OSHPC BARKI TOJIK

TECHNO-ECONOMIC ASSESSMENT STUDY FOR ROGUN HYDROELECTRIC CONSTRUCTION PROJECT

PHASE II REPORT (FINAL): PROJECT DEFINITION OPTIONS

VOLUME 3: ENGINEERING AND DESIGN

Chapter 1: Design Criteria

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Volume 3: Engineering and design

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CONTENTS

1   GENERAL

1.1   Applicability of the Design criteria

The present design criteria will be used for Phase 0, I and II of the project. More detailed design criteria will be elaborated for later phases of the studies and, in particular for detailed design:

- Phase 0: Assessment of the salt dome issue at the project site

- Phase I: Assessment of the Existing Rogun HPP site and Works

- Phase II: Rogun HPP Project Definition Options

These criteria are applicable to any component of Rogun project designed for a long term operation.

1.2   Existing works

The design criteria are applicable to any part of the existing works which will be integrated in any Stage of Rogun project to be designed for a long term operation. It means that, if necessary, the concerned existing works are not only to be rehabilitated, but they have to be adjusted or modified or reinforced in order to meet the design criteria.

1.3   Applicable General Recommendations

In general, we will follow the recommendations of ICOLD bulletins to apply international design standards for large dams to this project.

2   BASIC DATA

2.1   Dam Risk Classification

Dam risk classification will be performed in accordance with ICOLD recommendations to define the Risk Class that is applicable to Rogun. This risk classification will determine the choice of design flood and design earthquake (ICOLD Bulletins 148 and 82).

2.2   Design Floods

Design floods will be used in reservoir flood routing studies to determine the appropriate discharge capacity for the project. Design floods will be determined for intermediate stages of the dam construction taking into account the works schedule, in order to provide adequate protections against flood in consideration of the anticipated duration of each stage.

2.2.1   10,000 year Flood

The frequency analysis carried out in order to determine the 10 000 years flood (and floods for other return periods) will be based on a regional approach carried out in several steps:

- First step – Regional sample based on Vakhsh gauging stations,

- Other steps – First regional sample and transposed floods from rivers of the region having the same flood regime.

2.2.2   Probable Maximum Flood (PMF)

The derivation of Probable Maximum Flood will take into account the following guidelines / criteria. We recall that there is no standard method for PMF derivation. As stated by WMO in its publication about PMP derivation (1986), each case is specific due to data availability and climate patterns.

Data for PMF Derivation

The approach will be adapted to the available data. These data should encompass several types of data:

- Daily discharges at Rogun dam site.

- Monthly and seasonal rainfall at selected stations.

- Daily mean temperature at selected stations.

PMF Derivation

In a first stage of the study, the relation of daily discharge versus daily temperature will be investigated. This relation will be assessed for the rising limb of the hydrograph until the occurrence of the annual daily peak. It is likely that the relation will involve the degree-day factor which is the summation of positive temperatures preceding the date of occurrence of the annual maximum daily discharge.

In a second stage of the study, the relationship of daily discharge versus degree-day factor will be related to two independent variables which are:

- The seasonal precipitation, for instance the precipitation from October to May, as representative of the water available for melt.

- The degree-day factor at the occurrence of the annual maximum daily peak.

The third stage of the study will consist in maximising the obtained results in order to increase the daily peaks until reaching levels compatible with PMF concept. This maximisation is constrained by the fact that resulting PMF should be significantly greater than the 10 000-year flood.

Flood hydrograph will be obtained by defining a typical hydrograph shape based on historical floods.

Impact of Climate Change on PMF

The climate change will result in increasing temperatures. Precipitation forecasts by Climate Models are contradictory. Use will be made of observed data in order to find trends in temperature,

precipitation and discharge data. Care will be exercised when fitting "trends" to contemporary data and then extrapolating them into the future. Exploratory data analysis will be part of the initial data audit. Similarly, literature about Climate Change will be investigated in order to present an assessment about the period 2000 / 2100.

Glacial Lake Outburst Floods (GLOFs)

Additional freeboard has been taken into consideration for the risk of GLOFs as detailed in section 3.1. Detailed criteria will be elaborated during the next Phases of the studies.

Landslides within the Reservoir

The risks of landslides being triggered by reservoir impoundment, reservoir operation or earthquakes will be assessed and taken into account in the design as appropriate.

2.2.3 Construction Flood

In order to manage hydrological risks, it is essential that the construction of the dam is continuous above the level of the cofferdam.

