The Effectiveness of Desilting the Pulangi IV Hydropower Plant's Reservoir

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Introduction

The Pulangi IV Hydropower Plant's Reservoir (the "Pulangui IV Reservoir") is experiencing accelerated sedimentation and thus it is in danger of filling-up with sediments unless drastic engineering intervention measures are employed. In particular, the original storage capacity of the Reservoir in 1985 of about 70.37 MCM has been reduced by at least 23 MCM of sediment accumulation. This translates into a reduction in reservoir capacity of as much as 30 percent. Prolonging the life of this reservoir would require proper sediment management and control strategy.

The control of reservoir sedimentation may be accomplished by: 1) controlling the sediment yield from watersheds into reservoirs by erosion control and sediment traps; 2) mechanical removal of sediment by dredging; and 3) reservoir operations by letting high sediment-laden inflows pass through the reservoir (desilting sluiceway) with minimized deposition, or flushing out previously deposited sediments (Fan and Morris, 1992). NPC management is very concern on the danger of sediment intrusion in the Pulangui IV Reservoir. There are a lot of offers coming from private contractors offering their services on how to mitigate the effect of sedimentation. The more serious of it came from a very big contractor whose experience in off-shore dredging in the Philippines is without question. However, the offer involves a huge amount of investment. It is for this reason that NPC management takes a serious thought of examining the possibility of hiring an expert in order to study the nature of the sediment deposits scattered within the Pulangui IV Reservoir. The study aims to develop the best alternative scheme on how to mitigate the effects of sedimentation in the most economical option.

Capital investment as huge as the proposed rehabilitation of the Pulangui IV Reservoir requires governmental approval prior to its implementation. The approval of the project depends on the economic viability of the chosen alternative and has to be justified. The estimated silt deposit that had accumulated at the Pulangui IV Reservoir is approximately 23 to 26 million cubic meters and removal of such a huge amount of sediments thru dredging in order to restore the reservoir to its original storage capacity will not be technically viable and likewise financially and economically not feasible. However, the current level of silt deposits had already reached critical level and therefore rehabilitation is needed in order to prolong the economic and viable operating life of Pulangi IV Hydroelectric Plant.

Description of Pulangui IV Hydroelectric Plant

The Pulangi IV Hydroelectric Power Plant (the "Pulangui IV HEP") is located at Kiuntod, Camp I, Maramag, Bukidnon in Central Mindanao, Philippines. It is accessible thru some 150 kilometers of well-paved road from Cagayan de Oro City or thru an alternate route from Davao City, which has a distance of about 142 kilometers.

The plant began its commercial operation in 1986 with a total rated capacity of 255 MW (3 x 85 MW). Primarily, it features the upper and lower reservoirs, diversion dam, concrete spillway, headworks, headrace canal, surge pool, power intake, penstocks, powerhouse building, tailrace channel, 138 kV transmission line, switchyard and administration building (see **Figure 1** Pulangui IV HEP Configuration).

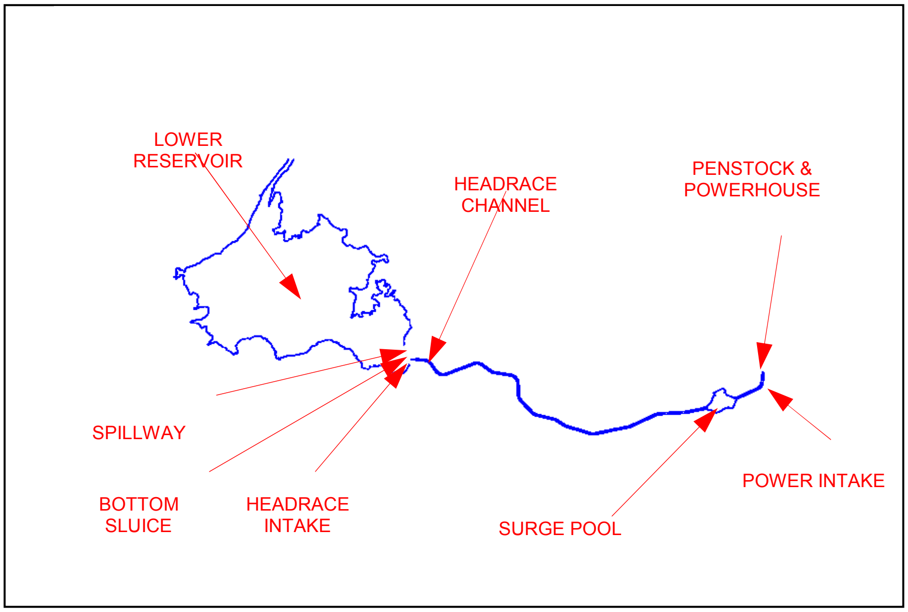

Figure 1. Pulangui IV HEP Configuration

The reservoir's upper and lower pondages cover an area of approximately 1,951 hectares with a designed live storage of 67 million cubic meters. Since its commercial operation, however, the reservoir had never been cleaned-up resulting to the accumulation of silt, sand, gravel, boulders and other debris thus significantly reducing the water storage capacity of the lower reservoir and converted the upper reservoir to a virtual river stream.

