大唐(老挝)北本水电有限公司
Datang (Lao) Pak Beng Hydropower Co., Ltd.

PAK BENG HYDROPOWER PROJECT

Sediment Management

POWERCHINA
KUNMING ENGINEERING CORPORATION LIMITIED

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1 MAIN SEDIMENT PRBOLEM ANALYSIS OF THE HPP

Construction of the reservoir on the river will influence the natural river sediment condition and the relative equilibrium state of the bed morphology, and readjust the river sediment and the bed morphology. Sediment deposition will be formed in the reservoir area by rising of water level in the reservoir area, increasing of water depth, retarding of water surface gradient, and conspicuous decreasing of sediment carrying capacity of flow. Reduction of flowing-out sediment will cause scouring of the downstream channel; water fluctuations between upstream and downstream during operation of the power station will also have a negative impact on the stabilization of the river banks. Change of water and sediment condition of upstream and downstream after completion of the power station may also have an impact on the survival of the aquatic creatures of upstream and downstream,

According to the above analysis and combining with the characteristics of Pak Beng Hydropower Station, potential sediment problems caused by the power station and impact on the surroundings include:

(1) Sediment deposition in the reservoir area will cause reduction of the effective storage capacity of the power station, affecting the power generation efficiency. As Pak Beng Hydropower Station is a Run-of-River hydropower station, with low rising of water level, inconspicuous sediment retaining effect and low requirements to effective storage capacity of the reservoir.

(2) Reservoir sedimentation and backwater will lead to raising the water level in the reservoir area, which further have a submerge impact at KengPhaDai in the tail section.

(3) The sediment deposition at the project area, especially the water intake of the power station may affect the water intake safety of the reservoir.

(4) The sedimentation in the entrances of the upstream and downstream approach channels will affect the navigation.

(5) Sediment reduction of flowing-out caused by sediment retaining may lead to scouring of the downstream river channel, and may have an impact on the fish in the downstream channel at the same time.

(6) Upstream and downstream water level fluctuation caused by the operation of the power station may lead to instability of the river bank.

2 MEASURES OF SEDIMENT MANAGEMENT

The impacts may be caused by sediment problems and on the surroundings when the power station putting into operation can be handled or mitigated by adopting corresponding measures by leaving discharging channels for coarse particles and fine particles in the complex layout during design of the power station and by adopting corresponding measures of sediment scheduling and management according to Preliminary DG of LMB Mainstream

Dams by Mekong River Committee (MRC).

2.1 COMPLEX LAYOUT AND SEDIMENT RELEASING FACILITIES OF THE HPP

The complex construction is composed of water retaining construction, discharge construction, power station construction, navigation construction and fish passing construction. According to Preliminary DG of LMB Mainstream Dams and the recommendations of CNR consulting experts, the recommended layout plan of complex for Pak Beng Hydropower Station is shown in the Attached Figure.

Water retaining construction includes left-bank non-overflow dam section, powerhouse dam section, flood-discharging and sand-sluicing gate dam section, lock dam section and right-bank non-overflow dam section. Elevation of the dam crest is 346.00m, and the maximum dam height is 69m. The dam crest length is 896.50m. The powerhouse dam section is located on the main channel area on the left side,-flood-discharging and sand-sluicing gate dam section is located on the on the beach land on the right bank, the lock dam section is placed on the right bank, and the non-overflow dam sections are arranged on the both banks.

The discharging construction is composed of sediment flushing gate, flood-discharging and sand-sluicing gate and sand sluicing outlet. The flood-discharging and sand-sluicing gate is located on the beach land on the right bank, and the sand-sluicing outlet is arranged on the powerhouse dam section. In order to prevent the bed load sediment entering the power station inlet, a silt sediment barrier is set in front of the dam section to lead the sediment in the flood-discharging and sand-sluicing gate, and the sediment is discharged to the downstream through the sluice holes.

It is preliminarily proposed to set 14 flood-discharging and sand-sluicing gates, with the opening size of 15m×23m.

To ensure “cleanness” of the power station intake, the sand-sluicing outlet is arranged on the powerhouse dam section, mainly used for discharging the suspended load sediment deposited before the powerhouse intake; a sand-sluicing outlet is arranged between every two units, 8 sand-sluicing outlets in total, with the opening size of 2.5m×6m opening size (width×height).

The station powerhouse is arranged on the main channel area on the left side of the river bed, and equipped with 16 bulb tubular turbine units; a erection bay is arranged on each end of the main powerhouse, an auxiliary powerhouse is set at the downstream of the main powerhouse, and an out-going line platform is set at the top of the auxiliary powerhouse crest. The powerhouse is set with 7 dam sections, with a total length of 410m.

