DISCLAIMER

1. The "Independent Advisory Panel to IDB Invest IAP Report N° 2, April 2019 for the Ituango Hydropower Project, Colombia" ("the Report") analyses the activities that Empresas Públicas de Medellín ("EPM") carried out until March 2019 in connection with the Ituango Hydropower Project ("the Project"). For this reason, the Report only reflects the status of the Project as at that date (March 2019) and does not include any analysis of the activities carried out by EPM in connection with the Project after such date.

2. The Report was prepared by independent experts hired by IDB Invest and was not prepared or produced by IDB Invest. The content, conclusions and any information in the Report do not reflect the position of IDB Invest (or the IDB Group) in connection with the Project.

3. Neither IDB Invest nor the IDB assumes any legal responsibility to any person, entity or governmental authority for the content, conclusions or any information contained in the Report, or for any information provided by IDB Invest or the authors of the Report about the Project.

4. The Report was prepared on the basis of: (i) information that EPM provided verbally and in written format; (ii) technical discussions with members of EPM, the Project's Construction Consortium, the Supervision (*Interventoría*), the Advisory firm (*Asesoría*), and EPM's Independent Board of Advisors; and (iii) information collected by the independent experts during their site visits to the Project.

5. The Report was prepared to provide IDB Invest and IDB Invest's B Lenders with qualified Project status information at March 2019 and not after this date.

Independent Advisory Panel to IDB Invest
IAP Report N° 2, April 2019

Ituango Hydropower Project
Colombia

Federico Ciampitti
Hydraulic, Mechanical & Electric Equipment

Via L Tolstoi 72, 20146 Milan Italy
Tel. +39 335 1007517
Federico.ciampitti@gamail.com

Pavlos Marinos
Engineering Geology and Geotechnical

23A, Penetoliou str. 11741, Athens, Greece
Tel. +30 694 4301993
marinos@central.ntua.gr

Alessandro Palmieri
Dam Engineering and Safety (Chair)

Via Massimi 25, 00136 Rome, Italy
Tel. + 39 063 5400737
Arp.palmieri@gmail.com

Table of Contents

Glossary of acronyms

ADT: Auxiliary Diversion Tunnel (GAD or SAD in Spanish)
BID: Banco Interamericano de Desarrollo
CAP: Reservoir capacity
EPM: Empresas Públicas de Medellin
FEM: Finite Element Analysis
GAD: Galeria Auxiliar de Desviacion, or SAD: Sistema Alterno de Desviacion
GSI: Geological Strength Index
IAP: Independent Advisory Panel to IDB Invest
IDG: Intermediate Discharge Gallery
MAF: Mean annual flow
MAS: Mean annual sediment yield
MLO: Middle Level Outlet
PH: Power House
TD2: Diversion Tunnel No.2

Executive Summary

The situation of the Project has considerably evolved from August 2018.

- Emergency discharge through power waterways stopped.
- The decision to move forward the closure of the last intake (No.1) was necessary on safety grounds and associated social impacts were adequately managed.
- Plans for plugging DT2 and GAD are being fine-tuned.
- Intermediate Discharge Gallery is being strengthened and will have a higher discharge capacity.
- Planning for an additional Middle Level Outlet is under way.
- Conditions of underground works are being appraised (very difficult work).
- Bad news: large void linking shaft 1 and 2; between PH cavern and north side surge chamber.
- Good news: main cavern roof undamaged.
- All in all, good news is slightly better than bad news.
- Damage to plant and equipment is also being assessed; for the time being, the IAP has no elements to revise schedule and costs implications, therefore the August 2018 assumptions are maintained.

The following table updates options assessment for Project completion:

Options	August 2018 assessment	March 2019 assessment
Full Rehabilitation	Preferable option; final confirmation after assessment of damages in the power house complex	Confirmed preferable option
Revise Project's Outputs	Not envisaged at this stage	Power output unmodified. Schedule of second stage power supply (units 5-8) to be assessed.
Revise Project's Purposes	Not realistic	
Project re-engineering	Addition of Middle Level Outlet essential	
Partial/ total retirement	Very unlikely, unless cavern location must be abandoned for excessive damages.	Partial retirement can be excluded.
Long-term vision	Project will have to be decommissioned at the end of its useful life, when coarse sediment management, to sustain run-of-river operation, will no longer be economical.	Bathymetric surveys should be initiated to assess sedimentation trends.

Based on the current status of knowledge, repairs to the underground works are the schedule-controlling factor. Until improved knowledge will inform a reliable planning, Adaptive Management is going to be the guiding principle for the implementation of underground repair works. EPM will be able to issue an update of the schedule in the next few months, after completing the dewatering and the assessment of the needed rehabilitation works.

Cost estimates are even more uncertain than schedule. For the time being, too few elements are available to reliably update the estimates which were made in September 2018. Based on current knowledge, it is safe to keep the September estimates for financial purposes. Expectedly, cost estimates should be updated in the third quarter of 2019.

Independent Advisory Panel to IDB Invest Report N° 2
Ituango Hydropower Project – Colombia, April 2019

1 Current project situation

1.1 General

The Ituango hydroelectric project is under construction at the northwest of Colombia since 2009. The Independent Advisory Panel (IAP) to IDB Invest visited the Project, for the first time, in August 2018 (IAP's phase I). The objective of the IAP's phase II involvement is to advise the IDB Invest on:

- Progress achieved with project implementation since July 2018;
- Current situation of the project with focus on:
  - Dam stability and implementation of the flexible wall to bond the priority embankment to the dam's body;
  - Slope stability;
  - Implementation of the intermediate discharge;
  - Sealing of the diversion tunnels;
  - Information about the powerhouse and cavern complex based on indirect monitoring and exploratory boreholes;
  - Stability of penstocks;
  - Overall condition the power house intakes.
- Critically evaluate options for project's completion, including re-engineering, revised schedule, and potential risks for successful project completion.
- Assess the overall safety of the infrastructure.

The present Report contains the IAP's findings and recommendations, following the IAP's second site visit to Ituango HPP in March 2019. Site visits took place on March 5th and 6th, followed by a de-brief meeting in EPM's headquarters in Medellin on the 7th. IAP members wish to acknowledge the outstanding commitment, cooperation and transparency of EPM and other parties.

At the time of the visit, the reservoir level was 407.33 meters above sea level (m.a.s.l.), the spillway discharge 650 m^3/s, and dam crest had reached elevation 418.

1.2 Comparison with August 2018

During the IAP's March 2019 visit, the situation of the Project has considerably evolved in comparison to August 2018:

- Emergency discharge through the power waterways has been interrupted.
- The conditions of the underground works through which the emergency discharge took place for nine months are being appraised, which is a very challenging task.
- The creation of a large cavity, between pressure shafts 1 and 2, has been an unpleasant finding, albeit explicable given the extensive period of dynamic loading of the waterways.
- The most satisfying finding has been the undamaged roof of the machine hall.

- Overall, pending a full appraisal of rock mass conditions, the balance seems to be on the positive side.
- Design and methodology for plugging DT2 and GAD have proved more demanding than expected, and specialized contractors are being mobilized.

Despite the extreme challenges encountered, and those expected ahead, Project staff, of all parties involved, demonstrate outstanding commitment. The IAP wishes to acknowledge the cooperation and the proactive attitude of Project's stakeholders.

The following table updates the IAP assessment of the "Options for Project Completion" which were put forward during the August visit.

Options	August 2018 assessment	March 2019 assessment
Full Rehabilitation	Preferable option; final confirmation after assessment of damages in the power house complex	Confirmed preferable option
Revise Project's Outputs	Not envisaged at this stage	Power output unmodified. Schedule of second stage power supply (units 5-8) to be assessed.
Revise Project's Purposes	Not realistic	
Project re-engineering	Addition of Middle Level Outlet essential	
Partial/ total retirement	Very unlikely, unless cavern location must be abandoned for excessive damages.	Partial retirement can be excluded.
Long-term vision	Project will have to be decommissioned at the end of its useful life, when coarse sediment management, to sustain run-of-river operation, will no longer be economical.	Bathymetric surveys should be initiated to assess sedimentation trends.

Finding the machine hall roof in safe conditions means that the project can be completed according to original design, although with significant delays and remedial works. The latter are being assessed.

1.3 Safety assessment

Hydrological safety is no longer an issue, dam crest cut-off has been completed and dam embankment is rapidly progressing to its final elevation.

Safety conditions of underground works are being assessed; this is a critical task because it controls project schedule and the possibility of definitively plugging GAD and DT2 to remove alert conditions to downstream population.

Underground investigations require increased attention to health and safety of workers.

Dam performance as good as observed in August.

2 After-closure of emergency waterways

2.1 Emergency discharge- essential chronology

The following table summarizes the sequence of the key events; the most critical dates subsequent to August 2018 (first IAP's visit) are shown in red, emergency response measures are highlighted in yellow.