Pulangi IV HEP plays a major role in the stability of the supply in the Mindanao Grid. It can operate at base load, peak load and more importantly as an ancillary provider. In 1997, the Pulangi IV HE Plant faced the drastic effects of an El Nino event. During this year, minimum operating levels hit as low as 278 masl crippling plant operations resulting to Gross Generation figures of 944,757 MWH in 1997 and further dropping to 699,819.00 MWH in 1998. Coupled with the effects of the accumulation of sediments near the headrace area, the operation was further aggravated. Historically, during normal years of operation the plant is generating an average annual energy of 956 Gwh. **Figure 2** shows the historical generation of the Pulangui IV HEP.

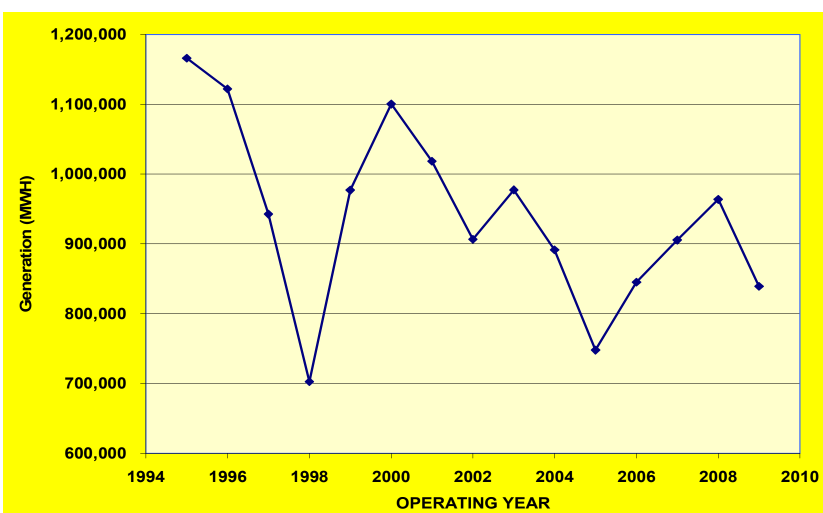

Figure 2. Gross Generation Figures from 1995-2009 (in MWH)

Beginning in 2003, cognizant of the sedimentation problem, NPC tried to identify an effective measure to prevent the reservoir and its associated waterways from further deterioration. Options has been studied, however, this should be supported by a detailed study that will determine the most appropriate measure to mitigate the effect of the sedimentation.

Reservoir Sedimentation Study

In the year 2004 NPC decided to commence the sedimentation study with the objective of, among others, identifying the most economical solution to alleviate the problem threatening the operation of Pulangi IV HEP. The study focuses on the type of control that involves control by flushing of sediments through reservoir operations with the aid of mechanical removal of sediments or dredging. In the dredging case, staging or sequencing in time and space of the dredging operations is investigated in combination with the sediment flushing operations. It is believed that sediment flushing operations is a more economical and long-term sediment control strategy, however, initially and perhaps occasionally in the future, dredging operations may be needed.

Another aspect in the flushing and control of sediment through reservoir operations is that it usually requires the release of large amount of water from the reservoir compromising future water supply. This is especially the case with small or medium size reservoirs with seasonal inflows. These different reservoir operation policies may be either complimentary or conflicting among the various purposes of the reservoir. A complimentary case is the allocation of flood control space before the flood season and routing of floods with high sediment concentrations. It is observed that sediment concentrations tend to be highest at the rising limb of floods. Thus, if reservoir levels are low (when flood control space is allocated), flood flows associated with high sediments can be passed through the reservoir through its desilting sluiceway (rather than the spillway) with minimum sediment deposition.

Due to the variability and probabilistic characteristics of natural inflows to the reservoir, the resulting reservoir storages and the actual reservoir flow releases to satisfy the various water demands cannot always be known with certainty. Likewise, the amount of sediment removed from flushing or the amount of sediment deposited cannot be ascertained whatever control strategy is used. Although reservoir operation rules allow a certain degree of freedom to control the outcome of reservoir operations, there are hydrologic and hydraulic conditions where control is not possible.

