

AFOBAKA HPP & BROKOPONDO RESERVOIR

Review of the Hydraulic Reservoir Operation from January to May 2022



Document no. Rev 1: 419011-00060-CI-REP-0001
19 July 2022

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PROJECT 419011-00060 – Afobaka HPP & Brokopondo Reservoir
Review of the Hydraulic Reservoir Operation from January to May 2022

Rev	Description	Originator	Reviewer	Worley Approver	Revision Date	Customer Approver	Approval Date
Rev 0	1 st Emission	LA	MFM	GSCR	15/06/2022		
Rev 1	Comments from Customer	LA	MFM	GSCR	19/07/2022		

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1. INTRODUCTION

Energie Autoriteit Suriname (“EAS”) has approached Worley to provide a cold eye review of the recent operation of the Brokopondo Reservoir performed by SPCS (Staatsolie Power Company Suriname) between January 2022 and May 2022.

Worley team has extensive experience with hydropower plants and reservoir operations in Latin America, which includes relevant direct experience with Afobaka Hydropower Plant and Brokopondo Reservoir, having study a few projects, since 2001, which involved this asset, both for Alcoa/Suralco as well as for Staatsolie.

So, Worley team is in good position to provide an independent review of the Brokopondo Reservoir operation of the last few months.

1.1 Objectives

The objective of this document is to present the results of an independent review of the Brokopondo Reservoir hydraulic operation by SPCS’s O&M (operations and maintenance) team, during the first five months of the year 2022 (until May 24th, 2022).

Additionally, Worley shall provide opinion on the operation adequacy, on potential issues and recommend some actions for improvement in the future.

This review was requested, as some of the total discharges from Afobaka HPP, caused floods and damage to some areas downstream of the dam.

1.2 Data Used in This Review

AES, though SPCS, has provide Worley with the following data:

- Excel file “2022_Spill_May”;
- Excel file “Lake Elevation 2022_April”;
- Excel file “SPCS-Afobaka Lake Elevation Readings on Hourly Bases_2022”;
- Excel “Hydro - Pizeta data - May 24 2022”;
- Excel “Hydro Shift Log 04-27-2022_Crew4_B shift”;
- Excel “NH_kwh_daily”;and a
- Power Point file “Afobaka Levels V4”.

Besides this data, Worley also used its knowledge about Afobaka HPP and Brokopondo Reservoir to facilitate the review, including operational limits, such as reservoir levels, rule curve, etc. Worley also used long term hydrological data for the Suriname River at Afobaka Dam, to support this review.

However, it is important to highlight that Worley team did not get any information and did not interact with any of the operators of the plant about the decision process of the spillway operation, allowing for a more independent review of the facts.

2. RESULTS OF THE REVIEW

As an initial consideration, it is important to point out that Brokopondo reservoir has always had a target level rule curve, to help guide the decisions on the operation of the reservoir, which is more focused on power generation, but also taking into considerations dam safety aspects. The rule curve is just an indicative tool to support the decision related to power generation. When reservoir is above the rule curve, if possible, operation should dispatch all the power capacity. When below, the rule curve, power generation should be restricted, to the extent possible. In no way it indicates when to start spilling, even if the reservoir water level is significantly above the rule curve.

It is also important to point out that as hydrology forecast is very difficult to make, it is a normal procedure used by many hydropower plants operators to consider the more frequent scenarios for decision making on the reservoir management. At the same time, when more drastic and uncommon inflow conditions occur, in particular of large inflows, reservoir operators normally and advisably need to assume a more conservative position in terms of the flood management and dam safety precautions, including assuming that the situation may be prolonged.

Before addressing the spills and its consequences, it is important to assess the inflow conditions prior and during the spill events, associated with the reservoir level.

In the 2022 first five months, Suriname River experienced above the average inflows, recording the highest flows in the 57 years of records for the period between Jan and April, resulting in inflows which were 284% higher than the long-term average for this period. These high inflows are likely associated with the La Niña meteorological event that has been registered in this period. It should also be noted that five (05) of the ten (10) largest floods of the Suriname River occurred in La Niña year.

It is important to point out that this definition of 2022 being a La Niña year was not available to SPCS, nor to the wider public, when they were making the decision about the spills at Afobaka, and such high inflows were not foreseen when they started to open the spillways. The projections SPCS had at the time was that April and May would have an average behavior, but, the actual rainfall and inflows were much higher than average, which was acknowledged by the meteorological agencies in early May, when they informed that 2022 was under the effect of La Niña phenomenon, as informed to Worley by SPCS.

