Techno-Economic Assessment Study
Rogun HPP

Phase II Considerations

Riparian Consultations

July 2014

Engineering and Dam Safety Panel of Experts

Presenters: R.Gill (Chair), L.Spasic-Gril,

Prof. Dr. E. Todini

Engineering and Dam Safety Panel

Roger Gill (Chair)	Hydropower Policy
Ljiljana Spasic-Gril	Dam Engineering/Dam Safety/ Seismic Engineering
Prof. Dr. Paul Marinos	Engineering Geology/ Rock Mechanics
Prof. Dr. Ezio Todini	Hydrology (Dr Peter Adamson until October 2012) *(also member of ES PoE)*
Dr. Greg Morris	Sedimentation
John Gummer	Hydromechanical and Electromechanical Equipment

EDS PoE Commentary

Subject	EDS PoE
Part 1 Dam Safety	Ljiljana Spasic-Gril
Part 2 Water Resources and Flood Risk Management	Prof. Dr. Ezio Todini
Part 3 Economics & Finance	Roger Gill
Part 4 Implementation	Roger Gill
Part 5 Conclusions	All

Terms of Reference

- To ensure due diligence and international quality standards in the studies
- To provide independent advice and guidance to support objectivity and credibility in the assessment process
- To share technical expertise and knowledge

Primary Outcome:

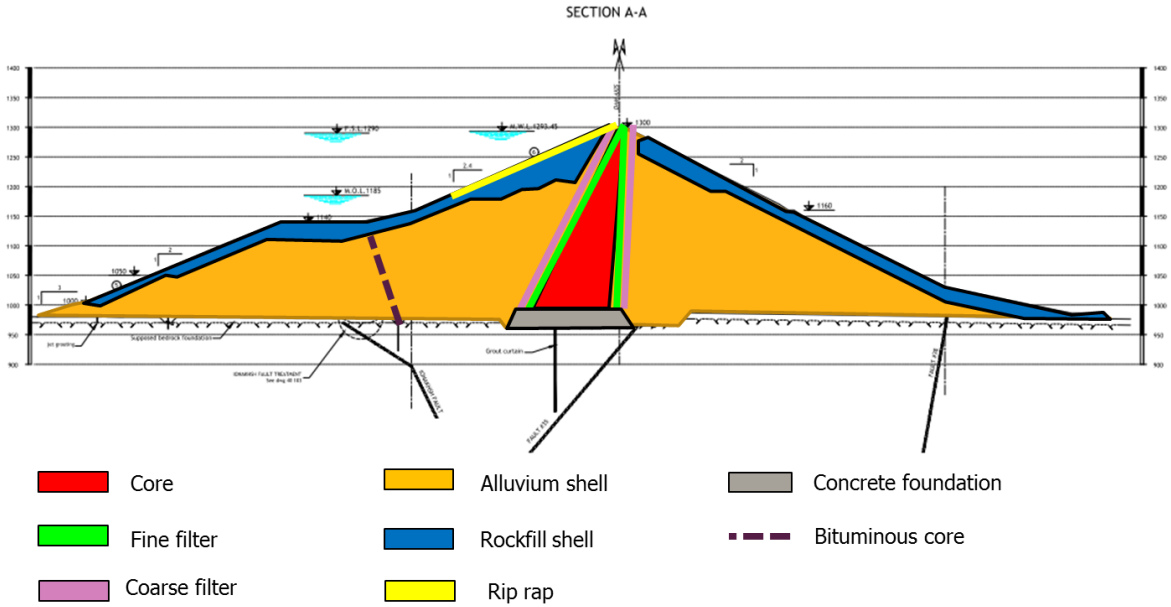
- Ensure international standards of design, risk evaluation and impact assessment are met for both the existing and the new works
- Assure a level of confidence amongst the international community in the quality and integrity of the assessment process and findings

EDS PoE Involvement

- PoE has been strongly engaged in the full assessment process spanning April 2011 till July 2014, including:
  - field missions and design review meetings in Tajikistan
  - design review meetings in Paris and Washington DC
  - extensive home base TEAS report reviews
  - participation in riparian consultations.
- PoE's comments and critique have been suitably integrated by the TEAS consultant
- Overall the analysis has been extremely thorough and has addressed all the necessary issues for this technical feasibility assessment
- PoE views on Phase 0 and Phase I have been presented in detail previously and key issues are briefly reiterated in this presentation along with commentary on the Phase II studies.