The study used a two-dimensional reservoir flow-sediment numerical model which is developed to perform simulation studies of the various sedimentation control strategies. The reservoir inflows as well as associated inflowing sediment are estimated using stochastic hydrology techniques. To test the various engineering measures and reservoir operating strategies to control sedimentation, the available historical data , and/or a stochastic model is used to generate long-term sequences of reservoir inflows and sediment inflows. Note that the simulation period is long-term since the sedimentation process can be a slow and prolonged process. With stochastic models, risk and uncertainty analysis of the sediment control measures and reservoir operations can likewise be performed.

Objectives of the Sedimentation Study

The main objective of the sedimentation study is to investigate the feasibility of various engineering measures and reservoir operations to control sedimentation in Pulangi Reservoir. The specific objectives of this study are the following:

- Analyze river hydraulics and bed material data collected in the Pulangi river and reservoir area.
- Estimate reservoir inflows and associated inflowing sediment to Pulangi reservoir for various simulation scenarios. Historical data if available and/or stochastic models will be used.
- Construct a two-dimensional reservoir, hydrodynamic flow-sediment model.
- Perform simulation studies using the watershed and reservoir flow-sediment model to study the effectiveness and impacts of the alternative engineering measures and reservoir operation strategies to control sedimentation. Reservoir sediment flushing studies will be conducted in particular in addition to other sediment control alternatives such as dredging and the use of check dams, if permitted.

Characteristics of Sediment Deposition

In the study, river and reservoir sediments are treated as non-cohesive materials and uniform in size. Dr. Conrado Duque, Professor of Soil Science at Central Mindanao University, Philippines found that Pulangi IV HEP reservoir sediments are virtually non-cohesive based on sediment yield studies as well as textural analysis of soils and sediments in the watershed and tributaries of Pulangi River (see also Duque, 2004). According to the (2002) study, the sediment samples in the Pulangi IV HEP reservoir consist of sand, silt and clay. In particular, the upper layer of the sediment deposits (penetrating 2 to 3 m deep) is usually mud and clay and had been characterized as soft to very loose. Below this first layer is a mixture of sand and silt. At certain portions in the reservoir especially along the old (submerged) Pulangi River, there is gravelly sand. Since the sediment sizes generally consists of fine sand, silt and clay, the reservoir bed sediment as well as inflowing sediment are treated as being uniform or single-size sediment in the study. In particular, the sediment size specified in the study is 1.2 mm. It may be noted that from clay to gravelly sand, the size ranges from 0.004 to 4.0 mm.

Model Geometry

The study area to be included in the model are as follows: 1) lower pondage of Pulangui HEP IV reservoir bounded upstream by the inflowing river link at Busco bridge and downstream end the dam site; 2) power channel, surge pool and hydropower plant penstock/outlet; 3) old river system from damsite extending to about 1 km downstream of confluence of hydropower plant tailrace. This model geometry is needed to assess the downstream impact of river sediments especially during sediment flushing operations.

Figure 3 below shows the finite volume grid of the study area. The geometry shown includes the lower pondage of Pulangi Reservoir, the power channel and surge pool, old river system and river linkage around Busco compound. The grid system consists of 1095 finite elements or volumes (grid) consisting of triangular or quadrilateral elements. The grid cells in ranges from 470 square meters to as big as 0.172 square km. The smallest grids have sidelengths of about 20 m and the biggest ones have sidelengths of 1400 m.

Model Boundary Conditions

For the lower pondage of Pulangi HEP IV Reservoir, the major boundary conditions imposed in the model are the following: 1) upstream inflow at the river link located at Busco bridge; 2) inflowing sediment discharge in this upstream river link; and 3) gated outlet at damsite from reservoir-to-power channel; 4) spillway at damsite; and 5) gated sluiceway structure for sediment flushing at damsite. Other boundary conditions that may impose in the model are lateral inflows from creeks or small rivers as well as rainfall, evaporation and reservoir bed leakage.

