased. The loss of storage limited Binga’s operational flexibility and therefore reduced the plant’s revenue. In the case of Ambuklao, the power plant had to shut down. A total of USD 280 million was required to rehabilitate both the Ambuklao and Binga plants, between 2010 and 2013.

Sediment management strategies
Since the acquisition and refurbishment of Binga, the implementation of sediment management strategies is key to keeping the plant operational in the long term. Due to the high rate of storage loss, the stabilisation of sediment inflow and outflow is crucial for operating Binga as a run-of-river project.

Any alternative approach to managing sediment requires changes in the operating rule of the flood gates. The operating rule, shown in figure 6, is based on the water level and does not include sediment routing during flood events greater than 500 m³/s.

Ongoing studies are looking at technically-feasible solutions to convert Binga into a run-of-river power plant. The proposed sediment management strategies will have to meet the following objectives:
- protect the intake from deposition and slide;
- trap the suspended load during normal flood season operation;
- flush deposited suspended load during floods;
- provide passage of incoming bed load during floods;
- maintain small reservoir for peaking/ancillary services;
- maintain ability to delay and dampen flood peak; and
- maintain dam safety and the integrity of the spillway.

A significant sediment management challenge is the high risk of clogging the current Binga intake, with an invert elevation of 555 masl. The longitudinal profile in figure 7 shows that sediment deposits are reaching that level.

Other challenges include maintaining the existing storage volume, avoiding backwater effect, the burying of the Ambuklao outlet, and maintaining dam safety when the bed load passes over the spillway to the downstream river reach.

Physical model studies include several sediment routing options and intake-level modifications to find a technically feasible solution and acceptable and implementable operational regime, which would provide for a reliable run-of-river operation in the long term.

Conclusions
Sediment management considerations are fundamental during the initial concept/design phase when building dams and hydropower plants. Without them, sediment is deposited in reservoirs, minimising a plant’s benefits, shortening its operational life, damaging the hydro-mechanical equipment and eventually losing sites for power generation and other benefits.

Monitoring and gathering sediment data taking account of the impact of natural disasters such as earthquakes and typhoons into the design is key to planning adequate sediment management strategies.

The annual cost of the research on sediment and sediment management at Binga is estimated to be around 2.5 per cent of the annual operation and maintenance costs, which are estimated at USD 2 million. Raising awareness of the benefits of regular monitoring and sediment management strategies in the operation and maintenance of a power plant could lead to an increase in the resources dedicated to sediment management.
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Graphs and figures

Figure 1 - Binga hydropower plant location downstream of Ambuklao dam (Google Earth)

Figure 2 - annual water inflow to Binga reservoir
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Figure 3 - storage capacity (Mm³) and elevation (masl) curve of Binga reservoir from 1960 to 2015

Figure 4 - sediment deposits in the backwater of Binga reservoir

Graphs and figures cont. >
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Figure 5 - water inflow to Ambuklao and Binga reservoir during the extreme flood of 2009

Figure 6 - flood rule curve for Binga dam - reservoir water level based operation
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Figure 7 - Longitudinal profile of Binga reservoir; the intake invert elevation is 555