Day	Key Events
April 28, 2018	April 28, 2018: Rock mass failure in the GAD started the sequence of events.
May 10, 2018	To avoid dam overtopping EPM let open Intake Tunnel 1 and 2 as well as 7 and 8; reservoir starts flowing through the Power House. Control of the reservoir level regained.
May 12, 2018	An abrupt washout of Right Diversion Tunnel obstruction caused a flow in excess of 4,000 m^3/s which lasted about 4 hours, causing serious consequences downstream.
May 17, 2018	Tailrace Tunnel 3 reduces its flow that subsequently will stop.
May 20, 2018	EPM closed Intake Gates 7 and 8.
June 5, 2018	Dam crest level reached elevation 410 m a.s.l. allowing operation of the surface spillway. Risk of dam overtopping averted.
November 2019	The level of the reservoir remained constantly at elevation 408 m a.s.l. without causing additional damages to the dam.
December 2019	Signs of deterioration of the fixed part of the Intake gates appeared, raising concerns of the future possibility of closing the Intake Tunnel using the Intake Gates. Such event could have had severe consequences for the power house.
December 2018 / Early January 2019	The acknowledgement that the activities on the intermediate discharge would not be completed before October / November 2019, the positive result of the monitoring of the dam and of the underground works jointly with the risk of facing problem in closing the Intake Tunnel recommended to reconsider the conditions previously identified as essential for closing the gates i.e. (i) final plug of GAD and RDT, (ii) completion of the plastic diagram of the dam (iii) completion of intermediate discharge. Careful preparations for closing of the first gate started, including installation of additional temporary instrumentation of the gate and extensive re-evaluation of the operating conditions of the Intake Gates involving Experts and Manufacturers.
January 16, 2019	Closing of the first Intake Gate (n. 2)
January 2019, days subsequent to the first Intake Gate closure	During the closing of first Intake Gate a direct physical connection between Intake Tunnel 1 and 2 is unequivocally evidenced by various phenomena. First investigations revealed that shafts 1 and 2 were severely affected by collapses of their walls that generated big cavities. Rock collapse was threatening the upper elbows, with a tiny pillar left of less than 20 m.
February 5, 2019	Closing of the second Intake Gate (n. 1)
February 2019, onward	Start of underground works' dewatering; activities were anticipated partially because the volume of debris at the lowest elevations of the underground works was higher than expected.
March 4, 2019	Independent Advisory Panel visit

2.2 Decision to anticipate closure of intake 1

Closure of the first Intake Gate n 2 was extensively and carefully planned.

Post-event recommendations of the Ituango Panel of Experts (in June 2018) were to avoid stopping diversion of the river through the power house without having achieved the following milestones:

- Final plug of the GAD;
- Final plug of the Right Diversion Tunnel;

- Completion of the plastic diaphragm of the dam (and wet reliability operation tests of the spillway);
- Completion of the Intermediate Discharge (that in the meantime was being re-designed to a higher discharge capacity).

However, signs of deterioration of the fixed part of the Intake gates started to appear at the end of 2018, rising concerns of the future possibility to close the Intake Tunnels using the Intake Gates. Moreover, since the start of the events, irregularities in the flow through the power house and tunnels had rapidly affected Intake tunnels 7 and 8 that were closed after few days of operation, even though they were significantly less completed than Tunnel 1 and 2. Subsequently, the same irregularities affected Intake / Tailrace Tunnel 1 and 2 generating worrisome fears of collapses in the underground works. Voids started to be detected in the area of shafts 1 and 2. If allowed to progress, such collapsed could have had severe consequences for the power house, and for the Project in general.

These troublesome signs and the positive result of the extensive monitoring of the behavior of the dam, underground works, temporary plugs, etc., led to the decision to proceed with the closing of the first Intake Tunnel. Particularly useful data were collected during the month of November when the reservoir remained at an elevation of approximately 410 m.a.s.l. over long periods of time.

The plan envisaged sequential closure of the two gates, starting with intake No.2. The closure of the first Intake Tunnel would have facilitated the closure of the second one, reducing the flow of water through the power house and granting the possibility of closing the second gate (intake No.1) with the spillway in operation. The environmental flow of 450 m3/s would have then been constantly ensured.

While the operation of closing the first gate (on January 16th) was successful, it evidenced an unequivocal physical connection among Intakes Waterways 1 and 2. Considering the risk of a further extension of the void between shafts 1 and 2, which was at less than 20 m from the upper elbow of the two penstocks, lead to the decision of antedate the closure of Intake 1. The environmental and social impacts of a temporary reduction of the flow downstream of the project were fully assessed and mitigation measures successfully implemented. It is worth mentioning that, in a parallel action, EPM negotiated with the Salvajina Hydroelectrical Project, (owned by CELCIA and located an upstream the Ituango reservoir) the release of additional water to increase the flow of the Cauca River and therefore, to shorten-up the dewatering period that was going to be caused by closure of the last gate. Also, EPM decided to release additional flows from the owned Porce II and Porce III reservoirs to supplement the Porce River flows (an affluent of Nechi River, and therefore of the Cauca River) to mitigate the possible impacts that the reduction of the Cauca flows would have caused in the wetlands located downstream the town of Nechi (about 150 downstream the Ituango Dam).

2.3 Observed phenomena: hydro-mechanical equipment

The May 2018 closure of Intake Gates 7 and 8 was “abrupt” having been carried out without the support of hydraulic servomotors. The gates were “manually” lowered as much as possible and then let close by gravity. Despite the presence of a correct ventilation system, the sudden closure caused extremely intense vibration in the entire cavern of intake gates 5 – 8 and, few hours later, the landslide in the area above these tunnels.

The closure of Intake gate No. 2 (January 2019) was widely successful thanks to an extremely careful planning. The involvement of Mr. Erbisti, one of the leading gates expert, and of the manufacturers represented key elements for managing the risks.

The closure of gate No.2 was carried out in approximately 40 minutes i.e. in a time almost double the one recommended by the manufacturer.

The temporary instrumentation installed on the gate body did not record any mechanical distortion of the frame, nor any overstressing of the entire system. Vibrations were very high as expected.

The surprise was instead the massive outflow of water from the pit of the adjacent Intake Gate 1 and the fluctuation of all piezometric values of both waterways 1 and 2. These events evidenced a physical connection between the two waterways.

An incorrect drainage of the air from one of the hydraulic circuits was the only minor problem reported during the closure of the two gates; it caused a delay in the complete closure of one of the gates.

2.4 Observed performance of underground works

The IAP visited the Ituango site on March 5th and 6th. Access to the underground works, which had been operating as emergency waterways for over 10 months, was constrained by the ongoing safety-related surveys. However, the IAP could get access to the following areas (see Figure No.1):

- The access tunnel E6 from where a general assessment of the Power House (PH) could be made.
- The access tunnel to the North end of the PH cavern, but it was not possible to advance further and only the transformer cavern could be partly inspected.
- The access tunnel to the PH, until the bifurcation with the “galería construction superior norte”; the access tunnel to PH was not accessible from there.

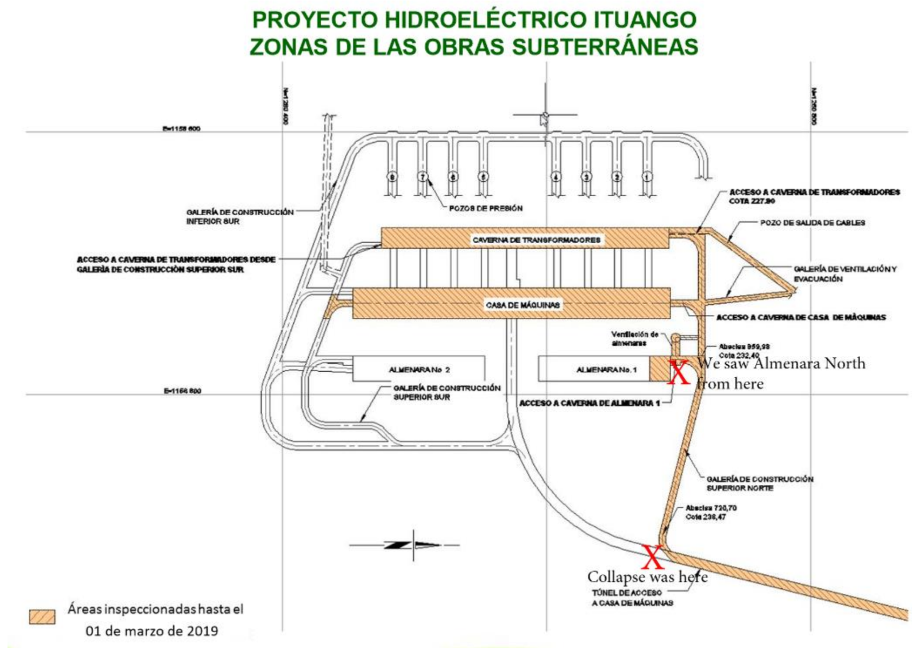

Figure No.1: Accesses to the cavern complex on March 5th.