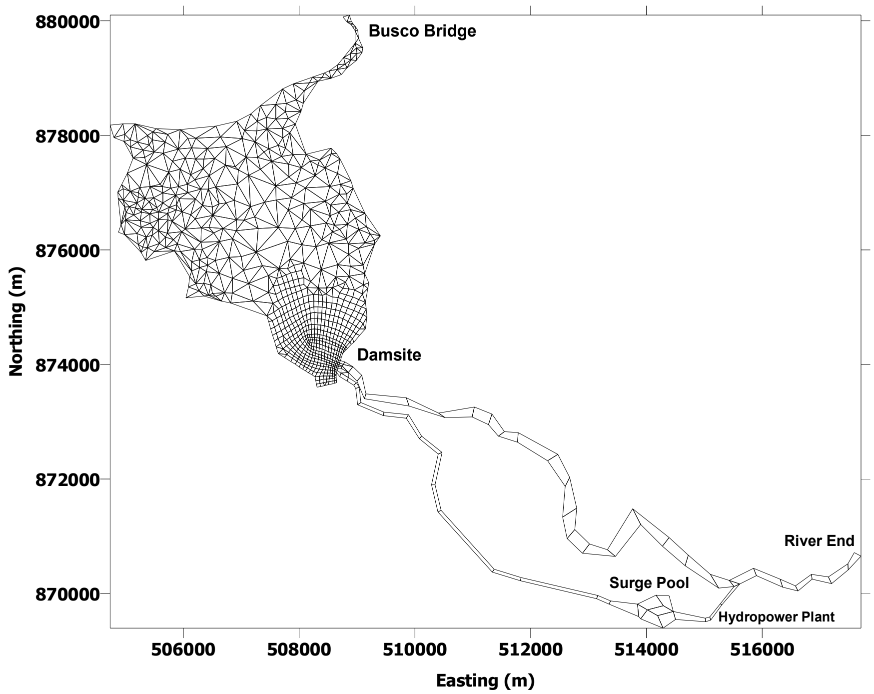

Figure 3. Study area of Pulangi IV reservoir representation in SEDFVM-2D model.

For the power channel and surge pool, the upstream boundary condition is the outflow from the Pulangi IV HEP reservoir model and the downstream boundary condition is the gate operations at the hydropower plant power intake structure.

For the old river model (downstream of damsite), the upstream boundary conditions include the outflows from the spillway and sluiceway of Pulangi HEP IV reservoir and side spills from the power channel. The downstream boundary condition is a water stage or free flow (using normal depth). Lateral inflows to this model include the discharge from the hydropower plant as well as local inflows from adjacent watershed.

Simulation Scenarios for Detailed Analysis

Given below are the simulation scenarios investigated in detail using the two-dimensional reservoir flow and sediment model.

Before the simulation study was conducted it was agreed that the most appropriate reservoir sedimentation control strategy is a combination of certain (initial and short-term) dredging operations and (long-term) sediment flushing operations. There are other options and cases that were looked into but were not further studied since it will affect the operation of the power plant on the process. This scheme was arrived as the most workable solution since the operation of the plant will not be interrupted during the process.

Base Case Simulation Scenario with Continuous Flow Flushing:

- This is the base case scenario with model geometry as shown in Figure 2.
- This is the case where no initial dredging is made but it is assume that there is room for sediment to initially move out of the sluiceway gate.

- In this simulation scenario, two sediment flushing operations are performed over a total simulation period of 600 hours (25 days) starting at 121 and at 432 hours.
- Each sediment flushing operation is a continuous flow flushing in which the sluiceway (sediment flushing) gates are open over a 48-hour period. The opening and closing of gates are accomplished in one hour. Two gates are opened, each opened by 1.0 meter.

Base Case Simulation Scenario with Intermittent Flow Flushing:

- The model geometry and topography in this scenario is exactly the same as above. Likewise, two sediment flushing operations are performed over a simulation period of 600 hours starting at times 121 and 432 hours.
- However, in each sediment flushing operation, intermittent flow flushing is performed in which the sluiceway (sediment flushing) gates are open continuously for 24 hours, then closed for 24 hours, then open again for 24 hours. The total number of hours of actual flushing is still 48 hours except for the 24 hours intervening or rests period.

Fan Shape Dredged Case Simulation Scenario with Continuous Flow Flushing:

- Dredge about 0.4M cubic meters of deposited sediment upstream of the sluiceway. This is a fan-shaped area around the vicinity of the dam site. This is shown in Figure 4 where the dredged areas are indicated by dotted finite elements (grids). Also given are the actual dredged area, volume and average depth for this scenario. The reservoir volume-elevation curve for this scenario is also given in Figure 5.
- The dredged area forms essentially a flushing cone and is especially effective to initiate sediment flushing for reservoirs with wedge-shaped deposits in the Pulangi reservoir. In any case, the main purpose of dredging is to clean area immediately upstream of dam (around sluiceway) for proper sediment flushing operations.
- As in the base case with continuous flow flushing, two sediment flushing operations are performed for a total simulation period of 600 hours starting at times 121 and 432 hours. Likewise, each sediment flushing operation is a continuous flow flushing in which the sluiceway (sediment flushing) gates are open over a 48-hour period. The opening and closing of gates are accomplished in one hour.

Fan Shape Dredged Case Simulation Scenario with Intermittent Flow Flushing:

- The model geometry and topography in this scenario is exactly the same as the fan shape dredged case above. Likewise, two sediment flushing operations are performed over a total simulation period of 600 hours starting at times 121 and 432 hours.
- However, in each sediment flushing operation, intermittent flow flushing is performed as in the base case with intermittent flow flushing.

