EXECUTIVE SUMMARY

1. Introduction

Several run-of-river schemes were identified on River Panjkora in District Dir of Khyber Pakhtunkhwa by PEDO-GTZ during their studies in 1992-98 for Potential Hydropower Projects in Northern areas of Pakistan. In 2012 M/s Electra Consultants in association with M/s Integration Germany were assigned to conduct the Feasibility study of Patrak Shringal Hydropower Project, District Upper Dir.

The project site is located on right bank of Panjkora River upstream Patrak; a village 35 km NE of Dir town in Shringal valley. The proposed weir site is located near village Patrak and powerhouse is located near Shringal upstream the junction of Dok-Darra Khwar with Panjkora River.

The Feasibility Report for Patrak Shringal HPP is preceded by the Draft Feasibility Report, Mid Term Report and Inception Report submitted earlier. Salient features of the project are given in Table-1 at the end of the executive summary. GTZ proposed a 47 MW installation using 50 m high dam at Patrak and powerhouse was located at Shringal. Later-on PEDO reduced the installed capacity to 21 MW in the TOR for present feasibility study, which has been finalized as 22 MW after carrying out optimization and hydraulic design of the project.

2. Topographic Survey and Satellite Images (GIS)

Topographic Survey has been carried out in the project area for establishing physical features like rivers, streams, roads, bridges, built up areas and agricultural lands etc on detailed topographic maps, which were prepared through comprehensive surveys carried out using modern equipments like Total Station SOKKIA 630R, SOKKIA B40 Engineers Automatic Level and E-Trex Ground Positioning System (GPS). The field data was computer-processed and computer-aided mapping was carried out on selected scales to suit the requirements.

Survey of Pakistan (SOP) had already established Standard Bench Mark (SBM) near the weir site at Kalkot area. But for the development of project layout more SBMs were established by the Consultants and used the bench mark values for establishing control points in project area.

Moreover, latest available high resolution satellite images were procured to digitize the land features while SRTM elevation data has been utilized to trace contours. However, actual survey points collected during topographic survey were also embedded into it to improve map quality.

3. Geology, Geotechnical Engineering and Construction Materials

Geological and geotechnical investigations have been carried out to study regional and local area geological and tectonic set up through geological mapping, scan line discontinuity survey, drilling works and geophysical survey. Test pits were excavated for determining potential sources of construction materials.

The Patrak Shringal Hydropower Project (Upper Dir) is situated in the geological and tectonic regime of Kohistan Island Arc (KIA) in Northern Pakistan, now sandwiched between the Indian and Asian plates, was formed during subduction in the Tethys Ocean between the Indian and Eurasian continental landmass. Kohistan block is broadly divisible into the units of Jijal-Spat mafic ultramafic Complex, Kamila Amphibolite Unit, Chilas Complex, Kohistan Batholith and Yasin-Gilgat metasediments from south to north respectively. Similar types of rocks are reported from the Ladakh block. The project area lies in Kohistan block in Dir district north of MMT. The rock sequence is comprised of various units of plutonic, volcanic, metamorphic nature with variety of sediments deposited by Panjkora River.

The weir site has been investigated by 3 boreholes at right, river bed of weir axis and at left bank respectively; right bank of the weir axis has been investigated by the drill hole PS-01R up to 30 meters depth. Rock has been encountered from top to bottom of drilling depth rock encountered is confirmed (Volcanic origin and is Andesite). Five numbers of water pressure tests were also performed indicating different rock quality horizons from top to bottom.

The intake structure for headrace has been proposed on the right bank of Panjkora River. Intake structure is coming on rock and during present stage of studies at right bank, rock even exposed at the surface or under few meters cover of scree and overburden materials.

The tunnel would be a low pressure tunnel, lined with shotcrete and wherever needed when the rock is considered weak, it will be concrete lined. The maximum rock cover over tunnel has also been assessed. Most of the tunnel area falls in Class-A rock while Class-B and C is also anticipated. Very week and poor quality of Pyroclasts/Andesite and tuffs can also be observed and recorded in headrace tunnel. Rock mass characterization and Stereonet plotting along the headrace tunnel has been done and analyzed.