Such flows could not be managed alone with the generation of power and the spillway was used to control the reservoir level, which was operating between 5 and 10 feet above the rule curve, between January and April 2022, reaching the Maximum Normal Water Level of the Brokopondo Reservoir in Mid-March/2022. The operations started in January 2022 about 6 feet above the rule curve. This is a normal and acceptable condition, and even expected, considering that 2021 was a year of above the average inflows. Worley agrees that at that point there was no indication of any need to start spilling water, as there was enough buffer in the reservoir to accommodate the more frequent high inflows expected for the period.

As a result of the reservoir operation and the spills made, during some periods, the Suriname river water level raised and caused floods and damage downstream of the Afobaka Hydropower Plant. The data concerning flood damages downstream and/or upstream the Brokopondo reservoir, for the period 01/03/2022 to 21/05/2022, were made available in the Excel "2022_Spill_May" sheet "spill_plan_22Mar01", and can be summarized as described below:

- No problems are pointed out for the upstream section of Pokigrón.
- Generally, above 128.2 feet tailrace (30400 cfs), villages downstream will notice water (see Cel U89 sheet "spill_plan_22Mar01" of the Excel file).
- In 01/03/2022 four (4) spill gates were opened producing a total outflow of 35166 cfs, and resulted in complaints about shore flooded and plots (Kostgrond) (Klaaskreek, Victoria, Asigrón).
- From 02/03/2022 to 12/04/2022) the total outflows were between 25000 e 35000 cfs and no major complaints from the community were notified.
- From 13/04/2022 to 02/05/2022 the total outflows were between 40000 and 48000 cfs and Villages close to the dam are flooded at the lower sections close to the shore (10-15 cm of water) and recreational facilities close to the dam received drainage backpressure from High level of the Suriname river
- From 03/05/2022 to 21/05/2022 the total outflows were between 52000 e 58000 cfs and Villages close to the dam are flooded at the lower sections close to the shore and recreational facilities close to the dam received drainage backpressure from High level of the Suriname river

According to these data no important damages has been occurred downstream due to the reservoir total outflows. The same for the reservoir levels and its effects upstream, near Pokigrón.

In consequence it is important to highlight two main conclusions about the outflows:

- Total outflows until 35000 cfs could be considered in the Afobaka HPP operation during the large flood periods. No major complaints from the community were expected.
- For Total outflows from 40000 and 58000 cfs some Villages close to the dam will be flooded at the lower sections close to the shore and recreational facilities close to the dam will receive drainage backpressure from High level of the Suriname river
- It is reasonable to expect, that from time to time, outflows above 35000 cfs will occur downstream of Afobaka, as the hydrology seasonality and variability would indicate that this situation is not uncommon. So, it is important to be prepared to deal with this situation.
- Ideally, it should be avoided any permanent occupation in the areas near the river at low levels, which can be considered the large riverbed for floods.

Another aspect analysed in this review was the rule/procedure to open the spill gates. Normally reservoirs only start to spill when they reach its maximum normal water level, which in the case of Brokopondo is at elevation 264 feet.

However, as it is shown in the Figure 01, in the 2022 flood operation the total outflow was raised, with the help of the spillway, from 15000 cfs to 25000 cfs (see 01/03/2022 to 03/03/2022 data) when the Reservoir Water Level was at 261,25 feet, almost 03 feet below the Maximum Normal of 264,00 feet. From what we can see, this decision was made as inflows were really high and the reservoir level was significantly higher than the rule curve, so it was an attempt to try to shave the peak of the flood, minimizing the impacts downstream.