The observed damages and mechanisms of failure can be divided in three types.

2.4.1 Erosion and failure

During the protracted emergency discharge period, water flow must have triggered pulsating pressures and probably penetrated through the joints inside the rock mass and destabilized wedges. The roughness of the shotcreted tunnel walls and the anomalies due to even small over breaks, could indeed, induce sub-pressures. In most of the tunnels visited, such mechanism caused the fall of roof slabs and wedges limited by rock-mass' discontinuities. The tunnels where such failures occurred can be rather easily restored.

Figure No.2: Erosion and failure mechanisms - Wedges and slabs collapsed from tunnels' roof

2.4.2 Overstressed zones

Sharp corners or junctions of differently oriented underground openings are typical areas of stress concentration. Such overstressed areas are in the corner of the access tunnel, where it meets the machine hall cavern, as evidenced by a number of fissures that form unstable portions of the rock mass. They can be treated by reinforcement or concrete support. A collapse, most likely due to this failure mechanism occurred on March 5th, during IAP visit at the cavern area, at the junction of the air shaft and the surge gallery (“almenaras”).

Figure No.3: Fissures in the corner of the access tunnel at the entrance to the power house cavern.

2.4.3 Tunnel invert erosion

Total destruction of the invert has been observed in several stretches along the emergency waterways. That may be attributed to either washing out of the floor material, or to crumpling of a light invert, which was probably not connected with the tunnel lining. Erosion may have progressed, from the floor, undermining the tunnel’s walls. If an invert was present and affected, a new one should be reconstructed and structurally connected to the tunnel’s lining to form a continuous shell.

Figure No.4: An eroded and destroyed tunnel invert

2.5 Cavity between shafts 1 and 2

The more severe damages that have been identified to date are in the inlet shafts (see Figure. No.5). Exploratory boreholes revealed that shafts 1 and 2 are severely affected. Sidewall's collapses have caused large voids and certainly created a loose and unstable rock mass at their boundaries. A reconstruction is obviously necessary. Backfilling and grouting to consolidate the surrounding ground should precede shaft reconstruction. Adequate rock reinforcement should be installed as the shafts are sunk. A self-standing steel lining is going to be necessary because no rock mass collaboration can be counted on in withstanding internal pressure during plant operation.

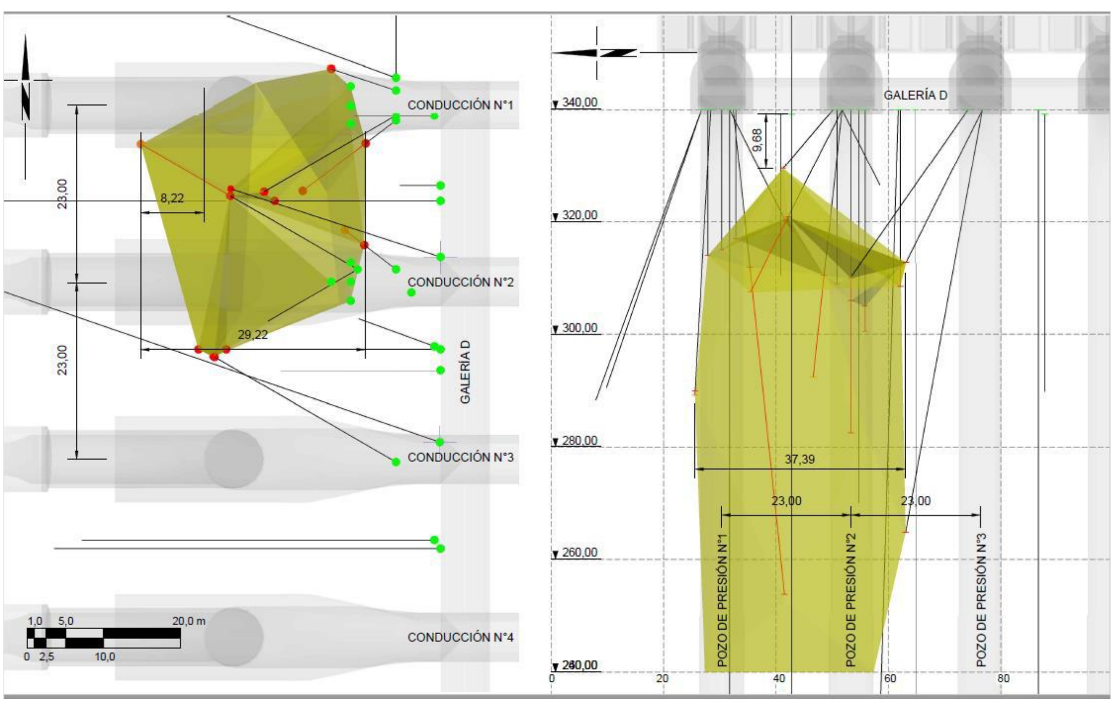

Figure No.5: Reconstruction of the cavity in the area of shafts 1 and 2 (from Integral report, March 2019)

2.6 Cavern complex

No major general collapses were observed in the cavern complex constituted by the machine hall and the transformers cavern. The surge chambers ("almenaras") deserve separate consideration in the following paragraph. The power house's cavern seems to have kept its geometry and no irremediable damages are evident. At the same time there may be parts in metastable conditions that need treatment. A detailed inspection is planned to define the reinforcement measures required to ensure short term safety and long-term stability of this vital part of the Project. A remote survey for the caverns with LiDar is recommended as a first step of the inspection.

Figure No.6: The cavern of the Power House; in February 2019 (left) and March 2019. The fundamental geometry is conserved.

New convergence readings and those of other monitoring devices will provide fundamental data for revising the cavern's stability analysis. Stability appraisal and detailed inspection of the cavity will permit to decide appropriate remedial measures, which could include:

- Spot of pattern rock anchors;
- Drainage and relief holes of the rock mass;
- Additional shotcrete layer, particularly on the roof;
- Possibly, anchored beams (straps).

2.7 North Surge Chamber ("almenara")

An area of expected massive instabilities is that of the surge chambers ("almenaras"). The limited access revealed extensive failure on the northernmost limit of the "almenara norte" with clear connection to the PH cavern. Most likely, the raging waters found its way to the tailrace through the almenara norte. This resulted in the local collapse of the 30 m wide rock pillar separating PH and surge chamber. Reconstruction will require detailed design and careful mining techniques. Although the current access limitations do not allow full appreciation of the volume involved, it is expected that rehabilitation measures will be of comparable complexity to those of the pressure shafts 1 and 2. The following figures show the collapse, as visible form “*galeria de construcion superior norte*”, and a cross section of the underground openings.

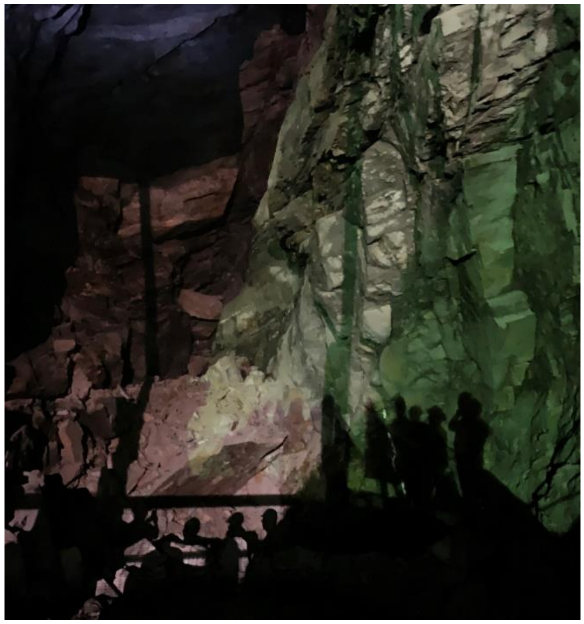

Figure No.7: Extensive collapse on the almenara norte with direct connection to the PH cavern