The lock is designed as per navigation of 500t class ship. It is a single-wire single-stage lock, and arranged close to the right bank; the effective size of the lock is 120m×12m×4m (length ×width×threshold depth), and the upper lock head is arranged by combining the dam. For

facilitating flushing of the approach channel, a channel sand-sluicing gate is set on the right side of the lock. The straight length of the upstream approach channel is about 300m. The total length of the downstream approach channel is about 1142m, with a bottom width of 45m, bending radius of 330m, and turning angle of 63°40′28″.

The project of water intake and sediment control of the power station, discharging and flushing sediment of the reservoir is mainly composed of generating set, flood-discharging and sand-sluicing gate, sand-sluicing outlet and sediment barrier. Most of the suspended load sediment (over 80%) during daily generating of the power station is discharged to the downstream channel with the flow through the generating set; To prevent the bed load sediment entering the power station intake, a sediment barrier is set at the upstream of the station intake; the bed load sediment is intercepted by the sediment barrier and lead to the flood-discharging and sand-sluicing gate, and then discharged to the downstream channel through the flood-discharging and sand-sluicing gate; the flood-discharging and sand-sluicing gate holes are multiple with large discharge capability; 14 flood-discharging and sand-sluicing gates, with the opening size of 15m×23m are set for flood discharging and sand flushing, which can discharge the deposited sediment near the sediment barrier and flood-discharging and sand-sluicing gate, and reducing the sediment elevation before the flood-discharging and sand-sluicing gate when these gate open; Meanwhile, a sand-sluicing outlet (with the intake elevation of 288.9m) is set in the middle of every two station intakes (with intake elevation of 285.6m), 8 sand-sluicing outlets in total. The sediment across the sediment barrier will be discharged to the downstream by opening the sand-sluicing outlets; To settle the sediment deposition of the inlets and outlets of the upstream and downstream approach channels, a channel sand-sluicing gate (15m×23m) is set on the right of the lock, and the sediment at the entrance of the approach channel is flushed by opening the channel sand-sluicing gate.

2.2 RESERVOIR OPERATING MODES

2.2.1 Control of the reservoir sedimentation

Pak Beng Hydropower Station is a run-of-river hydropower station, with low raising of water level, inconspicuous sediment retaining effect; especially after cascade sediment retaining at the upstream, the incoming sediment decreases greatly, and the sediment particles are finer. Most incoming fine particle suspended load sediment (over 80%) is discharged to the downstream through the turbine. The reservoir has a lower requirement for the effective storage capacity. According to the deposition calculation results, most of the incoming sediment is discharged to the downstream, with a discharging rate of over 80%; therefore, the storage capacity loss is very small; the effective storage capacity and deposition loss is 7.16% after operation for 50 years, and the deposition loss is 10.24% after operation of 100 years. The power station will maintain a daily regulation performance.

According to the sediment characteristics of Mekong River, the sediment volume is mainly

concentrated in the wet season, especially when flood occurs, when the incoming flow is more than rated flow 5961 m^3/s, bottom hole and the flood gate opened gradually, reservoir water level maintains at 340m; when the incoming flow is more than 10000m^3/s, discharge volume of the flood gate increase gradually, reservoir water level reduce gradually from 340m. In order to ensure navigation the reservoir water level is maintained at 334m if the incoming flow is the P=33.3% flood discharge of 12,900m^3/s. If the incoming flow is higher than the P=33.3% discharge of 12,900m^3/s and lower than the P=20% flood discharge of 14,600m^3/s and inflows are higher than the standard for navigation of ship lock, use of ship locks shall be ceased, the discharging sluices open gradually and reservoir water level reduce gradually from 334m. If incoming flow is higher than the 5-year frequency flood discharge of 14,600m^3/s, all gate should be opened, the flood passing and sediment discharging are basically approached to the natural channel, the sediment is prevented from depositing in the reservoir, and partial sediment in the reservoir will be carried away at the same time.

During sediment discharging of the power station, priority should be given to open flood-discharging and sand-sluicing gates which near the powerhouse, which facilitating increasing passing of the bed load sediment and flushing the sediment deposition near the sediment barrier and flood-discharging and sand-sluicing gate; for sand-sluicing of the approach channel, the channel sand-sluicing gate near the lock shall be opened firstly.

Sediment discharging and flushing shall combine with the operation situations of the upstream station. When the upstream power station operates sediment flushing, and the monitored incoming sediment concentration from Pak Beng Hydropower Station is heigh, the gate of Pak Beng Hydropower Station shall be opened for sediment discharging, to prevent the sediment discharged from the upstream power station depositing in the Pak Beng reservoir area. It is recommended to establish a coordinated operating mechanism between upstream and downstream power stations, to real-time communicate the operation situations of the power stations and facilitate the operating scheduling of all cascade power stations.