The sandtrap & forebay structure and also the penstock area has overburden and upper Secree materials cover, but as per investigated drill hole near the area of forebay just at downhill along proposed penstock location has sound rock at 1.5 meters depth then same goes to drilling depth of 25 meters. Upper 1.5 meters overburden and Secree deposits are widely spread along and around the forebay location but positive aspect of shallow bed rock for durable foundation is one added advantage of the selected forebay location. Rock is Diorites Greenish brown/Greenish grey in colour, medium to coarse grained, highly weathered, highly fractured, surface staining in joints, igneous origin and rock cores are highly fragmented.

At the proposed powerhouse area there is overburden/scree but rock exposures can also be seen just upstream side of the powerhouse. From 38.5 meters to drilling depth of 45 meters strata encountered is Andesite/Dacite/Volcanics group means it is the origin of volcanic rocks of Andesite, Light green color, fine to medium grained, slightly weathered, moderately fractured, medium to strong hard.

Geologically, the length of tailrace structure is coming on river bed deposits and terrace deposits, but as per surface geological mapping data, strata around tailrace is terrace deposits with Alluviums/Overburden consisting rounded boulder gravels. Analysis of powerhouse area geology reflected that at tailrace structure rock will be encountered at deeper depths even if rock will not be available along this structure, then such foundations can easily be designed on overburden/Alluviums unconsolidated materials.

For suitability of the construction materials, complete set of testing was being applied in the laboratory under the supervision of Consultant`s team. Results showed that project area rock is alkali silica reactive and may not be used an aggregate with ordinary Portland cement/High Alkali cement while these can be used either with low alkali cements or with volcanic ash/pozzolanic materials.

Fine and coarse aggregates available in ample quantity in the vicinity of project area are suitable for construction. Cement and steel is also available in nearest main cities like Mardan and Dir but for project requirements, bulk quantities will be transported from Peshawar or Rawalpindi region with quality confirmation certificates of the manufacturer. Low alkali cement would also be transported from Rawalpindi region if required.

4. Hydrology and Sedimentation

4.1 Hydrology

The topographic map of the catchment has been prepared using SRTM DEM. The drainage area of Patrak Shringal at proposed weir site is 1498 km^2. The length of the main stream is about 60 km. Highest flood level at weir axis is 1480 masl. The stream of Shringal joins with main river (Panjkora) at Chutiantan near Dir.

For present feasibility study a stream gauge was installed at site by PEDO. Daily stream flows have been recorded since the installation of the gauge i.e. February 2013. Also, the available Hydro-meteorological data such as daily and hourly rainfall, daily stream flows, temperatures, evaporations and sediment data of nearby stations was collected from Pakistan Meteorological Department (PMD) and WAPDA and has been used for determining power potential, maximum floods and flow duration curve. The hydro-meteorological stations in and nearby the project area were Chitral, Dir, Drosh, Kalam and Saidu Sharif. All the data was processed in computer and any omissions, errors and its consistency was checked prior to use.

The mean annual precipitation data for the period 1961 to 2011 was analyzed using computer programs Design Flood, HEC-HMS and excel sheets while flow duration curves were developed for pre-2010 flood and post-2010 flood data. Maximum floods of estimated return periods of 5, 10, 100, 1,000 and 10,000-year floods were calculated using different methods. It was concluded that 10,000 year return period flood of 2818 m^3/s is appropriate for the design of weir.

Flow Duration Data	
Time (%)	Discharge (m^3/s)
0	1637.88
5	105.20
10	88.41
15	75.94
20	66.20
30	47.88
40	31.67
50	20.69
60	14.91
70	11.89
80	10.20
90	8.92
95	8.39
100	5.29

4.2 Sedimentation

Long term sedimentation data is not available at the project site. However, sediment data of nearby stations is available and has been taken from SWHP WAPDA, who carried out sedimentation studies in Panjkora River at Zulam Bridge for the years 1999-2003. Also, sediment concentration data at gauging station Kalam and Chakdara has been available since 1961. A discharge measurement station in Panjkora River at Koto is also maintained and operated by PEDO since January 2005.

An analysis was carried out concluding sediments in Panjkora River at Zulam Bridge are quite high as compared to Swat River at Kalam and Chakdara. The river at Patrak Shringal weir site consists of large cobbles and boulders. Bed load measurements were not carried out on the Patrak Shringal in the past. Therefore, empirical formulas were applied for the estimation of the expected bed load.