Part 1 DAM SAFETY

Comments by
Ljiljana Spasic-Gril



Design Criteria

- Set robust criteria which are used to assess the existing works (Phase I) and guide proposed new works (Phase II)
- Set criteria which are in accordance with international expectations and international standards for dam safety
- Particular attention is paid to:
  - definition and handling of the PMF
  - definition of maximum credible earthquake (MCE) and fault displacements
  - handling of sediments
  - protection of the existing dams on the Vakhsh cascade, bearing in mind: a) that they have not been designed to handle the PMF

    b) sedimentation of Nurek reservoir

Geology

- There is a robust understanding of the site geology and geotechnics
- Special attention has been paid to studying:
  - the right bank suspected landslide (disproven as an issue)
  - the salt dome in the dam foundation
  - impact of geology and faults on the underground structures.
- Phase 0 studies addressed the risks posed by the salt dome in the foundation - PoE supports:
  - the mitigation measures proposed (installation of a hydraulic curtain and grouting) as they have been designed with a high geotechnical factor of safety
  - installation of a robust monitoring system which must be fully operational during the lifetime of the dam; and
  - implementation of measures that will permit remedial works to be undertaken, if and when required, to restore the efficiency of the mitigation measures.

Seismicity

- PoE has been actively involved in ensuring that seismic risks are adequately addressed
- Design of the dam and the structures is undertaken for the MCE:
  - Dam will be able to sustain the maximum movements that can be generated during an MCE (freeboard, filters, etc)
  - The structures that cross faults are designed to accommodate maximum displacements and fault movements (which was not addressed by the previous design)
- Impact of Reservoir Triggered Seismicity is assessed
- Recommendations in place for seismic monitoring prior, during and after construction

Assessment of Existing Works (Phase I)

- Objectives: to determine the usefulness of the existing works for the potential future development of the proposed project;

- PoE agrees with the assessments undertaken and measures proposed for:
  - DT1 and DT2 and other tunnels;
  - The Power House Cavern and the Transformers Hall: need to point out that there will be in-situ testing of the measures proposed

Dam Design: Selection of Dam layout

- The following key aspects have been taken into account to establish the dam layout:
  - Location of intake portals for the existing diversion tunnels
  - The Ionakhsh Fault and potential seismic movements
  - Fault No. 35 and potential seismic movements
  - Salt Dome in the foundations
  - Obishure Stream close to downstream tunnel portals

- PoE agrees with the selected layout

Dam Design: Selection of Dam Type

- Several types of dams have been considered by the TEAS Consultant:
  - Impervious core embankment dam,
  - Concrete arch dam,
  - Concrete Face Rockfill dam (CFRD),
  - Gravity Roller Compacted Concrete (RCC) dam,
  - RCC arch gravity dam,
  - RCC arch dam
- PoE agrees that the embankment dam with an impervious core is the best option bearing in mind all the relevant site characteristics;
- Based on the international dam portfolio, well constructed embankment dams perform well during high earthquakes;

Dam Design: Selection of Dam Type (continued)

- Rogun dam satisfies stability requirements for all loading conditions and special measures have been taken to enhance its performance during extreme earthquakes

- However, it is important from a dam safety perspective for the construction of the dam to be executed as a continuous process once the river is diverted, in order to maintain the factors of safety required during construction

Hydraulic Structures for Diversion and Flood Management

- The dam construction will have several construction stages: pre-cofferdam, cofferdam, Stage 1 dam and the Main dam
- Management of construction floods during all construction stages is essential for dam safety
- Proposed system, that takes into account all constraints, comprises:
  - Use of rehabilitated existing diversion tunnels DT1 and DT2;
  - Completion of the third Diversion Tunnel, DT3;
  - Construction of Mid-level outlet 1 and 2 (MLO1 and MLO2);
  - Construction of high level tunnels 1, 2 and 3 (HL1, HL2 and HL3).
  - Construction of surface spillway
- This system provides appropriate flood protection for all stages of the project, as there is adequate capacity to prevent overtopping of the dam