A contingency plan will be developed in order to mitigate the hydrological risks in case this condition would not be possible.

The mean period of return of construction floods will be selected on the basis of the probabilistic approach; the accepted probability should be adapted to the construction planning (time of exposure) and the gravity of potential consequences in the case of flood occurrence.

The flood evacuation system should be such that at any step of construction, the reservoir level remains lower than the dam elevation less the adapted dry freeboard.

Allowance shall be made during intermediate construction stages for the appropriate discharge/safety against construction floods, as determined in Section 2.2.3 above.

Appropriate spillway capacity should be in place to handle the design floods at any stage of construction.

2.3 Geological/geotechnical data

The design, including design of any required remedial treatment will use the existing data from previous geological investigations and also findings of the supplementary geological investigations undertaken in 2012.

2.4 Seismic design parameters including MCE acceleration, fault movement

In general, the Consortium will follow the recommendations of ICOLD bulletin 148 (2010). In brief:

- At this stage of the study, only two levels of earthquake will be considered: OBE and MCE. No consideration will be given to MDE.

- The Maximum Credible Earthquake (MCE) is the largest reasonable conceivable earthquake that appears possible under the presently known or presumed tectonic framework. It is determined by regional and local studies that include a review of all historic earthquake data of events sufficiently nearby to influence the project, and a review of the parameters attached to the local faulting.

- The Operating Basis Earthquake (OBE) is the level of earthquake for which only minor damage is accepted. The probability of occurring of the OBE should be about 50% during the service life (100 years); the corresponding return period is 150 years.

- Ratio of the horizontal to vertical design accelerations derived for MCE and OBE earthquakes will be selected on the basis of the outcomes of the studies on seismic hazard assessment.

- The studies on the seismic hazard assessment will allow determining the design spectra to be adopted in the analyses.

As active faults (Ionaksh, #35 and possibly others) cross the structures, evaluation of their co-seismic displacements has to be made for MCE and OBE events, in addition to the a-seismic displacements.

2.5 Sedimentation

At this stage of the studies, as no measurement of sediment content in the Vakhsh river was made recently, compilation will be made of the information presented in the HPI reports dated 2009.

3 DESIGN CRITERIA FOR THE DAM

3.1 Freeboard

The freeboard will be calculated on the basis of the recommendations of the USBR given in the document "Freeboard criteria and guidelines for computing freeboard allowances for storage dams", revised in 1992.

Furthermore, for the embankment dam, a dry freeboard shall include the allowance for permanent settlements, wave run up and GLOF. The freeboard for GLOF allowance will be estimated by using the following formula:

Additional freeboard $m = \frac{500}{S(km^2)}$

$S(km^2)$ being the area of the reservoir for the maximum water level. Therefore a very significant additional volume of 500 hm3 is available for damping unexpected artificial flood events.

The adequacy of the proposed freeboard will be reviewed when more information is collected, related to GLOFs and risk of slope instabilities (further phases of the studies).

3.2 Embankment

<u>Stability</u>

For all design stages, stability of the embankment dam will be checked on the basis of a two dimensional analysis, by using the effective strength parameters and the Bishop method. The usual design values of the USBR will be applied for the static cases (see following table extracted from Design standards n°13 – Chap 4):

Loading condition	Shear strength parameters	Pore pressure characteristics	Minimum factor of safety
End of construction	1. Effective	Generation of excess pore pressures in embankment and foundation materials with laboratory determination of pore pressure and monitoring during construction	1.3
		Generation of excess pore pressures in embankment and foundation materials and no field monitoring during construction and no laboratory determination	1.4
		Generation of excess pore pressures in embankment only with or without field monitoring during construction and no laboratory determination	1.3
	2. Undrained strength		1.3
Steady-state seepage	Effective	Steady-state seepage under active conservation pool	1.5
Operational conditions	Effective or undrained	Steady-state seepage under maximum reservoir level	1.5
		Rapid drawdown from normal water surface to inactive water surface	1.3
		Rapid drawdown from maximum water surface to inactive water surface	1.3
Unusual	Effective or undrained	Drawdown at maximum outlet capacity	1.2

Note*:*
According to USBR, unusual load conditions are: inoperable internal drainage, and unusual drawdown

Consideration about the 3D effects involved by the valley features will be included in Phase II of the studies. However three dimensional analysis will be carried out during the next Phases of the studies.