Fan Shape with Approach Channel Dredged Simulation Scenario with Continuous Flow Flushing:

- Dredge about 0.4M cubic meters of deposited sediment upstream of the sluiceway. This is a fan-shaped area with approach or retroregressive channels about 8 to 10 meters wide, extending several meters from dam face. These channels promote retrogressive erosion (sediment falling into the channel) during flushing operations. Figures 4 and 5 show the dredged areas as indicated by dotted finite elements (grids) and Figure 12 in particular gives the actual dredged area, volume and average depth for this scenario.
- As in the base case with continuous flow flushing, two sediment flushing operations are

performed for a total simulation period of 600 hours with continuous flow flushing operations over 48 hours.

Elevation	Base	FanShape	Fan w/ApCh
265	-	-	-
266	-	908	908
267	-	1,889	1,889
268	-	2,871	2,871
269	640	7,649	7,649
270	1,949	20,937	20,937
271	17,456	48,993	47,432
272	42,074	95,669	82,680
273	77,539	142,346	143,730
274	126,517	212,713	230,128
275	193,954	320,067	344,850
276	289,875	459,849	485,843
277	449,728	670,480	697,970
278	74,624	939,149	968,377
279	1,137,960	1,439,730	1,465,926
280	3,298,788	3,618,236	3,644,984
281	7,960,294	8,284,763	8,310,839
282	14,466,131	14,790,869	14,819,929
283	23,476,992	23,801,728	23,834,042
284	33,666,396	33,991,128	34,023,448
285	44,976,196	45,300,916	45,333,244
286	56,751,840	57,076,592	57,108,920

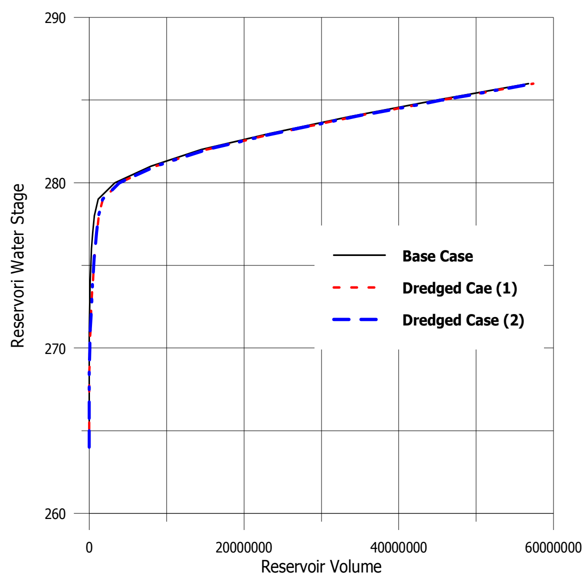

Figure 5. Reservoir volume versus elevation curves for the three basic simulation scenarios: 1) base case; 2) fan shape dredged area; and, 3) fan shape with approach channels dredged area.

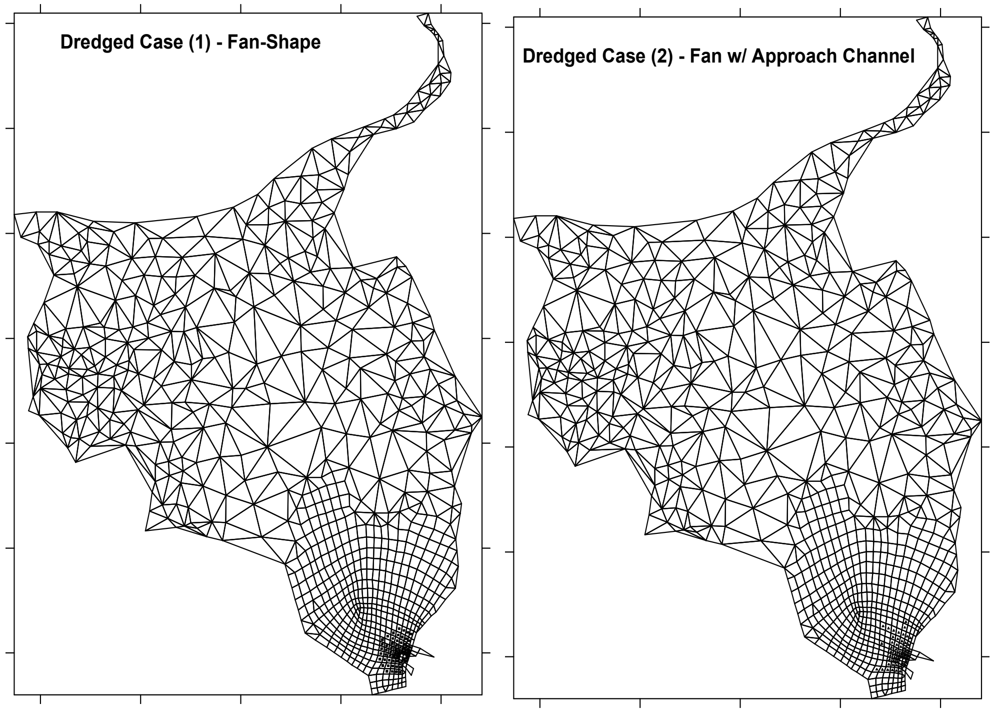

Figure 4. Reservoir area model geometry showing the fan shape dredged area (left figure) and fan shape with approach channels dredged area (right figure) simulation scenarios.