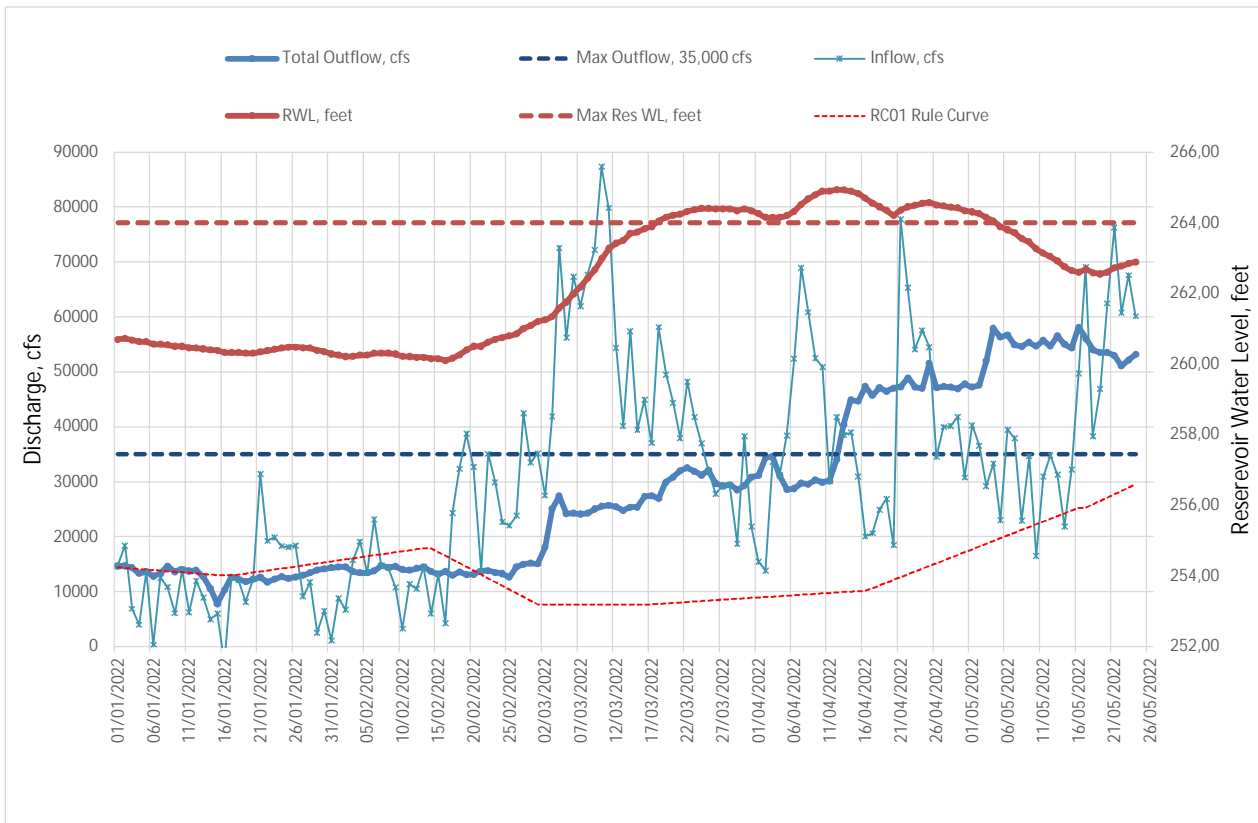


Figure 01 – Afobaka HPP - Brokopondo Reservoir -RWL & Total Outflow – 2022, January 01 to May 24

Thus, preventively, an outflow has already been adopted that it was known would not bring problems downstream and that, of course, would be reducing the accumulations in the reservoir. So, in fact this operation helped minimize impacts downstream.

From 03/03/2022 to 11/04/2022 the total outflow was equal 28500 cfs, lower than the 35000 cfs that could be maintained without causing damage downstream. Again, this operation helped minimize impacts downstream, by delaying the reservoir to reach its maximum normal water level, what could potentially had avoided any impacts to downstream population. Then, on 18/03/2022 the reservoir Maximum Normal level of 264,00 feet was reached/exceeded, which had to lead to a further increase in discharges downstream.

So, as expected, to avoid the continuation of the increase in the Reservoir Water Level, and guarantee the dam safety, the outflows were raised again to 47000 cfs in the period 12 Apr to 02 May. This action was able to invert the tendency of reservoir fill-up to reduce the Reservoir Water Level, that reached up to 265 feet, and came back to 264 feet (maximum normal WL).

However, from May 4th onward, the outflows were increased again, reaching an average of 55000 cfs. So, the Reservoir Water Level continued to decline, reaching 262,55 feet on May 19, 2022, close to 1,5 feet below the maximum normal of 264,00 feet. However, on May 20th, the reservoir started to fill-up again as inflows raised to more than 50000 cfs. Our view of this decision was that the plant operation team were trying to create some live storage volume at the reservoir, to be able to shave the peak of floods of the incoming rainy season, with minimum additional impacts to downstream population, to what they were already experiencing in the previous period. The decision could also be based on other information available to the

SPCS O&M team and on their experience, that the flood would continue and could also be more severe, but Worley has no information or data that can confirm this scenario.