For the analysis of the behaviour of the dam in case of MCE, irreversible displacements due to seismic events on earthfill and rockfill dam will be computed. The first step of the computation will be to determine several sliding circles and the associated limit acceleration corresponding to a safety factor of 1. Then, by using the various accelerograms resulting from the seismic studies, the displacements along each critical circle will be calculated.

The order of magnitude of the displacements resulting from this analysis will have to be considered as a reference only, as it cannot be considered as representative of the actual behaviour of the

dam during an earthquake event. The results will be compared with the results of the calculations carried out by Hydroproject Moscow for the dam at elevation 1300, which have anyway to be reviewed.

During the MCE, the global stability of the dam must insure that the crest elevation will be superior to the Maximum Water Level of the reservoir. The overall stability of the dam must be insured in any circumstance (in particular continuity of the core should be maintained).

Seepage

Attention will be paid to ensure that seepage is contained within acceptable limits with anti-seepage measures being implemented, especially with regard to the salt dome and dam/cofferdam foundations and abutments. Leakages bypassing through the far side of the right abutment and the continuation of Ionaksh fault may result in salt/gypsum dissolution and appropriate measures have to be considered such as an extension of the grout curtain.

Principles for the grout curtain under the dam have to be developed for both its depth pattern and into the abutment (depending on the hydraulic gradient recorded in the abutments)

The possibility of linear seepage paths, towards downstream, along faults associated with salt intrusions such as the Gulizindan fault (if elevations of water table allow), or inversion of feeding routes of springs will be studied. If necessary, mitigation measures must be developed to reduce seepage.

Settlements

Account will be taken of the long term settlements of the dam embankment and its foundations to ensure adequate freeboard is retained.

3.3 Design criteria of filters and transition

3.3.1 Filter criteria

We propose to use the recommendations of the USBR, 1994.

Filter criteria

Base Soil Category	Base Soil Description, and Percent Finer than 0.075mm (1)	Filter Criteria (2)
1	Fine silts and clays; more than 85 percent finer	$D_{15}(F) \leq 9 \times d_{85}(B)$ (3)
2	Sands, silts, clays, and silty and clayey sands; 40 to 85 percent finer	$D15(F) \leq 0.7$ mm
3	Silty and clayey sands and gravels; 15 to 39 percent finer	$D_{15} \leq \dfrac{40-A}{40-15}\left(4 \times d_{85} - 0.7mm\right) + 0.7mm$ (4) (5)
4	Sands and gravels; less than 15 percent finer	$D15 \leq 4 \times d85$ (6)

Notes:

D = Filter; d = Base Soil.]

(1) - Category designation for soil containing particles larger than 4.75 mm is determined from a gradation curve of the base soil which has been adjusted to 100 percent passing the No. 4 (4.75 mm) sieve.

(2) - Filters are to have a maximum particle size of 3 inches (75 mm) and a maximum of 5 percent passing the No. 200 (0.074 mm) sieve, after compaction, with the PI (plasticity index) of the fines equal to zero. PI is determined on the material passing the No. 40 (0.425 mm) sieve in accordance with USBR 5360, *Earth Manual*. To ensure sufficient permeability, filters are to have a $D15$ size equal to or greater than $5 \times d15$, but no smaller than 0.1 mm.

(3) - When $9 \times d85$ is less than 0.2 mm, use 0.2 mm.

(4) - A = percent passing the No. 200 sieve after any regrading.

(5) - When $4 \times d85$ is less than 0.7 mm, use 0.7 mm.

(6) - In Category 4, the $d85$ may be determined from the original gradation curve of the base soil without adjustments for particles larger than 4.75 mm, provided that the soil is not gap-graded or broadly graded.

3.3.2 Criterion to prevent segregation

We also propose to use the recommendations of the USBR, 1994.

Grading Limits to Prevent Segregation (USBR, 1994)
Minimum D10 (mm) Maximum D90 (mm)

Minimum D_{10} mm	Maximum D_{90} mm
< 0.5	20
0.5-1.0	25
1.0-2.0	30
2.0-5.0	40
5.0-10	50
10-50	60

3.3.3 Base soil analysis

As recommended on the ICOLD's bulletin 95, before starting the design of a filter, it is necessary to check whether the base soil is internally stable or not. We propose to use the Kenney and Lau method: it consists first in dividing the grading curve of the base soil into a coarse fraction and in a finer fraction, then in using the Terzaghi criterion for the comparison between the D15 of the coarser fraction with the d85 of the finer fraction; if the ratio is less than 5, then the material is self-filtering and therefore stable.