2.2.2 Sediment control before water intake

To prevent the coarse sediment entering the power station, a sediment barrier is set at the upstream of the station intake; the bed load sediment is intercepted by the sediment barrier and lead to the flood-discharging and sand-sluicing gate, and then discharged to the downstream channel through the flood-discharging and sand-sluicing gate; the flood-discharging and sand-sluicing gate holes are multiple with large discharge capability; flood-discharging and sand-sluicing gates which near the powerhouse are requested to open in priority during discharging flood or scouring sediment, which facilitating discharging the deposited sediment near the sediment barrier and flood-discharging and sand-sluicing gate, and reducing the sediment elevation before the flood-discharging and sand-sluicing gate. In addition, a sand-sluicing outlet (with the intake elevation of 288.9m) is set in the middle of every two station intakes (with the intake elevation of 285.6m), 8 sand-sluicing outlets in total.

The sediment across the sediment barrier will be discharged to the downstream by opening the sand-sluicing outlets.

In 2011, the Sediment State Power Corporation Ministerial Key Laboratory, a well-known sediment laboratory in China, and Ministry of Education Key Laboratory for Water and Sediment Sciences (joint) of School of Water Resources and Hydropower Engineering of Wuhan University have been commissioned to carry out calculation of the plane two-dimensional sediment mathematical model of the complex area. Based on the calculation of the two-dimensional mathematic model, the research results and countermeasures on the sediment deposition before the dam are shown as follows:

(1) Sedimentation before the sediment barrier. At the end of the 5th year, the elevation in the upstream side of debris barrier is 315m, which is lower than the crest elevation of 325.0m. It shows 5 years after the reservoir runs, debris barrier plays an effective role in intercepting bed load. At the end of the 15th years, the elevation in the upstream side of debris barrier is 321m, and at this time the debris barrier can still play the role of intercepting the bed load to enter into the hydropower station; At the end of the 25th years, the elevation in the upstream side of debris barrier is 325m, which is close to the crest elevation, it shows that at this time, debris barrier is going to be of no effect in intercepting the bed load to enter into the power station. After the power station operates 30 years, debris barrier is of no effect. When flood release and scouring sluices are opened, for the depositing sediment in the debris barrier nearby, only the part close to dam section will be taken away and flushing effect of upper debris barrier isn’t obvious, for flow velocity is small.

(2) Sedimentation before the power powerhouse. The silting situation before intakes of units close to flood release sluices is better than the situation of units close to non-overflow dam section on the left bank. For example, after the power station operates 30 years, sediment before intake of number 5 unit will deposit to the elevation of 285.5m, which is basically the same level with the bottom elevation of sand ducts, the longitudinal profile gradient of funnel-shaped before which is about 1/2.84, ranging about 60 m. For number 14 unit, after the power station operates 10 years, sediment before intake of unit will deposit to the elevation of 290 m, exceeding bottom board elevation of 288.9 m of power station intake. After 30 years, sediment before intake of unit will deposit to the elevation of 293.5 m, the longitudinal profile gradient of funnel-shaped before which is about1/3.8, ranging about 60 m. The silting situation of units close to non-overflow dam section on the left bank is serious and the problem is prominent, which needs to take seriously.

(3) The scouring-silting situation before the flood release and scouring sluices. The flood release and scouring sluices has a great releasing capacity, and it will open sluice gates for sediment release, thus flushing effect is obvious, and the deposition before the dam is little. After 30 years, the gradient of funnel-shaped before flood release and scouring sluices is about 1/27.3, ranging about 200 m.

Once the power station is in operation, the monitoring of the sedimentation before the dam shall be strengthened, and the discharge outlet shall be opened non-periodically according to the monitoring results, to reduce the sedimentation before the intake, and prevent the outlet blocked by sand, water grass and other debris. The sedimentation before the sediment barrier is scoured by mainly opening the sediment flushing gate, flood-discharging and sand-sluicing gate, and a section shall be selected with a water level difference between the upstream and downstream, less sediment concentration, and rich flow during sand-sluicing according to the monitoring results of the sediment before the dam, and fish spawning period shall also be avoided. Sand-sluicing shall be real-time monitored and the flowing-out sediment concentration shall be controlled as much as possible to avoid impact on the fish and other aquatic creatures at the downstream caused by the high sediment concentration flow. In brief, modes of eco-friendly flushing for sediment shall be adopted. For the parts with poor flushing effect, artificial or mechanical dredging measures shall be taken to clear the deposits.

2.2.3 Sediment deposition in the approach channel

The channel where the power station is located is a navigable channel. Lock is arranged at the beach land on the right bank of the complex, and power station the river as a navigable river, and approach channels are set at the upstream and downstream. As less flow velocity in the approach channel, the flow usually appears at the entrance of the approach channel in the form of backflow, which often caused massive sediment deposition. The deposition is mainly located at the inlets and outlets of the upstream and downstream approach channels. To this end, a channel sand-sluicing gate (15m×23m) is set on the right of the lock, using broad-crested weir flow, with the weir crest elevation of 317.0m.