The Chosen Alternative

A two-dimensional reservoir flow-sediment model was developed for purposes of Pulangi HEP Reservoir sedimentation control study. Specifically this model was used to evaluate alternative dredging and sediment flushing operations schemes to control reservoir sedimentation.

In the model, the major boundary conditions include the following: 1) inflow at Busco Bridge river link which is specified as a time series; 2) inflowing sediment discharge as a fraction of inflow such that it results in about 1.4 million cubic meters of sediment inflow annually; and, 3) water stage elevation at the river end specified as a time series. The interior boundaries are the gated outlet structure from reservoir to power channel; 2) gated sluiceway at the damsite for sediment flushing; 3) spillway structure which are specified as time series of gate openings.

The model outputs include the water stages, velocities, discharges (fluxes through element faces) and sediment concentration are computed for each time step and for all elements in the mode. Secondly, changes in reservoir bed and channel bed elevations are computed every time step and each element to allow detailed description and analysis of sediment movement (scour and deposition patterns) and calculation sediment volumes moved or deposited.

The best reservoir sedimentation control strategy is a combination of certain (initial and short-term) dredging operations and (long-term) sediment flushing operations. The dredging operation is needed in the Pulangi IV Reservoir, which entails removing as much as 4000,000 cubic meters of sediments in the vicinity of the damsite, designed especially to clean the area around the sediment flushing sluiceway. Two dredging operations schemes are suggested: 1) fan shape dredging scheme and, 2) fan shape with approach channel dredging scheme. In the flushing operations, two schemes are also investigated namely: 1) continuous flow flushing operations and 2) intermittent flow flushing operations.

It is recommended that initial dredging based on results of the study is the fan shape dredged case. Also, the flushing operations will be intermittent flow flushing. The volume of sediments to be dredged is about 400,000 cubic meters. As a result in the simulation studies, as much as 40,000 m^3 of sediments can be removed when reservoir inflows are about 85 m^3/s, and over 100,000 to 150,000 m^3 of sediments can be removed when reservoir inflows are about 110 m^3/sec. To remove as much as 1.4 million cubic meters of sediment a year, about 10 to 14 flushing operations can be conducted a year when inflows are 110 m^3/sec or higher. Also, the flows must be sustained for 2 days under continuous flow flushing operations or 3 days under intermittent flow flushing operations. From runs analysis, at the threshold level of 120 m^3/sec, the average number of positive run events is 24 events per year with an average length of 6 days

With the sediment conditions in the Pulangi reservoir, the clay layer, which is very loose or even with some degree of consolidation, can be easily washed out during flushing operations or even with high reservoir inflows. It can be concluded that the flushing operations will be effective as a long-term sediment management control in the Pulangi reservoir.

Economic Analysis of the Chosen Alternative

The decision to implement the dredging operation as a way to rehabilitate the Pulangi IV HEP reservoir is well supported by the results of the study. The study gave a more realistic and optimum plan rehabilitation works. It also gave a clear indication on the manner how the dredging works coupled with periodic flushing of sediments will help prolong the economic life of the Pulangi IV HEP operation. However, since this process will involve huge capital expenditures, the plan rehabilitation should be economically justified.

The results of the study will require removal of about 400,000 m^3 of sediments. Using HEC 3 Reservoir System Analysis developed by "The Hydrologic Engineering Center of the U.S. Army Corps of Engineer" it was found out that the plan dredging volume will give the optimum result in terms of energy generation. Although there is no significant improvement in terms of capacity and energy is expected, dredging of more than the 400,000 m^3 will only add up to the cost of rehabilitation works, but will not give any more significant energy benefits.

The economic analysis was conducted using the counterfactual theory of analysis that is for the purpose of justifying the project, it is the "with or without the project approach scenario". The work will consists of minimal dredging works at the immediate vicinity of the headworks to facilitate the repair of bottom sluice gates. Although primarily aimed at enabling periodic sediment flushing thru the sluice gates, this work phase is also considered a measure to minimize the intrusion of bed sediments into the waterways.