Should the base soil be not stable, then the filter will have to be designed for the fine fraction.

3.4 Criteria for dam design to accommodate regional seismicity

We will follow the recommendations of the ICOLD bulletin 120: "Design features of dams to resist seismic ground motion" (2001).

The main recommendations applicable to the design of the embankment dam of Rogun are reminded hereafter:

- Foundation must be excavated to very dense material or rock,

- The necessity of reinforced concrete foundation for core of the dam will be assessed.

- The transverse foundation slope across the core zone should be either horizontal or slope gently upstream along the upper 30 m of the abutments of high dams, to assure watertight contacts after shaking and/or preclude excessive settlement of the embankment materials.

- The shaping of the foundation/core contact should be gentle and free of sharp and re-entrant edges. The transverse foundation slope across the core zone should be less steep than 4h:1v from upstream to downstream.

- Filters must be provided on fractured foundation rock to preclude piping of the embankment into the foundation, should the fractures be opened by the earthquake.

- Wider than normal filter and drain zones must be used to provide continuity should zone offset occur and to heal any transverse cracks caused by the earthquakes.

- The upstream and /or downstream transition zones should be self-healing, and of such gradation as to also heal cracking within the core zone.

- The core contact along the upper portions of the abutments should be flared to assure long seepage paths through cracks in the abutments caused by the earthquakes.

- "Brittle soils should be avoided for use as water barriers and/or should be replaced with more plastic materials in areas where tension is more likely to develop during earthquake shaking.

- Since settlement and transverse cracking under strong shaking are possible, the dam should have a larger freeboard than normal to increase lateral dimensions at the maximum water surface. Sufficient freeboard should be provided in order to cover the settlement likely to occur during the earthquake and possible seiches.

These recommendations are not standards; they will be generally adhered to; if, for any reason, it is not possible for one of them, then it will be replaced with an alternative solution. For instance one of the recommendations of this bulletin is to have a longitudinal core foundation slope less steep than 2h:1v. The shape of the valley does not allow following such recommendation. The criterion to be used will therefore be to place against the bank about 4 m of plastic material, with a water content significantly higher than the water content at OPS (about 4%).

3.5   Criteria for faults crossing

3.5.1   Embankment

The dam design should accommodate foundation fault creep and displacement. Within a **distance of 50 m of the active fault, the thickness of any layer in the direction of the** movement of the active fault should be at least 1.5 times the fault displacement.

3.5.2   Tunnels

Measures shall be put in place to ensure that long term fault movements do not jeopardise the performance of the hydraulic operations of tunnels. The tunnels routes shall be studied so to avoid or minimize the crossing of active faults with pressure stretches; special structures (intakes, gates rooms, transitions, etc.) shall be located as far as practicable from faults. In correspondence with faults crossing, provisions shall be made to allow relative movements of tunnel short sections, designed to support large external loads, avoiding the tunnels lining collapse. The need for programmed maintenance interventions is anticipated.

3.6   Salt wedge

In addition to treatment of the upper, weathered part of the wedge, the following measures will be defined:
-   installation of a monitoring system to follow-up performance of the treatment works during reservoir filling and operation;
-   definition of a contingency plan which identifies remedial measures to be implemented in case the monitoring system triggers pre-defined indicators (see also paragraph 3.3).

3.7   Banks slopes

The banks presenting risks of future instability during reservoir impoundment shall be assessed and provisions shall be planned for necessary support, drainage or reshaping.

4 DESIGN CRITERIA OF HYDRAULIC WORKS

4.1 General

Layouts, characteristics and shape of hydraulic structures shall be as indicated in the relevant drawings.

During the detailed design phases of the studies, for major hydraulic structures or structures of particular complexity, studies on hydraulic models may be required to confirm the adequacy of the design, to test alternative solutions and determine detailed characteristics and special requirements, in order to arrive at an optimized design.

In principle, hydraulic design for project structures shall conform to the general criteria as set forth in the following paragraphs, except where in conflict with explicit requirements for individual cases.

The main hydraulic facilities envisaged for the project are the following:

- Diversion tunnels;

- Headrace tunnels;

- Tailrace tunnels;

- Spillways

4.2 Design Criteria for Power Waterways

Given the size of the units and the considerable relevant design flow, for the final design (powerhouse with maximum capacity) one independent waterway for each generating unit will be adopted. The dimension of the tunnels will be defined based on the concept of the economic diameter

4.3 Design criteria for Spillways

Due to the size and, importance of Rogun, and as well as due to the downstream risks, as addressed in Section 2.1, the Project should be designed for two levels of flood, and this whatever is the final height of the dam:

- the 10 000 years flood,
- the PMF.