At present, the Sediment State Power Corporation Ministerial Key Laboratory, a well-known sediment laboratory in China, and Ministry of Education Key Laboratory for Water and Sediment Sciences (joint) of School of Water Resources and Hydropower Engineering of Wuhan University have been commissioned to carry out calculation of the plane two-dimensional mathematical model of the complex area and three-dimensional sediment mathematic model. According to the calculation of two-dimensional and three-dimensional mathematic models, the research results and countermeasures on the sediment deposition in the approach channels at the upstream and downstream are shown as follows:

(1) The silting situation in the entrance area of upper approach. After the reservoir runs, there will be accumulative deposition in the entrance area of upper approach. At the end of the 10th year, the depositing elevation will reach 334 m, and the navigation will be intercepted when it’s not at the flood season (the water level before dam is 335 m). At the end of the 20th year, water depth in the entrance area of approach doesn’t satisfy the navigation condition for the whole year, and the dredging projects measures should be taken.

(2) The silting situation in the entrance area of lower approach. After the reservoir runs, there will be accumulative deposition in the entrance area of lower approach. After 5 years, the maximum depositing thickness near the entrance area of lower approach is about 5.0 m. Under the lowest navigation discharge, the channel width in the approach channel and the velocity of backflow near the entrance area can still satisfy the navigation condition, but there is navigation obstruction trend.

After completion of the power station, monitoring the sediment deposition of the approach channel shall be strengthened. The sediment at the entrance of the approach channel shall be flushed by opening the sand-sluicing gate in the case of lower flow and larger head differences between the upstream and downstream. For the parts with poor flushing effect, artificial or mechanical dredging measures shall also be taken to clear the deposits.

After independent review by CNR, according to opinions of the review experts, basic information about hydrology, sediment, etc. has been updated, and the project layout has been adjusted. At present, the research institutes have be commissioned to recalculate the plane two-dimensional sediment mathematical model of the project area and three-dimensional sediment mathematic model according to the latest results. Currently, this work has been carrying out and will provide the latest research results and subjective report after it will have completed.

2.2.4 Downstream channel scouring

The sediment retaining effect of Pak Beng hydropower station is small, and most incoming sediment was ejected to downstream, so the construction of the power station won't basically change the conditions of incoming water and sediment. According to the similar project experience, when the power station is constructed, there isn't big influence on downstream channel scouring, but the problem of water lowering caused by partial riverbed undercutting in the downstream of dam still exits, withal, it has left room in the design of sluice bottom board of lower approach channel. The downstream Luang Prbang power station is connected with Pak Beng hydropower station, and after it's constructed, downstream channel scouring will be decreased because the downstream water level is raised. Meanwhile, a monitoring project specifically for deformation of the downstream banks is set in the sediment monitoring system to real-time control the deformation of the downstream banks, and appropriate engineering measures will be taken for treatment.

2.2.5 Bank erosion

Water level fluctuation of the upstream and downstream caused by impounding and operation scheduling and discharging clear water may have a certain impact on the stability of the bank slope of the upstream and downstream channels. a perfect sediment monitoring system is designed for Pak Beng Hydropower Station, with the monitoring concentration specifically for deformation of the bank slope in the system. After putting into operation of the power station, especially the early years of operation, monitoring the bank slopes at upstream and

downstream shall be strengthened. When found instability occurs in partial bank slope, engineering measures such as block protection, gabion protection shall be taken. Specific measures shall be determined according to the actual situations of the instability of the bank slope, and it is recommended that the Employer shall reserve certain of emergency treatment fees annually as the treatment fees of bank slope instability.

2.2.6 Eco-friendly flushing for sediment

Environmental requirements shall be emphasized during operation of the power station and flushing sediment, and the flowing-in and flowing-out sediment concentration shall be monitored in the sediment monitoring system. Flushing sediment shall use a mode of eco-friendly flushing for sediment, and the specific requirements are as follows:

(1)Duration selection of flushing

According to the research, generally the spawning period of the main fishes is from March to June, therefore, spawning period shall be avoided when flushing sediment, in doing so, and impact on the downstream fish spawning due to sediment flushing of the reservoir will be avoided. Violent water level fluctuation of the upstream and downstream shall also be avoided; otherwise, it will have adverse impact on the navigation, life of the coastal residents, etc.

(2)Monitoring and control of sediment flushing

Monitoring (including sediment concentration, gradation of the sediment particles, etc.) specifically for inflow and outflow sediment concentration is set in the sediment monitoring system. Monitoring of the outflow sediment concentration shall be strengthened during flushing sediment, and the gate shall be adjusted to control the outflow volume and sediment concentration according to the monitoring results during sediment flushing. The flowing-out sediment concentration shall be not allowed to exceed the maximum sediment concentration allowing fish to survive at the downstream channel.