Suspended load studies were carried out on Panjkora River during mean and high flows at the gauging station at Zulam bridge from 1999 to 2003. Suspended load measurements are also available in Swat at Kalam, Swat at Chakdara and Panjkora at Koto. The suspended load measurements were carried out in connection with discharge measurements. The available data was considered for analysis and estimation of mean annual suspended load transport as well.

Monthly and annual total sediment load for the period 1961 to 2011 at proposed weir site was estimated. Year 2010 was a high flood year and therefore sediments are highest in the year as compared to other years. Where mean annual total sediments (1961-2011) comes out to be 0.369 MST (Million Short Ton).

5. Seismic Hazards

Patrak Shringal Hydropower Project is located in Dir, near the vicinity of Main Mantle Thrust (MMT) and Reshun Fault, in a zone which is seismically active due to continuing northward drifting of the Indian plate and its subduction under the Eurasian plate. This tectonic activity has resulted in the production of a crustal accretion wedge; The Himalayan range. Seismic Hazard Evaluation, based on available data / literature regarding regional geology, tectonics, non-instrumental and instrumental seismicity, has been carried out for Patrak Shringal Power Project by including some 1646 events in the present study (since 1928).

Relative to Eurasia, the Indian plate is still moving northwards. The latest GPS measurements indicate the North-Western Part of Sub-Continent i.e. mostly Pakistan is moving 10 mm per year in north direction and 11 mm in westward direction.

The Deterministic Seismic Hazard Analysis (DSHA) has revealed that for Patrak Shringal Hydropower Project, Main Mantle Thrust/Reshun Fault could be the critical fault, capable of generating a magnitude 7.6 Mw Earthquake (equivalent October 8, 2005 Kashmir Earthquake). Maximum Credible Earthquake due to active faults in the region is calculated to be of the order of 0.143g due to an earthquake 7.6 magnitude, having a hypocenter at 80 km from the site.

The return period as per Gutenberg-Richter Law for a 7.6 magnitude earthquake is calculated to be of the order of 422 years and for a Magnitude 7 earthquake is 90 years for Patrak Shringal HPP site. Hence, the possibility of occurrence of one earthquake immediately after another at the same location or in its vicinity is almost nil.

6. Project Layout and Hydraulic Design Considerations

6.1 Project Layout

Originally this scheme was proposed by GTZ who estimated its power potential as 47 MW with annual energy of 216 GWh. GTZ had proposed design discharge of 60 m^3/s and a dam of height 50 m.

Several layouts were studied for this project. In planning various layouts, recommendations of the GTZ report were kept in view. Initially six project layout alternatives were studied, all having 60 m^3/s discharges but giving six different capacities and project costs. However, after carrying out optimization of discharges, the design flow is kept as 35 m^3/s.

The project will utilize the flows of Panjkora River to generate 22 MW (2 x 11 MW) with average energy output of 109.01 GWh per annum which will be delivered to the transmission grid at Dir. The plant factor is about 56.6%. The rated discharge and rated net head for the project is 35 m^3/s and 73 m respectively.

6.2 Hydraulic Design Considerations

The hydraulic design studies of Patrak Shringal Hydropower Project include design of weir, power intake, Connecting Channel, headrace tunnel, forebay and sandtrap structure, overflow spillway, penstock, powerhouse, tailrace, switchyard and transmission line.

The main weir structure is proposed to be built in concrete in three sections. The overall weir length is 65.3 m comprising of an overflow, gated and under-sluice section. The full supply level is 1475 masl. The overall weir has been designed to pass a flood of 2000 cumecs which has a return period of 1000 years.

The ogee shaped overflow section of weir is 30 m wide and 13 m high and can pass about 1000 m^3/s discharge with an allowable surcharge of 2 m. The 30 m wide gated section of weir has 3 radial gates each of height 7 m.

The under-sluice section of weir has 2 no. vertical lift gates, each 4.5 m wide and 3.0 m high. There will be skimmer walls for gates to avoid overtopping at normal operating level of 1475 masl. When fully opened; the 2 gates of this section would be able to pass about 250 m^3/s while maintaining the headwater level at 1475 masl. The maximum discharge capacity of this section will be 300 m^3/s for the design flood of 1000 year return period.