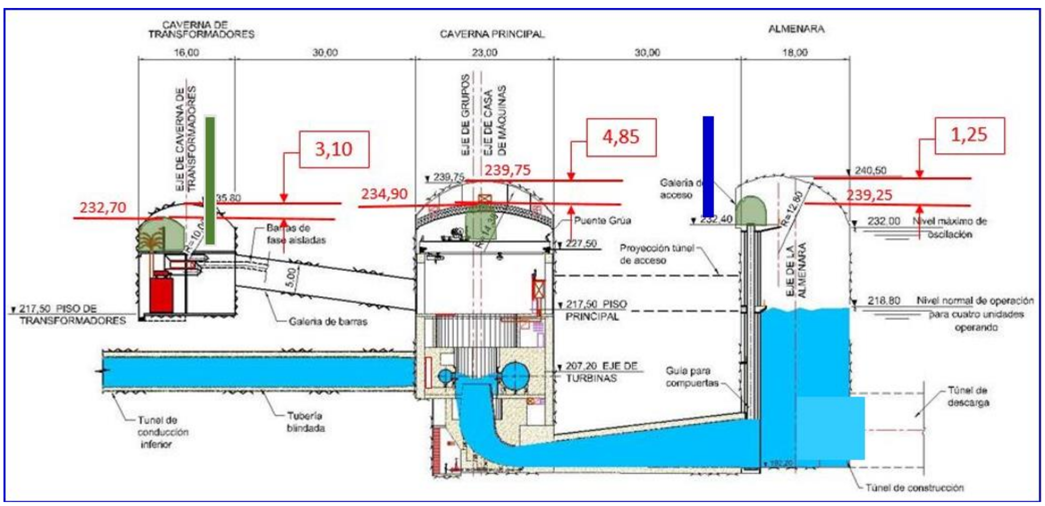

Figure No.8: **30m wide rock pillar separating PH cavern and almenara norte, which has been removed, on the north side, by the raging waters.**

2.8 Other instability occurrences – observed and expected

Detailed inspections are ongoing in all underground openings. Particular attention should be devoted to the zones which are affected by the two main faults (Tocayo and Mellizo).

Another area where cavities could have originated is that of the intake shafts 3 and 4. Those waterways were exposed to emergency discharge for 10 days and had to be closed following intense noise and vibrations in the intake area. Boreholes are planned to investigate the area and it is likely that some cavities could be discovered.

Ground reinforcement of the area could be found necessary, since the rock mass is probably relaxed, due to high stresses imposed by the raging flow during the emergency discharge phase.

2.9 Priority measures underway

A detailed inspection is ongoing of all openings to decide whether spot reinforcement or a pattern one should be applied. In cases (e.g. main caverns) anchored beams may be required.

Priority remedial or rehabilitation measures are aimed at removing the status of alert for the downstream population, so that they can return to normal life. Such measures consist of the two plugs of the Right Diversion Tunnel and the installation of GAD gates.

Ensuring safe access conditions at all levels of the underground works is essential. Assessing the condition of the first phase concrete of the power house and of the lowest embedded parts deserves special attention.

The two sets of activities require careful safety measures for underground work and are obviously interrelated.

The nature of the phenomena which have taken place underground is highly unpredictable. There is no precedent, in the hydropower industry, of a power house and associated caverns (transformer cavern, surge chambers, draft tubes, etc.) being exposed to turbulent water and debris flow for a period of nine months.

It is inevitable, and appropriate, that the investigation and design process progress in parallel, in an adaptive management fashion. Adaptive management implies continuous feedback between investigation and design, and vice versa, i.e. learning by doing.

3 Damage assessment to electro-mechanical equipment

Complying with essential safety provisions, the IAP had the possibility to visit the area of the north shaft chamber and of the power house cavern from the north-side gallery and to carry out a brief visual inspection of the cable gallery that occupies the upper part of the transformer gallery. The latter was not accessible.

Physical damages due to the action of water, rock-falls and loss of portion of the underground works are the evident effects of the prolonged submersion of the equipment.

A detailed survey of the damages to the electromechanical equipment will be available as soon as the safety of the underground works and the dewatering activities will allow them.

Nevertheless, it is already possible to affirm that the damages to the electromechanical equipment are within the range, albeit at the high end, of the August 2018 estimates.

Three out of four draft tube gates are no more in place, collapsed together with the portion of shaft chamber where they were installed.

The two overhead cranes are still in place. EPM staff is confident that they may obtain a crane suitable for temporary activity by cannibalizing the two cranes and replacing all electrical components. The crane will have to be replaced for long term operation.

The pit where generator No.3 was in advanced status of assembly appears empty. The pit of generator No.4 is covered by debris.

The highest level of the control building at the north end of the cavern doesn't exist anymore. The control system was almost completely installed before the incident, and all movable computerized equipment were removed before the start of emergency discharge.

The 10 single-phase HV cable Installed are physically damages and will be replaced.

The isolated phase bus ducts of unit 3 and 4, which are mechanically fragile, are lost.

In simple words the assumption that all electromechanical equipment installed at the time of flooding the power plant shall be replaced is not far from the truth.

Two parts of the electromechanical supply deserves a dedicated mention: the embedded parts of the Units and the transformers.

At the time of the Power House flooding the progress of the installation of the lowest part of the units was as shown in the following figure (green color shows installed equipment).

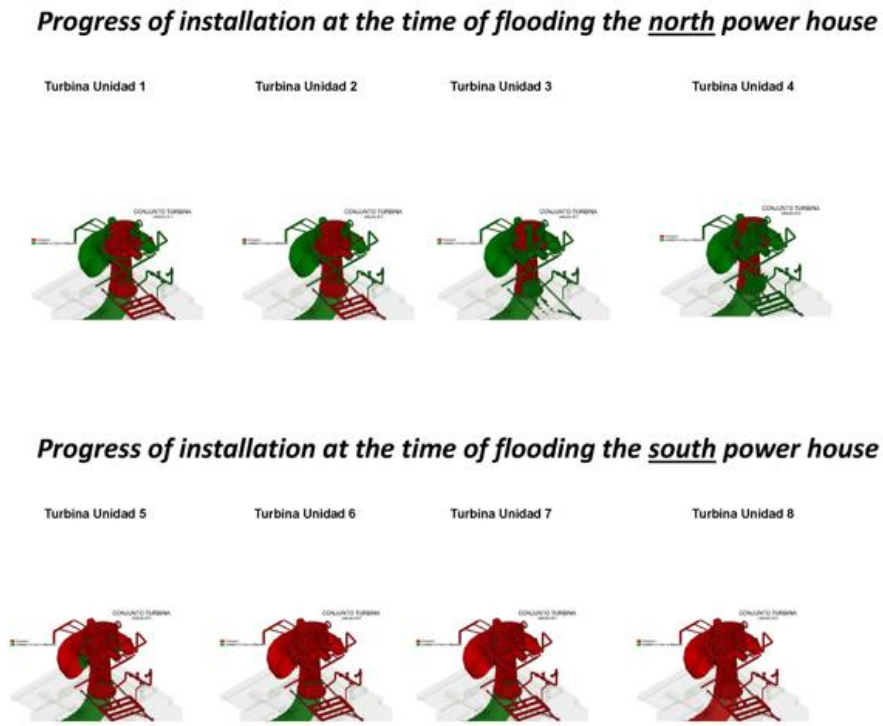

Figure No.9: Progress in the installation at the time of flooding

Installation of the north side turbines was well advanced, especially Unit 4 and 3 that were to be commissioned first.

Situation of Unit 4 is unknown being the area covered by debris, but there is room for some optimism for the embedded parts especially the lowest ones.

Unit 2 is in bad conditions and Unit 1 is the most affected. Situation of the draft tubes are little known, and their situation should depend on the length of time the flow of water needed to find an alternative way to flow through the tailrace tunnel.

The need of replacing the draft tube(s) may have consequence on the schedule as detailed in the relevant paragraph.

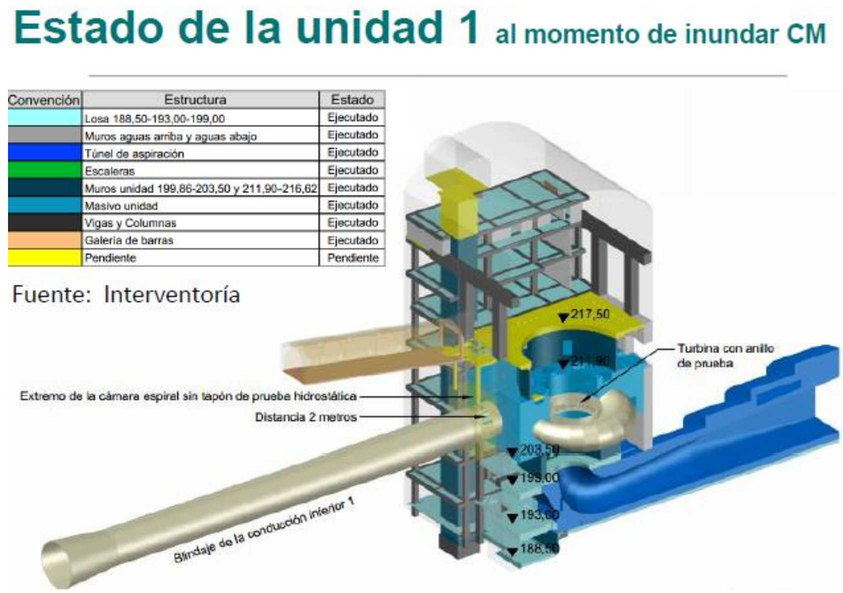

Figure No.10: Progress in the installation of unit 1 at the time of flooding

At the time of the Power House flooding 12 single-phase transformers of the north powerhouse, and the spare, were completely erected including auxiliaries and dielectric oil flushing (see figure below).