For rockfill dam with internal core, the maximum reservoir level has to be compared with the crest elevation of the core (therefore lower than the crest of the dam) less than the expected maximum settlement (or by consolidation or as the consequence of an earthquake), or long term core's crest elevation.

Assuming N orifice spillways and n gates for the surface spillway (for n=0, the surface spillway is a free-overflow spillway):

- for the 10 000 years flood, either with N-1 orifice spillways or with the n-1 gates of the surface spillway(s) (n-2 if the number of gates is more than 6), the maximum water level

should be not higher than RL less the total dry freeboard. Note that it is the tunnel with the largest expected discharge which should be considered as being not in operation.

- For the PMF, with the N orifice spillways and the n gates of the surface spillway, the maximum water level should be not higher than reference level (RL) less the total dry freeboard.

Concrete surface treatment

Whenever the spillways surfaces are constituted by concrete slabs/lining only, provided that high standard strength and surface finishing are adopted, the speed of the water flow in the spillways can reach 30 m/s or so.

Above that value, proper aeration devices shall be provided at the bottom and lateral sides of the hydraulic facilities working in free-flow conditions, to prevent cavitation problems.

Aeration shall also be provided in those stretches in which change of working conditions (from pressure flow to free flow or vice-versa) is expected.

Whenever the flow may carry solid material coming from sediments deposits in the reservoir, steel lining or other anti-erosion material should protect the surfaces likely to the eroded.

Some criteria to be adopted for specific structures of the hydraulic facilities are provided in the next paragraphs.

4.4 Specific Design Criteria for Other Structures

Inlets, Intakes and water entrances shall be shaped so that water is subjected to progressive, gradual acceleration.

Entrances and Upstream Ends of Piers shall be shaped according to Hydraulic Design Criteria of US Corps of Engineers Manuals, Bureau of Reclamation Manuals or other Hydraulic Criteria of reputable authors of technical literature.

Downstream Ends of Piers, where open-channel flow conditions prevail, shall be square cut on a plane roughly perpendicular to flow. Ample air supply shall be provided at the downstream face of pier, to prevent cavitation.

Bends, horizontal or vertical, in pressure conduits shall be designed so that a minimum positive pressure equivalent to 5 m of water is ensured on the conduit surfaces at the inside of the bend, notwithstanding the hydrodynamic effects due to centrifugal force.

Divergent Transitions (e.g. upstream of the gates) shall be designed so to provide a very gradual change in the water velocity and following the criteria provided by US Corps of Engineers Manuals, Bureau of Reclamation Manuals or other Hydraulic Criteria of reputable authors of technical literature.

Guide Recesses and Slots for gates shall be designed for minimizing the risk of cavitation, with round corners and depressed and tapered downstream edges.

Joints in Conduits, either structural joints or ends of steel liners shall be located so to avoid areas of hydrodynamic peaks or possible cavitation. Joints shall not be allowed at the initial or terminal sections of divergent transitions.

Transversal contraction joints in conduits subject to high velocity flow shall have the upstream edge rounded and the downstream edge depressed and tapered up.

Overflow Profiles shall be designed for a design head 20 % higher than the maximum expected effective head, so as to ensure positive pressure along the downstream surface.

5   DESIGN CRITERIA OF THE UNDERGROUND WORKS

5.1   General

Most of the Underground Works here below enumerated are already excavated and fully or partly lined/supported in accordance to the pre-existing design. Just some of them have still to be designed and excavated. The underground works are:

- the Headrace Tunnels

- the Pressure Shafts

- the Transportation Tunnels

- the Temporary Service Tunnels

- the Diversion Tunnels

- the Middle Level and Bottom Level Outlets and appurtenant Shafts

- the Tailrace Tunnels connections to the system

- the Manoeuvres' Chambers for the Gates Operation Devices

- the Powerhouse & Transformers Caverns and relevant Tunnels and Cable Shaft

5.2   Phase I: Assessment of the Existing Rogun HPP Site and Works

During this phase of the Project, the available design of the Works already executed will be duly reviewed for assessing their appropriateness to the project. This includes the existing design of all tunnelling, shafts, chambers and caverns like the power house and transformers hall.