Because the sediment tests by the Hydrological Station in the territory of Laos in the Mekong River are used with tour gauging method, the annual test times for sediment are less; while the test times in the upstream Chiang Sean Hydrological Station are relative more, with annual sediment tests over 50 times. Due to less test times, the maximum annual sediment concentration may be failed to be tested. According to the actual testing information of the station, the maximum daily average sediment concentration is 2.78kg/m^3, which occurred on August 14, 1978; Annual sediment tests in Yunjinghong Hydrological Station are about 3000 times and it is more frequently during flood period, therefore, the information accuracy is relatively high. The maximum sediment concentration by actual test is 19.4kg/m^3, which occurred on July 27, 1986. As the station is far away from the Pak Beng Hydropower Station, and the characteristics of the sediment in the river reaches may differ, the maximum sediment concentration is for reference only. At present, HYDROCHINA Kunming has been carrying out sediment tests at Pak Beng Hydrological Station, which will obtain more detailed sediment information. Gate may be opened gradually to flushing sediment according to the

situations, thus avoiding the sudden increase of the sediment concentration in a short time. the sediment concentration shall be monitored during flushing, and the impact on the downstream channel and fish shall also be monitored and investigated, which accumulate information and experience gradually in determining the reasonable flowing-out sediment concentration.

Navigation at the upstream and downstream river reaches shall be prohibited in advance, and the downstream residents along the banks shall be notified to suspend hypertensive surface operation, monitoring of the upstream and downstream river reaches shall be strengthened to avoid risk of hypertensive surface operation and deformation of the bank slope caused by violent flow and water level variation of the downstream during flushing sediment.

2.3 MONITORING AND MANAGEMENT

Perfect sediment monitoring design scheme is compiled in the feasibility study and design. For the detailed design, see < Overall design report of sediment monitoring system>. Main sediment monitoring items include:

(1) Monitoring water and sediment in/out the reservoir (including: sediment volume, sediment concentration and sediment gradation of the inflow station and outflow station);

(2) Observation of water surface line of the front dam and tail section;

(3) Observation of sedimentation in the reservoir area;

(4) Observation of sedimentation in the project area;

(5) sediment deposit in approach channel;

(6) Monitoring of downstream river course;

(7) Monitoring of the channel trend and bank slope deformation.

All sediment monitoring data are required to be integrated and analyzed to provide detailed and reasonable guidance for the sediment scheduling and management.

Different treatment measures are listed for different sediment problems in the operating mode of sediment discharging and sediment management. The main measures are as follows:

(1) According to the sediment characteristics of Mekong River, the sediment volume is mainly concentrated in the wet season, especially when flood occurs, when the incoming flow is more than rated flow 5961 m^3/s, bottom hole and the flood gate opened gradually, reservoir water level maintains at 340m; when the incoming flow is more than 10000m^3/s, discharge volume of the flood gate increase gradually, reservoir water level reduce gradually from 340m. In order to ensure navigation the reservoir water level is maintained at 334m if the incoming flow is the P=33.3% flood discharge of 12,900m^3/s. If the incoming flow is higher than the P=33.3% discharge of 12,900m^3/s and lower than the P=20% flood discharge of 14,600m^3/s and inflows are higher than the standard for navigation of ship lock, use of ship locks shall be ceased, the discharging sluices open gradually and reservoir water level reduce

gradually from 334m. If incoming flow is higher than the 5-year frequency flood discharge of 14,600m^3/s, all gate should be opened, the flood passing and sediment discharging are basically approached to the natural channel, the sediment is prevented from depositing in the reservoir, and partial sediment in the reservoir will be carried away at the same time. Water level shall be lowered to transport sand to flush partial sediment in the reservoir area according to the sediment monitoring after the power station putting into operation.

(2) Monitoring of the sedimentation before the dam is set in the sediment monitoring system. The monitoring of the sedimentation before the dam shall be strengthened after the power station put into operation. The sand-sluicing outlets shall be opened non-periodically according to the monitoring results, to reduce the sedimentation before the intake, and prevent the outlet blocked by sand, water grass and other debris. The sedimentation before the sediment barrier is mainly flushed by opening the flood-discharging and sand-sluicing gate. For the parts with poor flushing effect, artificial or mechanical dredging measures shall be taken to clear the deposits.

(3) After completion of the power station, monitoring the sediment deposition of the approach channel shall be strengthened. The sediment at the entrance of the approach channel shall be flushed by opening the sand-sluicing gate in the case of larger flow and head differences between the upstream and downstream. For the parts with poor flushing effect, artificial or mechanical dredging measures shall also be taken to clear the deposits.