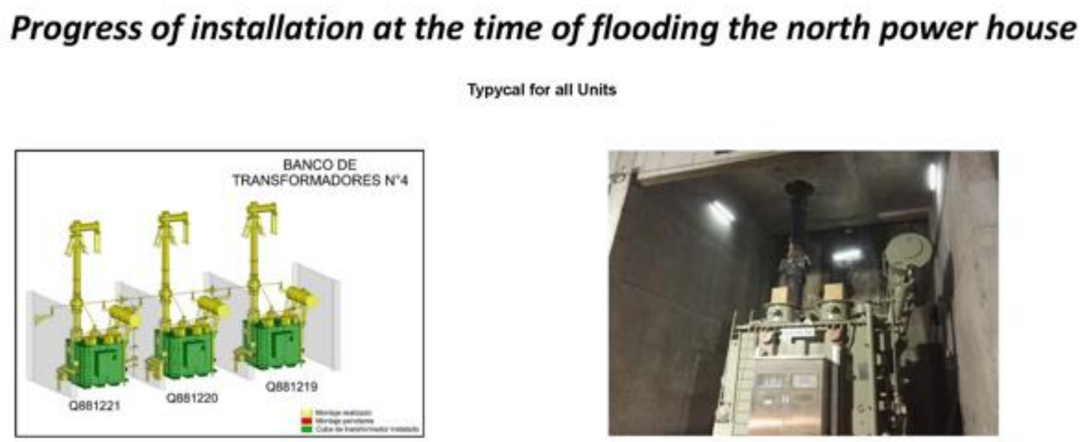

Figure No.11: Progress in the installation at the time of flooding of the north power house

Two single-phase transformers of the south powerhouse were in similar conditions, 4 were in transport condition (with nitrogen) while 6 are currently in standby in a Colombian port.

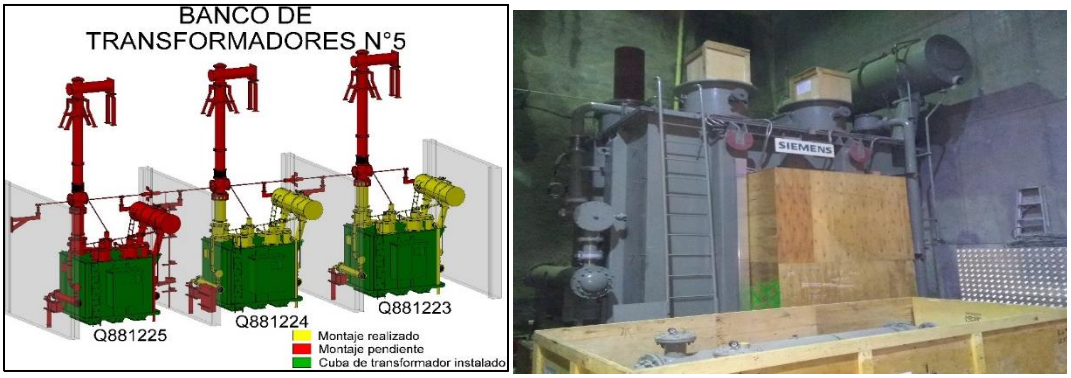

Figure No.11: Progress in the installation of the transformers at the time of flooding

Preliminary visual investigation by EPM did not remark any sign of losses of oil from the transformers and excepting the presence of thin debris in the transformer cavern no damages to this area was reported.

As viewed from the opening in the cable gallery's floor, at least part of the transformers is in place. The matter is of relevance because EPM has in the warehouse only 6 out of the 12 single phase transformers needed to energize the four Units of the North Power House. Final decision on their long-term availability may depend on the agreement with the insurance.

3.1.1 Brief update on hydromechanical Equipment

The following table summarizes the IAP's remarks on the Spillway's and IDG's gates.

Hydro Mechanical Equipment	Progress of installation and testing	Remarks
Spillway Gates Four Radial Gates (two with flap for debris) 15 m x 19,50 m Discharge capacity: 22.600 m³/s (PMF) Operation: oleodynamic servomotors, single control and oleodynamic stations for each gate + common control	Already in operation, testing and common control completed.	In case of earthquake, rocks may fall from the slope and hit the diesel generator building. Risk assessment is recommended.
Gates to intermediate Discharge Gallery Two Radial Gates + two Emergency Sliding Gates Size: 3 m x 3.90 m (Radial Gates) Setting capacity: 750 m³/s with both gates in operation for all reservoir elevation higher than 350 m.a.s.l. Operation: oleodynamic servomotors, single control and oleodynamic stations for each gate.	Already in operation conditions, testing and control completed. Steel lining installation duly completed	None

The following table summarizes the IAP's remarks on the Intake and Diversion gates.

Hydro Mechanical Equipment	Progress of installation and testing	Remarks
Intake Gates Height Sliding Gates, 5.03 x 6.87 m, with stoplogs Operation: oleo dynamic servomotors.	The area is now accessible. A physical protection was installed above pit and control box of Unit 1 and 2.	Gates close under balanced pressure conditions and, in emergency, under the maximum hydraulic head and the rated flow of the Unit.
Diversion Gates Two-wheel gates, 9 m x 18 m	EPM is working to lower the gates through a temporary fixed crane already installed to plug the ADT.	During the hydraulic transient of ADT, the gates were lifted back to the gate chamber and damaged.
Bottom Outlet Gates	They will be blocked and plugged without having been utilized.	

The IAP was able to visit[1] the Intake Gates and service stoplogs which were initially put in place and lifted using mobile cranes and maintained in their position using dogging devices. Oleodynamic systems are currently operational for Intake Gates 1 and 2 and they were utilized for their closure.

The Intake Gates are designed to operate under balanced pressure and, in emergency, under the maximum hydraulic head and the rated flow of the Unit. The actual technical limits of such emergency operation were investigated in detail when planning the closure of Intake Gates 1 and 2. That was done with the support of manufacturers (including manufacturers other than the one that supplied the gates). Quite unusually, the outcome of the re-evaluation allowed to extend the operating condition: the gates were judged capable of closing under any reasonable flow under the maximum hydraulic head. This outcome is also reassuring for the future operation. Closing the turbine’s ring gates allows balancing pressures but, in case of large leakages from the intake waterways, it would be impossible to achieve hydrostatic conditions. Therefore, in case of collapse in any part of the intake system causing an uncontrolled flow of water, there is now enough confidence that it will be possible to stop such flow.

Activities on the Intake gates and their operating systems are mostly on hold because they are not in the critical path and EPM’s attention in these areas is concentrated on reinforcement works underground and slope stabilization.

3.1.2 Brief update on 500 kV GIS switchyard

During the March 2019 visit, the IAP collected information and documentary evidence that the 500 kV switchyard is already completed though the HV power cable will need to be reinstalled, including their connections with the 500 kV GIS switchyard. Minor stabilization works were carried out by EPM in the slope above the switchyard area.

[1] They were not accessible in March 2018 due to the incumbent landslide

4 Control of Reservoir levels

4.1 General

The possibility of controlling the level of Ituango's reservoir is extremely limited, in the current configuration. Only the IDG, with sill at 260 m.a.s.l., offers partial capability in that regard. Its design has been revised to allow discharging up to 750 m^3/s and upgrading in underway. This is dealt with in the following paragraph.

While such uprating is certainly part of the solution, it will be insufficient to guarantee reservoir control when river inflows approach or exceed 750 m^3/s, which can occur yearly during rainy periods.

4.2 Intermediate Discharge Gallery at el. 260

Extensive monitoring of the behavior of the plug and of the entire portion of tunnel upstream of the gates of the Intermediate Discharge Gallery (IDG) made EPM confident to start working in that part of the Project. Ongoing activities include reinforcing the concrete lining and completing contact grouting behind the still lining. Steel lining extends few meters upstream of the emergency gates. The total length of the steel lining upstream of the gates (a few meters), in the gate stretch, and downstream of the gates is 100 meters.

EPM addressed the IAP's recommendations to reinforce the tunnel lining and increased the IDG's rated capacity from the previous 450 m^3/s, corresponding to the required environmental flow, to 750 m^3/s. The IAP welcomes the decision that adds much needed discharge capacity to the Project.

The hydraulic regime upstream and downstream of the gates, is the same as in the original design, respectively pressurized and open channel flow. The height of two vertical walls of the downstream channel has been increased and the walls strengthened with rock anchors. IAP assumes that the Designer has verified that the higher flow is compatible with the results of the physical model tests and would like to have confirmation in that regard.