In the conduct of the economic analysis, below are the comparative factors used in order to check the viability of the rehabilitation works:

Parameters	Without Rehabilitation	With Rehabilitation
Operating Life of the Plant	- The annual sediment yields of 1.4 MCM will continuously spread in the reservoir area. Based on the simulation, plant will cease operation within 8 years since sediment will	- Although small amount of sediments will be taken out, it is enough to clean up the headrace area and at the same time, it will give way to the operation of the sluicegate for

	intrude and clog the intake area. - There will be a huge reduction of generation due to sediment intrusion at the power plant	flushing operation. - Upon completion, it is safe to assume of 30 more years of operating life of the power plant
Sedimentation Rate	- Increase deposition of sediment at the reservoir at the rate of 1.4 MCM per year. - At the end of year 2003 it was estimated that sediment deposit is around 26 million cubic meters scattered all over the reservoir area.	- Desilting of the immediate area within the headworks will permit the restoration & operation of the sluicegate for flushing operation. - Flushing of sediments will help minimize deposition of silts.
Generation Capability	- Originally, the power plant can generate at reservoir operating level between elevations 276 to 279. - Minimum operating level increases between elevations 281 to 283. This scenario resulted in an increase of spillages and lower generation. This will continue as sediment inflowing the reservoir will not be abated.	- Improvement in the operating level thereby resulting increase in generation even during low flow. - It also reduces the occasion of spilling - It increases reservoir usable storage thereby increasing the firm energy by approximately 46.5 GWH per annum

Results of the Economic Analysis

With the results of the sedimentation study, it was determined that only minimal amount of silts are needed to be dredged. Compared with the previous assumption that there's a need to dredge the whole reservoir in order to restore the functionality of the reservoir, only 400,000 m^3 of silts is needed for removal. This amount of sediment is confined at the area near the headworks which upon completion is enough to clean-up the area around the sluicegate. Primarily the restoration of the sluicegate will also restore the flushing functionality of the sluicegate which according to study will be enough to prevent the accumulation of sediment around the headrace and intake area. Moreover, this option eventually generates huge amount of savings for NPC, which initially conceived to dredge an amount equivalent to US$ 40 million based on the evaluation of private contractor. As a result of the study the total investment was reduced to an equivalent amount of US4.2 million. However, NPC knew that the 400,000 m^3 is too small as compared to the estimated 1.4 mcm annual sediment yield. It is for this reason that if this works proved to be not enough to induce sediment flushing, further study shall be pursued to determine the need for additional dredging works.

For purposes of investigating the economic viability of the chosen alternative, only the incremental costs and benefits which are attributable to the rehabilitation of the reservoir were considered. The economic viability of the project was evaluated by comparing the cost of the project against the benefits derived from its improved operations. The economic cost considered in the analysis only includes the investment cos. No incremental operating & maintenance costs were added because the existing O&M costs were deemed sufficient for the plant to continue its function. In the worst case scenario, it was assumed that if the sedimentation remains unabated, the probability that the power plant will cease operation was considered which means that an equivalent power plant, most probably coal or diesel plant will be installed. This option is more expensive than the option of dredging even the entire reservoir.

The result of the economic analysis indicates that the rehabilitation project is economically viable as it obtained an NPV of PhP 1,784.30 million and EIRR of 70.33%.

The Present Situation

A series of hydrographic surveys were conducted within the 9.5 hectare area of the reservoir after completion of the project. Though this area is just 0.8% of the total reservoir area, its proximity to the dam headworks makes it more significant. This was done to check improvements resulting from the Phase 1 project. Table 1 shows the comparison of this scenario.

Year-Month	Impounding Capacity (in cu. meters)	Flushed Volume (in cu. meters)	Remarks
2005-July	837,180.00		Before Phase 1 Project implementation
2007-Sept	881,760.00		Completion of the Phase 1 Project
2008-May	876,300.00		
2009-Aug		225,520,974.90	Intermittent flushing operations were conducted from June 2008 to August 2009 (please see Table 3)
2010-Feb	883,500.00		

Table 1. Comparison of Impounding Capacities and Flushed Volumes within a 9.5 hectare area near the dam.

From the results of the survey, it is apparent that there was movement of silt from upstream of the reservoir. Intermittent flushing operations within a 14-month period during high water elevation and inflows greatly contributed to the improvement in impounding capacity within the area. Results of simulation studies conducted correlate to these results.

It is noteworthy that silt deposition increases exponentially through time. Previous silt deposits obstruct the water path resulting in areas with lower velocities, conditions hastening to silt deposition.