Considering the information available to Worley, and the experience of the review team, our assessment of the spill operation is the following:

- SPCS operation team did a good job to start early spills limited to a total outflow that would not cause issues downstream, to minimize the risk of having to discharge larger flows, assuming the risk of “loosing” some water that could be used to generate power, if the inflows would have reduced after this decision.
- As the large inflows continued to arrive the reservoir, the reservoir reached and surpassed the reservoir maximum normal WL, which led the plant operation team to correctly raise again the outflows, limiting the raise in WL to 1 foot above the maximum normal WL and bringing it back to it.
- However, once the level returned to the maximum normal WL and inflows reduced to 30000 cfs, the plant operation team decided to raise the outflow once again. This operation was not the expected one by Worley team, and although it resulted in the creation of some good live storage capacity to allow some additional flood routing in future floods, it also raised the level of impacts from the outflows as this new value raised some more the downstream level. A few considerations about this needs to be made:
 - The last week of the period under evaluation (third week of May), already shows new high inflow values, that shows the importance of having some live storage capacity to rout the flood resulting in a reduction of the maximum outflow at the dam. If operators had this visibility that this was a probable scenario, it shows the importance of having increased the outflow and adding live storage capacity in the reservoir.
 - The increase from 48000 cfs to 55000 cfs apparently did not cause damage to additional areas, just some additional impacts to the areas already flooded. If this is the case, then the decision made by SPCS operation team was very acceptable, with the clear intent of preventing the need to have even higher outflows, that could cause damages to extended areas, through the creation of live storage volume availability for potentially incoming floods.
 - However, our expected operation would be to maintain the same level of outflow, of about 48000 cfs, which would still allow for the creation of some flood routing storage volume in the reservoir but would limit the impacts downstream to the same level as before.
 - Worley agrees that they should not have reduced the outflow back to 35000 cfs, as this could briefly improve the situation, but would almost certainly need to be raised again not adding any value.
 - Finally, the decision of keeping the outflow at 55000 cfs up to the point of the data available to Worley was correct once it was already raised to it and as inflows are still higher than outflows.

Finally, it is important to highlight another observation:

- The operating team must have a properly documented Flood Operation Procedures Manual and the team must be trained on it. This manual must establish the Normal Maximum Water Level of the Reservoir for the flood situation, the upstream and downstream restrictions, the decision hierarchy, the actors who must participate in the decision-making about the total outflows, the public communication about the actions to be taken and other topics. Worley is not aware if such procedure is in place or not, but even if it is, it would be advisable to revisit it and also bring clarity about it to the general public, in particular to the main stakeholders which it relates to.

3. CONCLUSIONS

Worley understands that the operational procedure decided by the SPCS Afobaka O&M team was acceptable given the following conditions:

- The inflows that occurred previously and during the spill event were significantly higher than average, probably due to the La Niña meteorological event recorded in this period. However, it is important to point out that most likely, this information about the La Niña event was not available to SPCS team during the time of the events under review.
- The level of impact downstream and upstream of the reservoir was very limited, as per the data made available to Worley.
- Entering the rainy season with the reservoir in its maximum level, especially on a La Niña year, raises a lot the risk of much higher flood damages occurring upstream and downstream of the Afobaka Dam, as no storage capacity would be left to shave the peak floods that could come, resulting in much higher outflows and reservoir levels above the normal water level, that can cause impacts upstream and downstream.
- *Normally spill operations are started when the maximum reservoir level is reached. In the Afobaka case this would be 264 feet. We observed that SPCS Afobaka operations team started the spill operations (at outflows that it was foreseen not to cause floods downstream) at 261,25 feet, within the calendar small dry season in Suriname. This decision was made when it was observed abnormally high inflows for that time of the year. In our opinion this decision demonstrates prudent practice, anticipating on the normally high inflows to be expected in the calendar big rainy season that starts in the month of May in Suriname. We understand that the objective was to create sufficient buffer capacity to shave peak inflows in the rainy season, and it proved as a good measure as very high inflows continued to be observed until May 2022, which is the end of this review period.*
- Not addressing the issue when it occurs, hoping that hydrology can be favorable in the future is a very risky situation and not advisable at all, both from a flood management as well as dam safety perspective. So, taking action is the most important behavior, and based on the information provided for this review, SPCS Afobaka operation team did not fail to make tough decisions and actions when they understood it was necessary.

To conclude, Worley believes that it would be beneficial to SPCS Afobaka operation team, as well as to all surrounding communities and stakeholders, to implement or review a solid procedure (Manual) for the operation and management of the Brokopondo Reservoir water level and Afobaka Spillway, defining not only the decision process for raising or lowering the reservoir level, but also for identifying and communicating with stakeholders and communities and defining actions to minimize the impacts of eventual situations that could cause floods either upstream or downstream of the dam. If such manual is not available or existing, Worley recommends that one is created, which will bring clarity, comfort and protection to the plant operation, operators, managers and to Staatsolie.

Worley would also recommend that the large riverbed or flood areas of the Suriname River should not have any permanent occupation, as from time to time, even with proper reservoir management, the natural inflows of the Suriname river shall cause the need for large discharges at Afobaka HPP. So, by preventing this area to be occupied, no significant damage shall occur when such natural flood events take place.