The intake consists of 2 No. gated inlets each 4m x 4m. The invert level of inlets is at El. 1470 masl which is 6 m higher than the apron level of adjacent sluicing section of weir structure. The inlets are separated through 1.5 m wide pier with top level at El. 1480.5 masl. Total width of intake including piers but excluding side walls is 14 m while the intake crest is 20.86 m wide. Each inlet is equipped with vertical stop-logs and trash-rack inclined at an angle of 82^o with the horizontal floor on intake. There is provision of stop logs at the downstream side of intake gates in order to carry out repairs of one gate while the other gate is still open and transferring flows to the connecting channel.

The flows will then be carried through a 4.5 m wide, 4.3 m deep and 25 m long rectangular connecting channel to the headrace tunnel. It will resume from headrace tunnel outlet to the forebay structure covering the length of 97 m with a longitudinal slope of 1 in 1000.

The headrace tunnel is designed as a horseshoe shaped free flow conduit of 4.5 m diameter; having 16 m^2 area. It is 5 km long and has a slope of 1 in 1000. At start of the power tunnel the invert has an elevation of 1469.67 m.

The combined forebay and sand trap structure have been proposed and will be a reinforced concrete structure with full supply water level as 1467.85 masl. The total length of forebay / sand trap will be 113 m; including 15 m long transition from the channel end. The width of combined structure is 22 m while its depth varies between 13.7 m and 15.5 m having 3% longitudinal slope. The normal velocity of water in the sand trap /forebay is 0.03 m/sec. The structure has been divided into two hopper shaped compartments with flushing duct which will initially convey the flushed water into the dissipation chamber of size 4m x 8m and then via 2m channel to the cascade channel which is finally discharged to the river Panjkora.

An overflow spillway of cascade type has also been provided in the forebay structure for the expulsion of excess water. The spillway will emerge from the forebay with a

crest level of 1467.85 masl. There will be energy dissipation at each drop of 20 m wide spillway. The cascade channel will cross the main road to Kalkot as a culvert before discharging the excess water to the river Panjkora.

There are two penstocks, each about 215 m in length finishing at the inlet valves of Vertical-Francis turbines. The diameter of each penstock is 2.35 m.

A surface type powerhouse in open cut will be provided on the right bank on the inner side of a small bend of river. The powerhouse will be equipped with two Francis turbine units having vertical axis. The concrete lined free flow tailrace of about 40 m length will convey the discharge from the draft tube outlet gates up to the Panjkora River.

7. Mechanical Equipment Studies

Mechanical equipment and systems will include turbines, governors, inlet valves, gates, stoplogs, trashracks, cranes and hoists etc. The turbine selection was made considering 73 m as rated net head. As stated earlier, for the installed capacity of power plant 35 m^3/s flow at 35% exceedence has been selected. From the comparative study of various turbine sizes and combinations, two (2) units of Vertical Francis turbines each with 17.5 m^3/s flow have been selected. During 53.5% of the total time both of the turbines will operate, simultaneously, while for 29% of the total time only one turbine will operate. Considering turbine efficiency of 92% for the net head of 73 m and design flow of 17.5 m^3/s, the power will be 11 MW for each turbine. These values will result in the turbine specific speed (Ns) of 375 rpm. An average runner diameter is considered as 1.56 m. The turbine shall be capable to operate within a wide range of head and discharge at maximum attributable efficiency. Each turbine is connected to the penstock via a butterfly type valve.

For determining the appropriate unit capacity, both technical as well as economic aspects have been examined in a comparative study taking into account equipment dimensions, transport limitations, power and energy benefits, manufacturing experience, power system regulation and cost estimates etc. Considering generator efficiency as 97%, the total turbine output will be 22 MW corresponding to total rated discharge of 35 m^3/s and rated head of 73 m.

8. Electrical Equipment Studies

The most important components of the main electrical equipment are the 3-phase synchronous generators, 11 kV self-regulated brushless excitation system, coupling to turbine units, complete with other auxiliary equipment as specified. Two generators

selected for Patrak Shringal which will generate 22 MW with a power factor of 0.85 and 11 KV rated voltage have been proposed.

The generators are envisaged to be three-phase synchronous machines designed for 30 years minimum operating lifetime. A closed circuit air-cooling system with air/water heat exchangers has been specified. The synchronous speed of the generator is 375 rpm as determined by turbine hydraulic considerations and design net head. The generators will be connected to the generator step-up transformers by means of isolated phase bus (IPB).