At present, the resurgence of El Niño proves to be another threat to the operations of not only the Pulangi IV HE Plant, but all hydroelectric plants in the country as well. Prior to the implementation of the rehabilitation work, the operation of the power plant is limited up to 282 masl only, thus reducing the opportunity to generate more for the reason that sediments are already encroaching the intake area. But the completion of the rehabilitation works gave a more headway even during the occurrence of the El Niño in the late 2009 to early 2010, the Pulangi IV is still generating as compare to the same phenomenon in 1997-1998 & 2005. Table 2 show the comparative results confirming the benefits of the dredging conducted for the rehabilitation of Pulangui IV HEP reservoir.

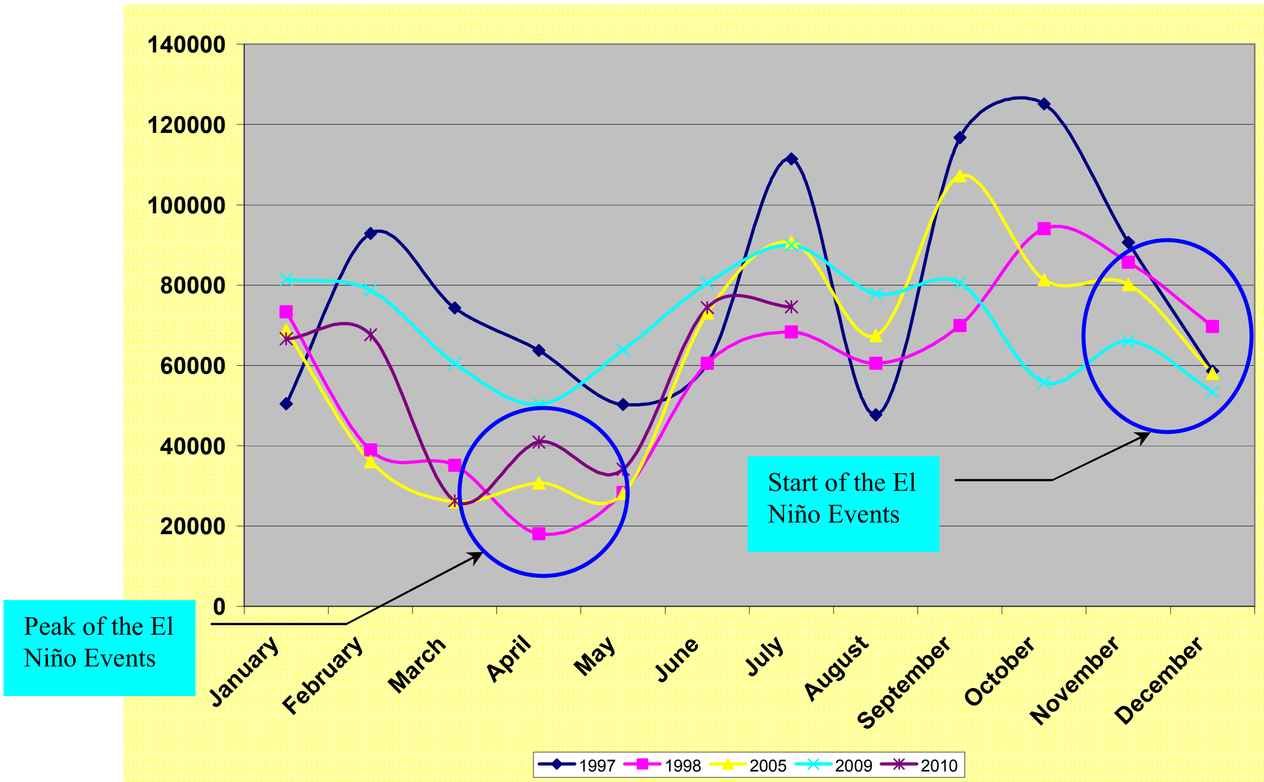

Table 2. Comparison of Energy Generated During El Niño Events

Conclusion

It is very important to note that rehabilitation of Pulangi IV HEP is only the initial phase of the work which provided an avenue for disposing silt through the use of the bottom sluice gates; however, this is not enough to address the pre-existing alluvial plain that has been deposited through the previous years. If left uncorrected, it is expected that these formations grow in volume and will further reduce live storage capacity of the reservoir.

The effort of doing the rehabilitation of Pulangi IV HEP proves to be very beneficial. The capital expenditures are justified and the benefits are realized. NPC already saves a huge capital expenditures and the power plant is experiencing a good operating environment although the threat of sedimentation remains if not properly managed.

Reservoir sediment flushing, although considered the most economic and practical means to clean the reservoir, normally requires the release of significant amount of water that somehow conflicts with the reservoir's main purpose of storing water for hydropower generation. This generally applies to smaller and shallow reservoirs where live storage capacities are often designed for short-period hydropower operations, like the case of Pulangui IV HEP. It is through this notion that a further study is being proposed in order to establish sediment flushing strategies for the most advantageous use of the reservoir's sediment flushing facility.

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