Structural measures are being finalized along the IDG lining[2]. The IAP finds such provisions adequate, also based on the visit made to the ongoing works. At the same time, the IAP wish to underline that the increased rated capacity determines higher hydrodynamic loading, which entails more attention to details, notably to surface finishing of the lining.

EPM is still evaluating different options for the design of the tunnel stretch between the inlet portal and the existing plug. The option to use steel lining is obviously the most conservative and is recommendable in this critical component of the Project.

The following gate operation rules apply to the uprated IDG:

[2] Re. Presentación VP Proyectos e Ing EPM _ Mision BID marzo 2019.

Reservoir elevation	Gate opening	Rated discharge from IDG
Above 405 m.a.s.l.	Gates closed. Discharge through the surface spillway.	zero
405 m.a.s.l.	80%	750 m^3/s
390 m.a.s.l.	90%	750 m^3/s
350	Fully opened	750 m^3/s

With the current layout, the upstream part of the IDG would not be accessible for inspection during project operation. Moreover, the gates operate under a static head exceeding 150 m, i.e. on the high side of the operating range for this type of gates. The possibility of accessing all control works is recommendable given the level of stresses that Ituango has experienced.

The inlet portal of the IDG will be constructed by an underwater rover, which makes the addition of an additional closing device a challenging endeavor. The IAP recommends considering this possibility and points out that, recently, a similar need raised at Mosul dam (Iraq) and, even though extremely complex in their operation, the availability of bulk head gates stored for approximately 50 years underwater demonstrated effective.

4.3 Additional Middle Level Outlets under study

The increased hydraulic capacity of the IDG is a positive design measure that will improve the operation of the Project. At the same time, such measure is insufficient to ensure adequate control of reservoir levels is all conditions foreseeable during the life of the scheme.

The IAP reiterated its recommendation to endow Ituango with an additional Middle Level Outlet (MLO) for, at least, two reasons:

- Safety: the upper part of the reservoir must be lowered in emergency conditions (e.g. post-earthquake, or for internal erosion manifestations).
- Operational: to access the intake gate areas for extraordinary maintenance or repairs.

During the March visit, the IAP was pleased to learn that the Designer is studying options to add an MLO facility. The IAP would like to review such options, including the Panel of Experts opinion on them.

Construction of the additional MLO is not essential for the entering in operation of the Project, but its implementation should comply with a time-bound action plan of a few years after commencement of Project operation.

5 Stability of the right bank

The right bank slopes are in critical stability conditions. Part of the area was destabilized by the events in the zone above the diversion tunnels, which followed the main GAD's collapse.

These instabilities affect the cover and the overstressed zone of the rock, which has not been removed or modeled. Such movements will be enhanced by the fluctuation of the reservoir during its operation, or during reservoir drawdown.

In its September 2018 report, after reviewing and commenting the stability analysis carried out by the Designer, the IAP recommended to protect such slopes by extending the treatment and protection upstream of the spillway slopes, as far as the destabilized area over the two diversion tunnels
.
The uphill extension of the slope protection measures is necessary to safeguard the intake to the powerhouse ("El Romerito" zone) as well as the intake of the Intermediate Discharge Gallery.

The IAP recommended the protection works should aim at removing as much as possible of the distressed zone and proceed by benching. Cable anchoring to be used as appropriate. Fortunately, the morphology of the slope flattens soon uphill where a concavity, probably associated to an old landslide, is present.

Figure No.12: The slope over the intake structures and the treatment works initiated uphill.

During this mission the panel visited the works in progress in the higher part of the slope, which feature reprofiling with benches and stabilizing by anchors the "El Romerito" landslide; surface drainage and perforated drains are foreseen. Both design and implementation are considered satisfactory. This treatment will also contribute to the stability of the extended slope re-profiling recommended by the IAP.

Figure No.13: The upper part of the "El Romerito" landslide under treatment with shotcrete and anchors. Benching down in the right photo.

The IAP understands that the design of the recommended extension of the stabilization works is being developed.

Figure No.14: The destabilized area above the two diversion tunnels. In the far upper end the shape of the "El Romerito" landslide

Remote slope monitoring (by satellite) of the slopes around the dam started in July 2018, and it should be extended in the upstream area. IAP recommends adding geodetic targets, piezometers and inclinometers in all benches of the extended treatment.

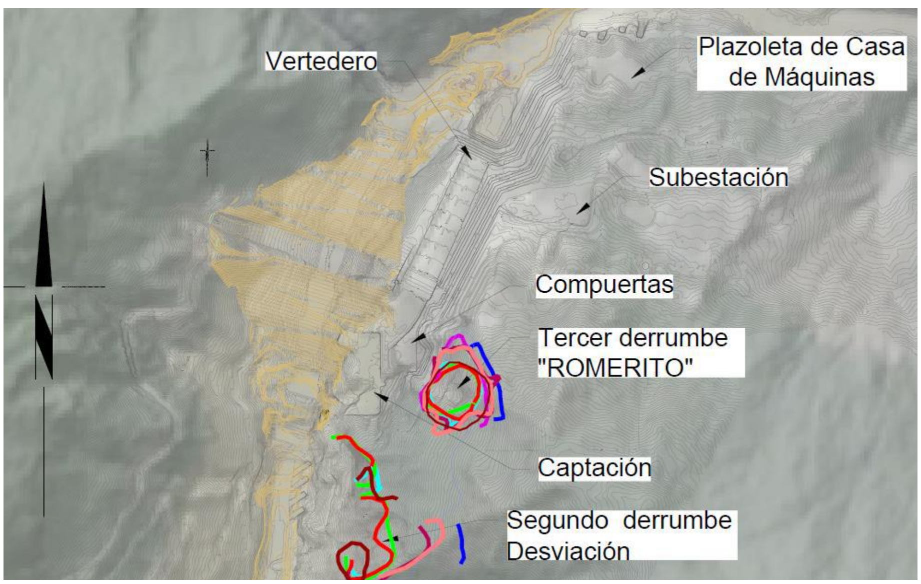

Figure No.15: Satellite monitoring of the right bank (from Integral 2019)

Fissures were detected on the permanent slopes above the spillway. Join extensometers are in place to monitor the evolution of the movements. The Designer should re-assess the stability of the area to identify the need of possible strengthening measures.

6 Dam

Elevation of the dam to final crest level is proceeding as planned and the freeboard is fully satisfactory. The plastic cut-off wall on the upper part has reduced seepage from 35 to 7 liters per second (l/s). The contact of the wall and rock in the left abutment was grouted.

The need of additional grouting works in the left bank was discussed in the IAP's report of September 2018. The origin of such seepage is the left drainage gallery at level +250, where initial curtain grouting holes were not oriented to intercept sub vertical joints. In this abutment total seepage reached 80 l/s. Although not excessive, remedial measures were identified, and additional grouting executed. However overall seepage is today not substantially changed. Currently is reported of about 50 l/s and follows fair well reservoir levels. Additional multidirectional grouting is recommended. All seepage water is reported clean.

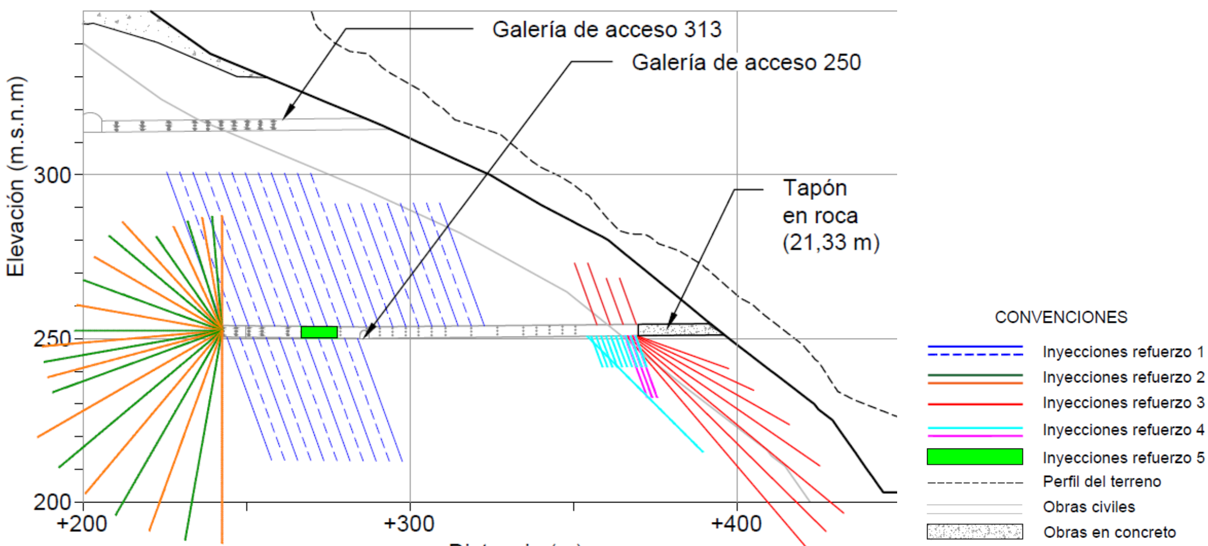

Figure No.16: Additional grouting in the left abutment (From Integral 2019)

Piezometric levels in the foundation exhibit significant changes only in a confined area in the left abutment. The core – spillway contact design is satisfactory: the downstream three- layers filter is widened in the abutment contact areas. The core's plasticity index, in the contact zone, has been increased to mitigate cracking.