(4) For the bank slope deformation after operation of the power station, the monitoring concentration specifically for deformation of the bank slope is set in the monitoring system. After putting into operation of the power station, especially the early years of operation, monitoring the bank slopes at upstream and downstream shall be strengthened. When found instability occurs in partial bank slope, engineering measures such as block protection, gabion protection shall be taken. Specific measures shall be determined according to the actual situations of the instability of the bank slope.

3 CONCLUSIONS AND RECOMMENDATIONS

Main sediment problems of Pak Beng Hydropower Station include: sedimentation in the reservoir area, sedimentation in the approach channel, sediment control before water intake, scouring of the downstream channel, deformation of the channel and bank slope, etc.

(1) Sedimentation in the reservoir area

Pakbeng Hydropower Station is a runoff power station. Its reservoir is featured with low backwater, large discharge and without sediment retaining effects. According to the sediment characteristics of Mekong River, the sediment volume is mainly concentrated in the wet season, especially when flood occurs, when the incoming flow is more than rated flow 5961 m^3/s, bottom hole and the flood gate opened gradually, reservoir

water level maintains at 340m; when the incoming flow is more than 10000m^3/s, discharge volume of the flood gate increase gradually, reservoir water level reduce gradually from 340m. In order to ensure navigation the reservoir water level is maintained at 334m if the incoming flow is the P=33.3% flood discharge of 12,900m^3/s. If the incoming flow is higher than the P=33.3% discharge of 12,900m^3/s and lower than the P=20% flood discharge of 14,600m^3/s and inflows are higher than the standard for navigation of ship lock, use of ship locks shall be ceased, the discharging sluices open gradually and reservoir water level reduce gradually from 334m. If incoming flow is higher than the 5-year frequency flood discharge of 14,600m^3/s, all gate should be opened, the flood passing and sediment discharging are basically approached to the natural channel, the sediment is prevented from depositing in the reservoir, and partial sediment in the reservoir will be carried away at the same time. Regularly lower the water level to transport sand according to the monitoring after putting into operation of the power station, and discharge the partial sediment away from the reservoir.

(2) Sediment control before water intake

Pak Beng Hydropower Station is a run-of-river power station, and the sedimentation is less; especially after upstream cascade sediment retaining, the incoming sediment reduces greatly, and the sediment particles are also small; therefore, the problems for water intake and sediment control of the power station are not prominent. To prevent the coarse particles entering the power station, a sediment barrier is set at the upstream of the station intake; the bed load sediment is intercepted by the sediment barrier and lead to the flood-discharging and sand-sluicing gate, and then discharged to the downstream channel through the flood-discharging and sand-sluicing gate; the sediment deposit across the sediment barrier is discharged through the sand-sluicing outlets. The parts with poor flushing effect, artificial or mechanical dredging measures shall be taken to clear the deposits.

(3) Sediment deposit in approach channel

To settle the sediment deposition of the upstream and downstream approach channels, a channel sand-sluicing gate (15m×23m) is set on the right of the lock, using broad-crested weir flow, with the weir crest elevation of 317.0m; and the sediment at the entrance of the approach channel is flushed by opening the channel sand-sluicing gate. The parts with poor flushing effect, artificial or mechanical dredging measures shall be taken to clear the deposits.

(4) Downstream channel scouring

As Pak Beng Hydropower Station has less effect of sediment retaining, and most incoming sediment is discharged to the downstream, therefore, construction of the power station has less impact on the scouring of the downstream channel. After the downstream

power station putting into operation, the channel scouring will be greatly reduced due to the rising of the downstream water level.