A Static Excitation System with a Digital Automatic Voltage Regulator is envisaged for Patrak-Shringal units being the state-of-art for generators. Excitation power shall be taken from the generator itself, through a branch-off from the generator terminal bus bars and supplied to the excitation rectifier via the excitation transformer.

The station auxiliary supply system will be fed by two station service transformers (SST), each rated for 100% of the auxiliary load. The Plant Operation Building will be supplied by two distribution transformers. The conditions and requirements for mechanical and electrical design of transformer is described in Chapter 10 of this report.

For the safe and reliable operation of the control, protection and communication systems 220 V DC and 230 V AC UPS systems will be provided in the Powerhouse, the Plant Operation Building and the weir Site.

The fire protection system consists of the equipment to detect and extinguish fire in the most endangered zones of the power plant. The detection will be realized by use of heat, flame or smoke detectors initializing the fire alarm system of the powerhouse including the general fire siren and will triggering in-place fire extinguishing equipment.

Electrical protection systems will be provided to isolate faulty circuits with speed and certainty, to limit damage and to maintain healthy systems in stable operation. Telephone system, radio communication system, closed circuit television system (CCTV), access control system etc will be the communication and security systems.

Selection of power transformers has been made keeping in view the load requirements and transportation constraints. For generator transformers at Patrak-Shringal, single phase water cooled units have been selected. Power transformers to be provided AIS substation for meeting the power requirement of the local area at 132kV will be single phase units. Oil filled transformers will be equipped with explosion prevention and fire protection system.

The 132kV switchyard has been proposed at Patrak-Shringal consisting of six bays and two bus bars. The electric power generated at Patrak Shringal hydropower station will be fed to Dir Grid Station through 26 km long double circuit 132KV transmission line.

9. Initial Environmental Examination, Resettlement and Social Assessment

This project, because of its size of 22 MW, is classified as a Category "B" project, in accordance with ADB Guidelines for environmental assessment, 2003. An Initial Environmental Examination (IEE) is required to determine the significant impacts.

The present IEE reveals that some moderate to significant negative environmental impacts are likely to occur due to the construction activities with few minor impacts during operations after the proposed construction. Recommendations are made to mitigate expected negative impacts. Implementation of appropriate mitigation measures during the construction and operation phases will minimize the negative impacts of the Project to acceptable levels. The Project will have an overall beneficial impact and any negative environmental impacts will be carefully monitored and mitigated. Therefore, the completion of this IEE fully meets the ADB and EPA standards. The construction of the project will open job opportunities for the local people. This will help in raising their livelihood.

The total environmental and resettlement cost is estimated as Rs. 158.35 million including land acquisition for the reservoir upto retention level of El: 1475 masl.

The Client should make necessary arrangements such that during operation of the project sufficient release of water is ensured from the Weir for downstream uses because some agricultural practices do depend on river water.

Social assessment being an integral component of the Environmental Studies was carried out for this project during IEE. The main objective of studying social aspects of the project was to gain insight into certain social characteristics, problems, conflicts and expected bottlenecks to be utilized for technical design choices during detailed design stage of the proposed project.

The Stakeholders play an important role in the success or failure of a project. Stakeholders for Patrak Shringal have been identified as those persons and institutions who have their interests, roles, responsibilities, benefits or losses from the proposed project. Lands in Patrak Shringal HPP area comprise of a large proprietary land. The project will consume 44 kanals of cultivated lands and 232 kanals of waste lands and settlements.

However, the Stakeholders welcomed the efforts of Government for promoting hydropower projects in their area but they also requested that their precious property should be saved as far as possible. They demanded that proper justice should be done while making compensation to the affected persons and the payments should be made only to the legitimate owners only on the prevailing market rates. They also demanded that the electricity generated through this project may also be provided to the area if possible. They said that their rights and privileges on the local resources must be recognized by the Government.

10. Construction Planning and Cost Estimate

10.1 Construction Planning

The construction planning for 22 MW Patrak Shringal Hydropower project is largely dependent on Construction of weir, headrace tunnel, combined forebay & sand trap and powerhouse. The 5km headrace tunnel is on the critical path, high and low flow periods in Panjkora River, excavation in hard strata of tunnel, foundation treatment of powerhouse on soft strata, E&M works and 26 km transmission line.

Main components of the project are weir, intake structure, headrace tunnel, combined forebay and sand trap, overflow cascade spillway, penstock, powerhouse, tail race, E&M equipment and transmission line.