7 Spillway

Currently, and until the IDG is completed, the surface spillway constitutes the only discharge facility of Ituango. It is being operated very judiciously, regulating gate openings to meet the following criteria:

- Ensuring a managed river flow of not less than 450 m^3/s, for river health and downstream water uses;

- Maintaining the sky jump effect to avoid water prolonged impingement on the stepped slope underneath the downstream lip.

The radial gates are designed for regulation purposes and are doing their job egregiously.

During the March visit, the spillway was discharging 650 m^3/s and the flow pattern was according to design. The two aeration lines were providing the required air entrainment (see figure below).

Figure No.17: Spillway in operation

Surveys of the plunge pool area will be necessary during operation, and following high discharge events, to check the evolution of the pool boundaries.

The slopes above the plunge pool area are saturated by the mist and stressed at their toes. That has already caused some minor failures, which will inevitably progress in time. This is an expected condition for this type of energy dissipation design. At the same time, it is necessary to monitor its evolution.

8 Reservoir

8.1 Stability of rims

The IAP made a dedicated helicopter flight over the entire reservoir in order to detect potential large-scale instabilities and landslides.

No geomorphological features denoting major old landslides were recognized. The hydrographic features are also reassuring. Generally, the slopes exhibit stable overall configurations.

In the upstream part, the basin' slopes present erosion landforms. These forms indicate a stable background in terms of slope retention. They cannot generate significant landslides.

Figure No.18: Erosion forms in the reservoir basin, on stable overall background

Erosion feeds tributaries forming small deltas of fine material at the confluence with the reservoir. Such deltas only contribute to reservoir sedimentation and cannot generate waves.

Erosion is reduced in the downstream part of the basin, probably due to the hardness of the bedrock. Again, no feature of large-scale mass movements is detected.

Landslides of reduced size and small scale, either rotational or planar, are observed in places and new ones may be generated by the operation and fluctuations of the reservoir. They cannot generate waves of concern.

Figure No.19: Small scale landslides at the rim of the reservoir. Similar are frequent

Existing studies hinted at the possibility of an old mega slide, 50 km upstream of the dam site, at the left side of the reservoir (“Guasimo” mega slide). No strong evidences were observed in the geomorphology and features of the area. There is no well-defined morphology of an old escarpment from where the landslide might have originated. Heavy erosion is present denoting overall stability of that escarpment area. The size of the downhill mass supposed to have slid is not compatible with the uphill morphology. The whole area is characterized by persisting erosion.

Figure No.20: The Guasimo area, hypothesized to be an old mega slide. No strong evidences were found in the geomorphological form and features.

Even in the extreme hypothesis that this were an old landslide, there are no features that allow to forecast its future re-activation.

8.2 Debris management

The April 2018 emergency did not permit to complete the vegetation matter produced by reservoir clearing operations. Floating logs have formed a base on which vegetation has grown producing several islands in concave areas of the reservoir rims. In some places, where the reservoir narrows, the “green carpet” covers the entire reservoir width (see photo).

Figure No.21: Vegetated debris floating on the reservoir

Inevitably, the next large flood will move such debris towards the spillway. A dedicated section of the emergency preparedness plan (EPP) should be prepared to manage that eventuality.

8.2.1 Sedimentation trends

Following the discourse initiated during its first visit, the IAP recommends planning reservoir surveys aimed at providing early elements for sedimentation management purposes. Two types of surveys are recommended:

- Bathymetric surveys of the reservoir, and
- Grain size distribution of the delta deposits that are starting to accumulate in the upstream limit of the lake.

The latter are important to assess the life expectancy of the reservoir, as shown in the following figure[3].

[3] Adapted from Morris, G. And Fan, J. (1998) "Reservoir Sedimentation Handbook" McGraw-Hill. ISBN: 007043302X.

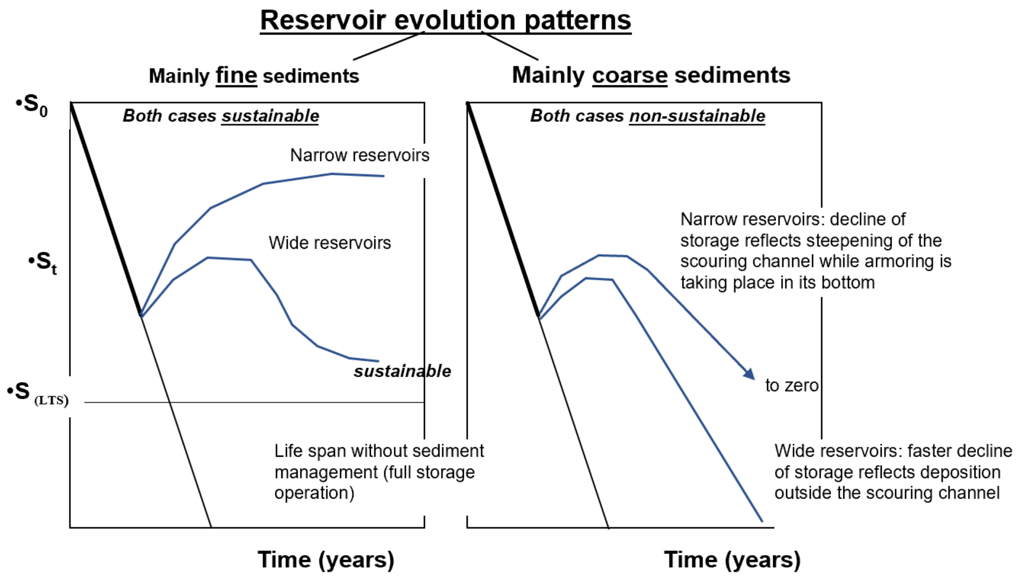

Figure No.22: Reservoir evolution patterns

The two graphs represent the decrease of storage capacity ("S") in time. The decrease proceeds until sediment flushing is implemented. Sediment flushing could be a long-term option for Ituango, which could be performed through the additional MLO being under planning.

If the sediments are mainly fine (left diagram), significant recovery of storage capacity can be obtained in the long term, and a sustainable capacity can be achieved. The upper curve represents the case of narrow reservoirs, wherein the scour channel during flushing represents a significant portion of the reservoir capacity. The lower curve refers to wide reservoirs, where the scour channel only occupies a fraction of the reservoir capacity.

The right diagram illustrates the case of mainly coarse sediments. The key difference is that a long-term sustainable storage capacity cannot be reached, and only the life of the reservoir can be extended with flushing operations. In fact, when the coarse sediment delta reaches the discharge works, erosion and wearing will be such to rapidly damage any engineering structure, discouraging periodic flushing operations.

9 Project Completion

9.1 Schedule

The schedule provided by EPM ahead of the mission, and dated February 18, 2019, is substantially unchanged with respect to the September 2018 one.
As per the current schedule, EMP has adopted a completion strategy with the same two phases planned in September 2018:

- Units 1-4 (North Power House), completion by end of 2021.
- Units 5-8 (South Power House), completion by end of 2023.

Tentatively the first four Units will be commissioned, in reverse order, on May, July, September and December 2021.

EPM is confident to achieve the 2021 milestone and has submitted the relevant financial guarantee to the Regulator to get market access rights (such financial guarantee was already forfeited once at the end of 2018).

Based on the current status of the assessment of the damages to the underground works, it is clear that the repairs works are the schedule-controlling factor. This is also because an entire set of electromechanical equipment, originally assigned to Unit 5-8 (South Power House), is already available in the warehouse of EPM.

Despite the early status of underground investigation activities, EPM illustrated selected parts of the schedule as described below.

Activity	Remarks
Plugs to the ADT and the RDT	The two interventions are on the critical path to guarantee the possibility for the relocated families to return to their houses and for EPM to start reconstruction of the infrastructures, among them the four bridges washed away by the sudden release of more than 4000 m^3 on May 12th, 2018. Consolidation of RDT's pre plug 1 should be completed in April 2019 while the other activities, not on the critical path, between November and January (2020). Installation of the Diversion Gates of the ADT and final concrete sealing should be completed in July 2019 and the other activities, not on the critical path, within the end of the year.
Intermediate Discharge Gallery	Operational in the first months of 2020.
Additional Middle Level Outlet	Currently under study, construction should be the completed in two / three years.
North Power House	Waterways 1 – 4 and all civil works shall be rehabilitated within 2021 in time for the commissioning of the corresponding units (Unit 4 and 3 will be completed first). The schedule for equipment installation, testing and commissioning, currently set at 13 months, is reasonable.