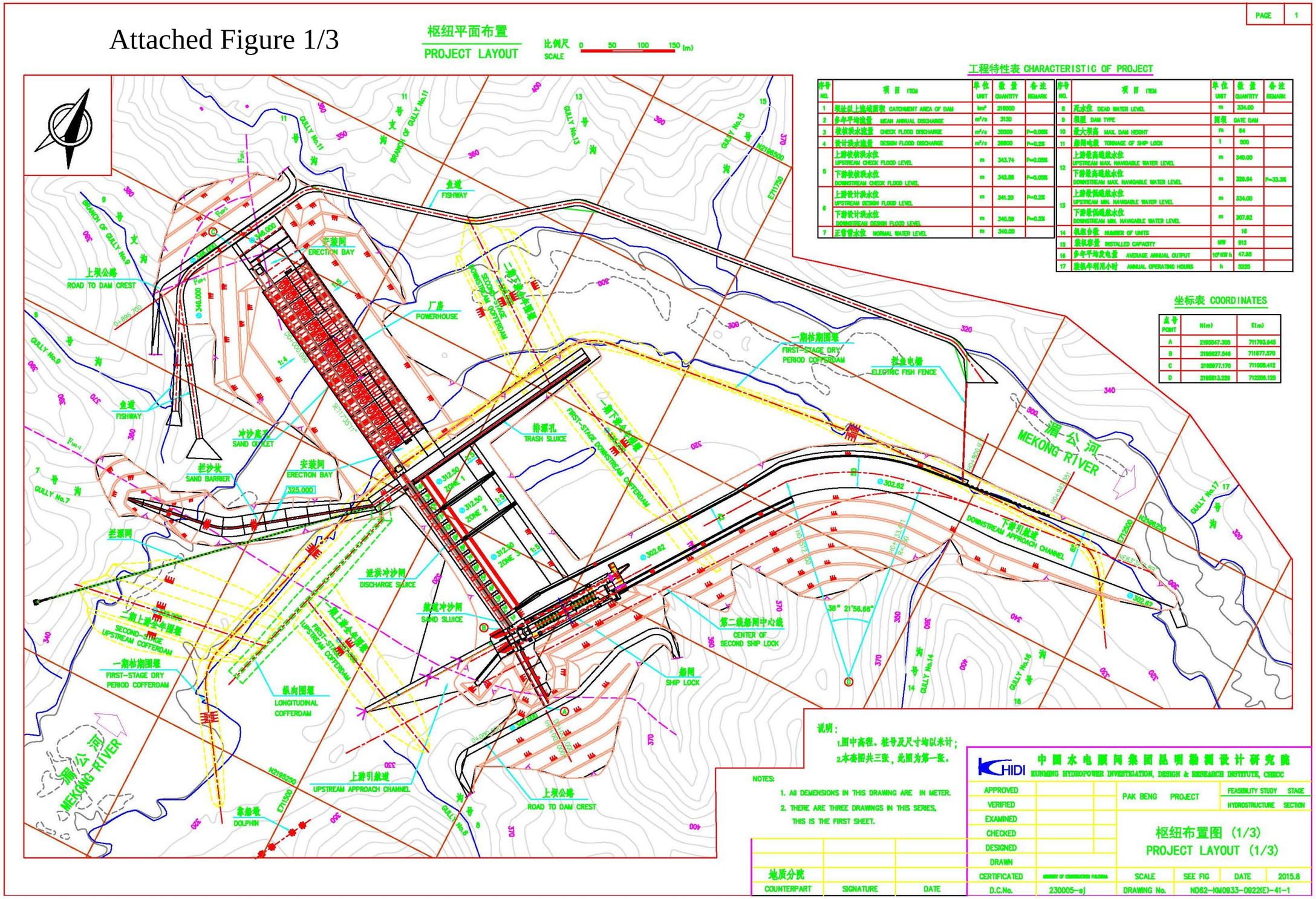
(5) River bank scouring

A monitoring project for bank slope deformation is design for Pak Beng Hydropower Station. After putting into operation of the power station, especially the early years of operation, monitoring the bank slopes at upstream and downstream shall be strengthened. When found instability occurs in partial bank slope, engineering measures such as block protection, gabion protection shall be taken. It is recommended that the Employer shall reserve certain of emergency treatment fees annually as the treatment fees of bank slope instability.

(6) Eco-friendly flushing for sediment

Fish spawning period (generally between March and June) shall be avoided when flushing sediment, in doing so, impact on the downstream fish spawning due to sediment discharging of the reservoir will be avoided. Gate may be opened gradually to flushing sediment according to the situations, thus avoiding the sudden increase of the sediment concentration in a short time. the sediment concentration shall be monitored during flushing, and the impact on the downstream channel and fish shall also be monitored and investigated, which accumulate information and experience gradually in determining the reasonable flowing-out sediment concentration. Meanwhile, the gate is opened gradually to avoid violent water level fluctuation between the upstream and downstream sections; otherwise, it will have adverse impact on the navigation, life of the coastal residents, etc.