Part 2: WATER RESOURCES AND FLOOD RISK MANAGEMENT

Comments by
Prof.Dr. Ezio Todini
&
Roger Gill

Assessment of Water Resource Availability and Flood Extremes

- PoE endorses the:
  - Assessment of the hydrological dataset records to be used as basis for Rogun and Vakhsh cascade water allocation analysis
  - Independent estimation of 1:10,000 years return period flood and PMF: both, on the safe side, substantially larger than previous estimates
  - Assessment of Rogun operation based on the assumption of no change from the current downstream seasonal flow-release pattern below Nurek

Value of Flood Mitigation

- Without Rogun: downstream reservoir cascade only resistant to 1:10,000 year flood.
- With Rogun dam at FSL 1255 or 1290, which both attenuate the PMF inflow sufficiently, the whole cascade becomes able to withstand the PMF.
- Can further increase Vakhsh cascade response capability to floods, by integrating a monitoring and flood forecasting system to a real-time reservoir operational management support system.
- Can increase downstream inhabitants flood preparedness and flood warning potential using the integrated flood forecasting and management system.

Water Resource Management Benefits from Inclusion of Rogun in Vakhsh Cascade

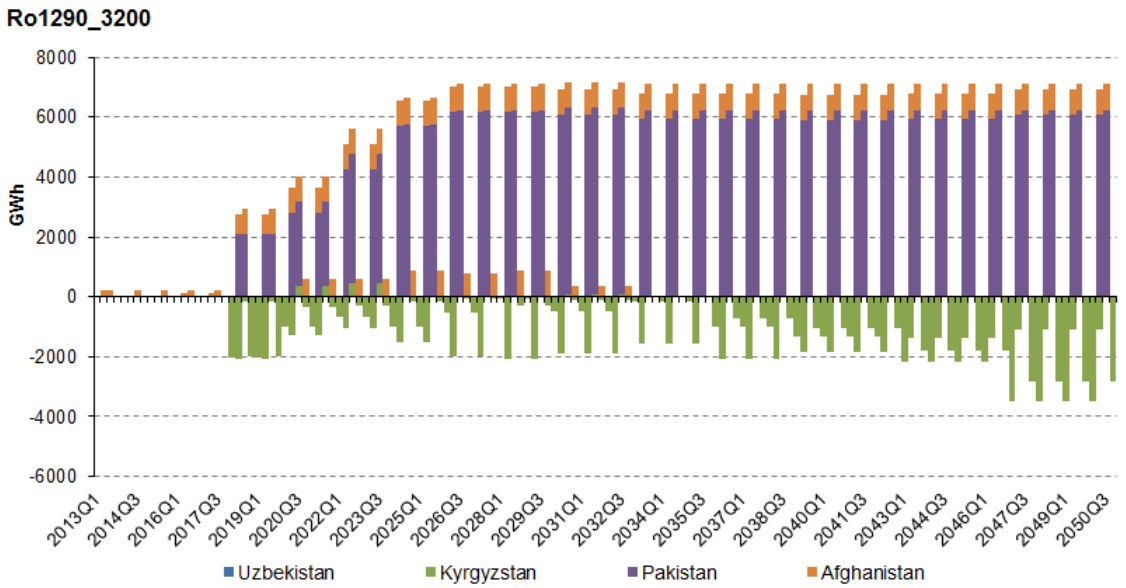
- Positive assessment of additional future energy production resulting from Rogun without changing the operation principle, other than the change due to the full use of Tajik water share during filling phase
- Potential increase of water availability to the downstream areas during the operation phase of Rogun/Vakhsh cascade in exceptionally dry years, conditional on:
  - commitment to operate the cascade by respecting ICWC water allocation
  - establishing an operating rule for managing Rogun and the Vakhsh cascade in exceptionally dry years
  - setting in place a transparent monitoring/forecasting and management system

Sedimentation

- Developing a robust sediment management plan is a key issue for this project
- Ensuring the project can safely accommodate an end of life scenario with a sediment filled reservoir has been a significant change to the design criteria from previous designs
- The PoE strongly endorses the resultant adoption, and staged implementation, of a surface spillway - It is a vital dam safety element that can be cost effectively deployed
- However, more work remains to finalise the operational sediment management regime once additional data is gathered on sediment characteristics.
  - PoE considers this to be a priority task for the next design phase.