At the moment, there are two activities for completion of Unit 1 - 4 that raised raisons of concerns:

- Steel lining to vertical shafts

The original design foresaw steel lining only on in the horizontal section between the lower elbow and the spiral case of the Units. Given the severe damages to the rock mass in the area of the pressure shafts (see section 2.5), it must be assumed that the ground has lost its capacity to collaborate with the lining in withstanding internal pressures. The adoption of a self-standing steel lining seems inevitable and is recommended by the IAP. The decision should be rapidly made to avoid delays in commissioning the first unit. Time for design, manufacturing, transportation, installation and testing of the lining may, should be included in a revised schedule.

- Draft tube replacement

It is not yet known whether the second phase concrete to draft tubes 1 and 2 require replacement. Being the first component of the Units to be installed, its procurement, manufacturing, transportation and installation may affect the schedule of Unit 1 and 2.

In conclusion, until improved knowledge will inform a reliable planning, Adaptive Management is going to be the guiding principle for the implementation of underground repair works. Having said that, EPM's decision to maintain the previous schedule appears sound, and EPM will be able to issue an update in the next few months after completing the dewatering of the underground works and the assessment of the needed rehabilitation works.

9.2 Costs

Cost estimates are even more uncertain than schedule. For the time being, too few elements are available to reliably update the estimates which were made in September 2018.

Based on current knowledge, it is safe to keep the September estimates for financial purposes. Once the design of underground rehabilitation works is available, cost estimates shall be updated. Expectedly in the third quarter of 2019.

10 IAP's Conclusions and Recommendations

For convenience of the reader, the present chapter summarizes the main conclusions of the IAP that are scattered in the previous chapters.

10.1 Progress since July 2018

The situation of the Project has considerably evolved from August 2018.

- Emergency discharge through the power waterways has been interrupted.
- The conditions of the underground works through which the emergency discharge took place for nine months are being appraised, which is a very challenging task.
- The creation of large cavities, between pressure shafts 1 and 2, and between the PH cavern and the north-side surge chamber, have been unpleasant findings, albeit explicable given the extensive period of dynamic loading of the waterways.
- The most satisfying finding has been the undamaged roof of the machine hall.
- Overall, pending a full appraisal of rock mass conditions, the balance seems to be slightly on the positive side.
- Design and methodology for plugging DT2 and GAD have proved more demanding than expected, and specialized contractors are being mobilized.

10.2 Safety assessment

- Hydrological safety is no longer an issue, dam crest cut-off has been completed and dam embankment is rapidly progressing to its final elevation.
- Safety conditions of underground works are being assessed; this is a critical task because it controls project schedule and the possibility of definitively plugging GAD and DT2 to remove alert conditions to downstream population.

- Underground investigations require increased attention to health and safety of workers.
- Dam performance is as good as observed in August.

10.3 Slope stability

Slope reinforcement works are in progress in the higher part of the right bank in the area affected by "El Romerito" landslide. Both design and implementation are considered satisfactory. The IAP understands that the design of the recommended upstream extension of the stabilization works is being developed.

10.4 Implementation of the intermediate discharge

IDG's discharge capacity has been increased to 750 m^3/s. Structural measures are being finalized along the IDG lining. The IAP finds such provisions adequate, also based on the visit made to the ongoing works. The increased rated capacity determines higher hydrodynamic loading, which entails more attention to surface finishing of the lining.

EPM is evaluating different options for the design of the tunnel stretch between the inlet portal and the existing plug. The option to use steel lining is obviously the most conservative and is recommendable in this critical component of the Project.

During the March visit, the IAP was pleased to learn that the Designer is studying options to add an MLO facility. The IAP would like to review such options, including the Panel of Experts opinion on them.

10.5 Power Intakes and pressure conduits

The more severe damages that have been identified to date are in the inlet shafts. Sidewall's collapses have caused large voids and certainly created a loose and unstable rock mass at their boundaries. A reconstruction is obviously necessary. Backfilling and grouting to consolidate the surrounding ground should precede shaft reconstruction. Adequate rock reinforcement should be installed as the shafts are sunk. A self-standing steel lining is going to be necessary because no rock mass collaboration can be counted on in withstanding internal pressure during plant operation. The Designer will have to check whether full steel lining is required also in all the other shafts. Given the extent of disturbance of the rock mass in the area, that may well be the case.
Another area where cavities could have originated is that of the intake shafts 3 and 4. Those waterways were exposed to emergency discharge for 10 days and had to be closed following intense noise and vibrations in the intake area. Boreholes are planned to investigate the area.

10.6 Powerhouse and cavern complex

The power house's cavern seems to have kept its geometry and no irremediable damages are evident. At the same time there may be parts in metastable conditions that need treatment. A detailed inspection is planned to define the reinforcement measures required to ensure short term safety and long-term stability of this vital part of the Project.

10.7 Surge chambers

Extensive failures have occurred on the northernmost limit of the "almenara norte" with clear connection to the PH cavern. Most likely, the raging water found its way to the tailrace through the almenara norte. This resulted in the local collapse pf the 30m wide rock pillar separating PH and surge chamber. Investigations are under way.

10.8 Plant and equipment

Damage to plant and equipment is also being assessed; for the time being, the IAP has no elements to revise schedule and costs implications, therefore the August 2018 assumptions are maintained.

10.9 Project's completion schedule and costs

The schedule dated February 18, 2019, is substantially unchanged with respect to the September 2018 one. Based on the current status of knowledge, repairs to the underground works are the schedule-controlling factor. Until improved knowledge will inform a reliable planning, Adaptive Management is going to be the guiding principle for the implementation of underground repair works. EPM will be able to issue an update of the schedule in the next few months, after completing the dewatering and the assessment of the needed rehabilitation works.

Cost estimates are even more uncertain than schedule. For the time being, too few elements are available to reliably update the estimates which were made in September 2018. Based on current knowledge, it is safe to keep the September estimates for financial purposes. Expectedly, cost estimates should be updated in the third quarter of 2019.

Annex: List of documents made available to the IAP

- DECISIÓN DE CIERRE DE LA COMPUERTA No. 1 - Informe ejecutivo
    - [Anexo 1] Informe N°19 de la Junta de Asesores, Medellín, enero 2019
    - [Anexo 2 a] ANÁLISIS DE CAPACIDAD DE LA ESTRUCTURA DE CAPTACIÓN, INTEGRAL, 2019
    - [Anexo 2 b] Flujo por la Casa de Máquinas Cierre compuerta No 1, Integral, febrero 4 de 2019
    - [Anexo 3] Escenarios de cierre de compuerta considerando aportes de Salvajina, Unidad Hidrometría y Calidad Generación Energía, 04/02/2019
    - [Anexo 4] Análisis de Riesgos de los escenarios para el cierre de la compuerta No. 1 en el Proyecto Hidroituango, VPE Finanzas Corporativas, Gestión de Riesgos e Inversiones, Dirección Ingeniería de Riesgos, febrero 04 2019
- Presupuesto y el cronograma de construcción actualizados para el Proyecto Ituango, EPM
- Cronograma Ituango Feb 25 _ 2019, EPM
- Respuesta para el BID (marzo 4 de 2019) V2, EPM.
- Reporte de resultados de la simulación CFD-FSI-FEA de maniobra de cierre de las compuertas de aducción en condiciones de contingencia, INTEGRAL, septiembre de 2018
- Avance informativo No. 124 / Medellín, 1 de marzo de 2019, EPM
- Resultados Subasta de energía firme 2022 -2023, EPM, Gerencia Mercado de Energía Mayorista, 07/03/2019
- RESULTADOS TRABAJOS DE EXPLORACIÓN DIRECTA ZONA NORTE CONDUCCIÓN, INTEGRAL, 03 03 2019
- RESULTADOS TRABAJOS DE INYECCIÓN DURANTE LA CONTINGENCIA EN LA PRESA, , INTEGRAL, 03 2019
- ANÁLISIS DE INSTRUMENTACIÓN DE LA MARGEN DERECHA, INTEGRAL, 02 2019
- Cronograma de recuperación y Puesta en Operación del Proyecto Ituango, Presentación Gráfica y línea de tiempo de fechas de la última versión del cronograma, EPM, febrero 21 de 2019
- COSTO DE EQUIPOS CASA DE MÁQUINAS EN INUNDACIÓN, Inventarios, Registro fotográfico, Presentación BID, EPM, 2019.
- Subestación 500 kV Fotos, EPM.
- Presentación VP Proyectos e Ing EPM _ Misión BID marzo 2019.
- INFORME DE AVANCE DE LAS OBRAS DURANTE LA CONTINGENCIA EN EL PERÍODO MAYO DE 2018 A FEBRERO, INGETEC, febrero 28 de 2019.