The tunnels are to be designed (recommended strengthening measures or new linings) so to make the structures capable to resist:

- Loads due to rock-lining interaction.
- Seismic loads;
- Water pressure, not less than 200 kPa for all stretches upstream from fault 35 and 100 kPa for stretches downstream from the same.

Detailed calculations have to be carried out to define the details of the scheme of interventions, which may have to be adapted to the local conditions, on account of rock mass characteristics and structure location.

5.3   Phase II: Rogun HPP Project definition options

During this phase of the Project, the remaining works, not yet executed, which mainly consist of some tunnels and valves operating chambers, will be designed with the main scope to establish appropriate technical features of the works (geometrical characteristics, temporary supports, concrete thicknesses and reinforcements) for a reliable operation and for carrying out a pre-estimate of the relevant quantities for the best ranked technical and economic alternative. Therefore, during this phase, simple empirical design criteria may be adopted based on:

- Rough estimate of the rock mass characteristics (RMR);

- Predimensioning of the temporary supports based on Barton classification, where appropriate;

- Predimensioning of the lining thickness as a function of the RMR. Lining thickness may range between 1/9 and 1/12 of the diameter for the tunnels and shafts.

5.4   Earthquake effects on stability and integrity of underground structures

The seismic effects on the Caverns and Tunnels stability shall be estimated taking into account:

- The static and dynamic geo-technical properties of the rock masses.

- Selection of the constitutive laws parameters of the various materials of the rock masses.

Implementation of the static stress – strain analysis results, respectful of the construction sequence, in order to take into account, especially for the Caverns, the actual state of stress applied to the installed anchors and linings.

For this stage of the Project, the seismic effects will be evaluated by means of a pseudo-static analysis based on the values of peak accelerations evaluated at the elevation of the specific underground work. The accelerations values will be gathered from the available documentation.

6   SCHEME OPERATING CRITERIA

6.1   Safety criteria for reservoir operation

The Rogun Project will be designed to handle the PMF flood. Modelling of the operational discharge regime of Rogun will be a part of the Cascade Operations Model, including reservoir flood routing.

Rogun Project shall attenuate the PMF in order to protect the Nurek dam.

Floods during construction have been covered in para. 2.1.3 Construction floods.

6.2   Rate of filling and emptying

The rate of reservoir filling and emptying should be controlled in such a way that:

- the intensity of triggered seismicity can be controlled or reduced by limiting the impoundment rate.

- the hazards of landslides in the banks of the reservoir can similarly be limited or controlled by lowering the impoundment rate.

- no more than   1.2 km^3 may be stored every year in Rogun reservoir. It represents the difference between the average volume of water allocated to Tajikistan and the average volume of water actually withdrawn in Tajikistan (for the Vakhsh river only).

There is no need to consider the two first operation criteria for the phases 0 to II of the design. Consideration will be only given to them for the further phases of the studies.

6.2.1   Emergency Dewatering

 Should a rapid reservoir drawdown be needed, the drawdown rates should not endanger the safety of the dam. The capacity of the facilities designed as per para. 4.1 shall be consistent with the expected drawdown rate.

6.3   Use of water

The reservoir operation study will be based on the principle that the present use of water is accepted by all parties, and that the Vakhsh river operation principle shall remain unchanged. This means that the present volume of water transferred from summer to winter thanks to the Nurek reservoir shall remain unchanged when Rogun and Nurek will operate jointly.

6.4   Energy production

The studies of reservoir operation will aim at optimizing the energy output consistent with the above stated principle of unchanged Vakhsh cascade operation. The optimisation concerns not only Rogun but all downstream hydro-power plants along the cascade. Optimisation concerns both guaranteed energy and total energy produced.

Early generation shall be studied to bring as much benefit as possible to the project.

7   SEDIMENT MANAGEMENT

Mitigation measures addressing the sediment impacts shall be considered to confirm the long term dam safety.

The reservoir operating rules will have a large influence on the way sediment deposits take place. Attention has therefore to be paid in the operation simulations to the variation of reservoir elevation throughout the year, particularly during the flood season.

For instance, a reservoir remaining high:

- leads to a reduction of the live storage,
- but hold sediments away from the powerplant intakes for a longer time,

In addition, in a site as Rogun with intense seismic activity, attention has to be paid to the liquefaction potential of the sediment deposits for their potential impact on the intakes of the tunnels.

The concern of assuring a satisfying sediment management will also deeply impact the arrangement of the spilling facilities and the selection of the type of spillways. For instance the vortex spillways can only be envisaged for spilling water totally free of sediments.