Part 3 ECONOMICS AND FINANCE

Comments by
Roger Gill



Comprehensive Economic Analysis

- TEAS Consultant adopted a comprehensive, but complex modelling approach encompassing a full regional power system analysis

- PoE satisfied that the results reflect an extremely rigorous testing of the modelling assumptions which extended the study duration

Robust Outcomes

- Extensive sensitivity analysis was vital to test the robustness of Rogun's contribution to the least cost plan and its economic viability and this has been done
  - As an example, given recent international commentary on hydro project cost overruns, the Rogun project provides a positive economic return at a 10% discount rate even for cost overruns up to 31% (in addition to its inherent contingency cost allowance)
  - It is to be noted that a major cause of cost overruns is underground works, a large part of which has already been undertaken at the Rogun site

Regional Interconnectivity

- Important to recognise that once Rogun reaches full production it can meet the winter energy needs of Tajikistan

- However, the project economics are supported by export sales of summer energy surpluses with Pakistan a very likely export market

- Appropriate development of supporting interconnectors will require regional co-operation

Finance and Dam Safety

- While it is not the role of the EDS PoE to directly assess the finance issues, a key safety issue must be highlighted:
  - The construction flood protection of the project assumes that once diversion occurs the dam fill will be placed continuously through to completion
  - Dam safety would be compromised if there were a significant multi-year hiatus during fill placement.
  - Consequently, it is essential that full financing for the relevant contract is secured prior to commencement of dam fill placement.

Installed Capacity

- For the purpose of the alternatives analysis the machines were assumed to be equi-sized for each total installed capacity option
- While costing of those options and high level modelling of the various overall installed capacity levels indicated a preference for 3200 MW, the TEAS Consultant acknowledges that further detailed assessment is needed to establish the optimal maximum installed capacity and machine size.
- PoE strongly supports the need for such further analysis including assessment of the system regulation and recovery, plant maintainability, and longer term peaking value of 600 MW units as opposed to 533.3MW units in addition to justifying both economically and technically restricting the two existing 600 MW units to 533 MW

Part 4 IMPLEMENTATION

Comments by
Roger Gill
&
Ljiljana Spasic-Gril

Quality Implementation

- The scale and complexity of this project demands high quality implementation and the POE:
  - endorses the recommended international tendering approach
  - recommends external expert oversight during the detailed design and construction phase
  - stresses that PoE support for the project is contingent on ALL the recommendations of the TEAS assessment being incorporated into the final design

Risk Assessment

- PoE participated in the risk analysis for the project
- There are no outstanding technical risk issues that affect the feasibility of the project
- Mitigating the key geological, hydrological, seismic and construction risks requires effective delivery during the detailed design phase of the suite of mitigation measures proposed by the TEAS Consultant
- The PoE recommends that the risk matrix is regularly reviewed during the ongoing phases of the project

Part 5

CONCLUSIONS of EDS PoE

Conclusions (1)

- From a techno-economic perspective the FSL 1290 dam is endorsed by the PoE:
  - Key dam safety issues can be acceptably addressed
  - From a sedimentation perspective it provides the longest project life
  - Addresses the exposure of Nurek to sediment build up in the medium term;
  - Improves the extreme flood safety of the Vakhsh cascade enabling it to withstand the PMF
- This endorsement is made with the requirement that ALL the recommendations proposed by the TEAS consultants are followed in the detailed design stage

Conclusions (2)

- PoE also notes that work is required at the detailed design stage, in particular, to:
  - determine the optimum installed capacity configuration
  - establish an effective sediment management regime
  - confirm the stabilisation measures proposed for the powerhouse cavern
- PoE reiterates the importance of securing full financing for the relevant contract prior to placement of the dam fill