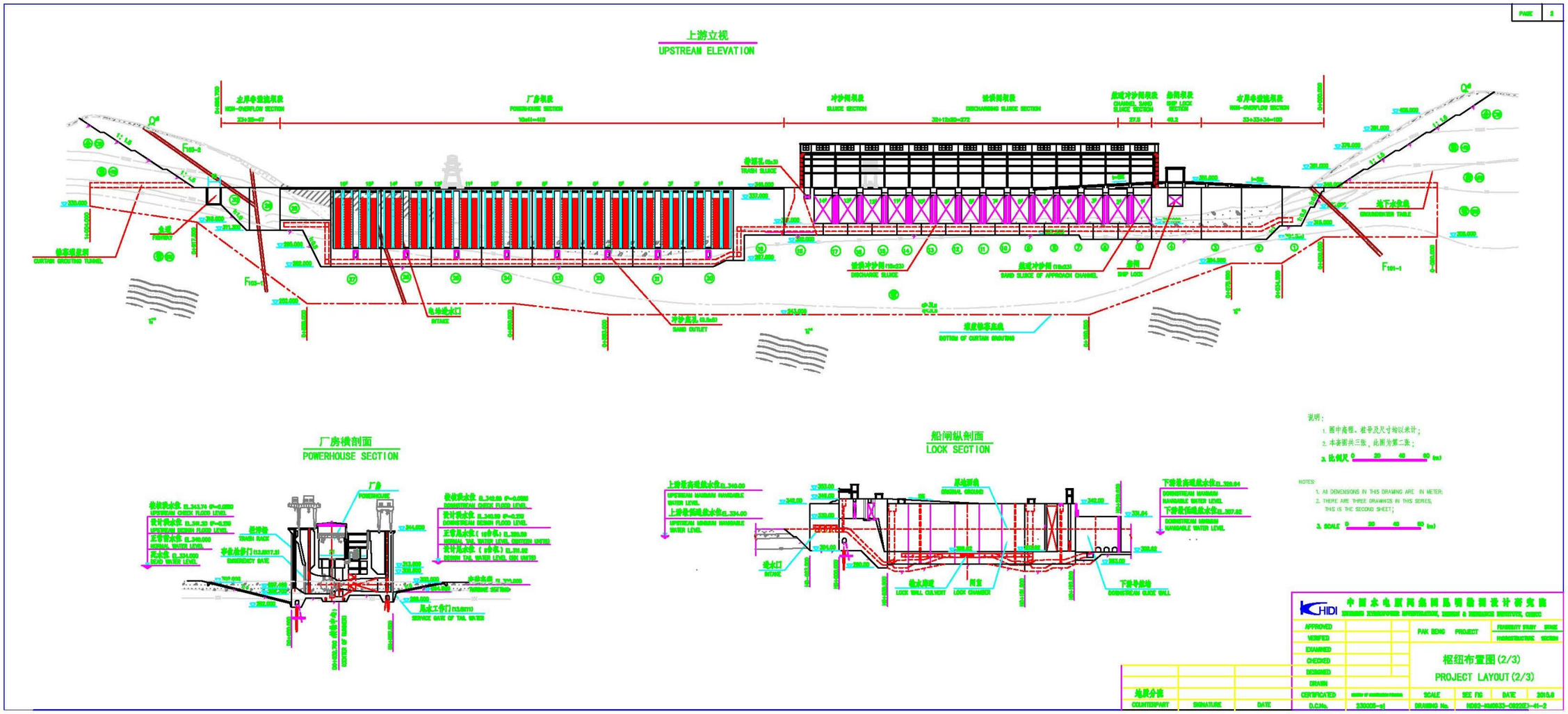
Attached Figure 1/3



序号 NO.	项目 ITEM	单位 UNIT	数量 QUANTITY	备注 REMARK
1	坝址以上流域面积 CATCHMENT AREA OF DAM	km²	216000	
2	多年平均流量 MEAN ANNUAL DISCHARGE	m³/s	3130	
3	校核洪水流量 CHECK FLOOD DISCHARGE	m³/s	30200	P=0.05%
4	设计洪水流量 DESIGN FLOOD DISCHARGE	m³/s	26800	P=0.2%
5	上游校核洪水位 UPSTREAM CHECK FLOOD LEVEL	m	343.74	P=0.05%
	下游校核洪水位 DOWNSTREAM CHECK FLOOD LEVEL	m	342.88	P=0.05%
6	上游设计洪水位 UPSTREAM DESIGN FLOOD LEVEL	m	341.20	P=0.2%
	下游设计洪水位 DOWNSTREAM DESIGN FLOOD LEVEL	m	340.59	P=0.2%
7	正常蓄水位 NORMAL WATER LEVEL	m	340.00	
8	死水位 DEAD WATER LEVEL	m	334.00	
9	坝型 DAM TYPE	闸坝 GATE DAM		
10	最大坝高 MAX. DAM HEIGHT	m	64	
11	船闸吨级 TONNAGE OF SHIP LOCK	t	500	
12	上游最高通航水位 UPSTREAM MAX. NAVIGABLE WATER LEVEL	m	340.00	
	下游最高通航水位 DOWNSTREAM MAX. NAVIGABLE WATER LEVEL	m	339.64	P=33.3%
13	上游最低通航水位 UPSTREAM MIN. NAVIGABLE WATER LEVEL	m	334.00	
	下游最低通航水位 DOWNSTREAM MIN. NAVIGABLE WATER LEVEL	m	307.02	
14	机组台数 NUMBER OF UNITS		16	
15	装机容量 INSTALLED CAPACITY	MW	912	
16	多年平均发电量 AVERAGE ANNUAL OUTPUT	10⁸KW h	47.85	
17	装机年利用小时 ANNUAL OPERATING HOURS	h	5225	

点号 POINT	N(m)	E(m)
A	2195547.305	711793.948
B	2195527.546	711877.570
C	2195977.170	711008.412
D	2195913.229	712206.128

Attached Figure 2/3



Attached Figure 3/3