The work on all these components can be carried out independently and the schedule has been prepared in such a way, that the work is taken up simultaneously on various sites in order to complete the project in the shortest possible time. It is thereby estimated that the construction of the project will be completed in 36 months. The sequence, in which the construction of various components of the project will be taken up, has been shown in Annexure – 14 A of the Main Report. The construction activities along with time required to complete them is summarized as follows:

Summary of Construction Schedule

Sr. No.	Description of Activity	Duration
1.	Mobilization	30 Days
2.	Acquisition of Land	07 Months
3.	Temporary and Preliminary works	12 Months
4.	Coffer Dams (two Nos.)	03/02 Months

5.	Right part of main Weir, Intake and ancillary works	08	Months
6.	Left part of main Weir and ancillary works	10	Months
7.	Forebay & Sandtrap Structure and ancillary works	12	Months
8.	Cascade Spillway	07	Months
9.	Power Tunnel (5 km) and ancillary works	26	Months
10.	Penstock	08	Months
11.	Powerhouse Civil works	17	Months
12.	Tailrace and ancillary works	05	Months
13.	Powerhouse E&M manufacturing and installation	21	Months
14.	Switchyard, Transmission Line ancillary works	12	Months
15.	Testing and Commissioning	06	Months

10.2 Cost Estimate

It is envisaged that the construction of the project will be completed in 36 months. The estimated cost of the project has been worked out as Rs. 8,435 million out of which local cost is Rs. 6,683 million, while for import of Electrical / Mechanical & transmission line equipment, a provision of Rs. 1,752 Million has been made.

11. Economic & Financial Analysis

For realistic cost estimate the following factors / criteria has been considered.

i. Market Rate System 2013 Khyber Pakhtunkhwa
ii. Prevailing market Rates
iii. Unit rates adopted for similar constructed / under construction projects
iv. US$ versus Pak rupee impact

The summary of the project capital cost is given as under:

Sr. No.	Component	Estimated Cost (Rs. Million)		
		Local	Foreign	Total
A	Preliminary Works	249	0	249
B	Environment & Resettlement Costs(Land Acquisition)	158	0	158
C	Civil Works	4263	0	4263
D	Electrical & Mechanical Works	127	1147	1274
	Transmission Line	60	540	600
	Total Works Cost	**4858**	**1687**	**6545**
E	Physical Contingencies (Unforeseen) @2% of C+D	89	34	123
F	Transportation and Erection Charges of E&M Equipments @3% of D	56	0	56
G	Survey ,Geotech Investigation and Detail Design of Civil and E&M Works @ 2.5% of (C + D)	123	0	123
H	Management Consultancy Cost @ 3% of (A + C + D)	255	0	255
	Total Base Cost	**5381**	**1721**	**7102**
I	Client Expenses, Administration and Legal Costs @1% Base Cost	71	0	71
J	Custom Duty@ 5% of D (on FEC)	84	0	84
K	Escalation @ 6.50% on Local cost & 1.3% on FEC	343	31	374
L	Interest during Construction (IDC) @10.65% of Base Cost	804	0	804
	Total Project Cost	**6683**	**1752**	**8435**

The annual energy of the Project is 109 GWh. Based on it the unit cost generated per kWh comes out to be Rs. 9.96 & US cent 10.06. A summary of Economic and Financial Analysis indicator is given as under:

NPV (Rs. Millions)	2869.35
BCR	1.48
EIRR	21.65 %
FIRR (Without CDM)	13.55 %
FIRR (With CDM)	14.34 %

The sensitivity analysis results are summarized as under:-

Scenario	**NPV (Rs. Millions)**	**EIRR**	**BC Ratio**
10 % cost over-run	2356	18.70%	1.35 : 1
One year delay in benefits	1991	17.03 %	1.32 :1
Combination of above	1377	15.14%	1.20: 1

NPV - Net present Value

BCR - Benefit Cost Ratio

EIRR - Internal Economic Rate of Return

12. Conclusions & Recommendations

12.1 Conclusions

- Base cost of the project is estimated as Rs. 7,102 million, while the capital cost is estimated as Rs. 8,435 million.

- Environmental Impact Assessment Studies have determined the overall impact rating of the project activities as “low to medium”.

- The EIRR calculated in comparison with equivalent thermal plants as replacement alternative to the proposed Hydropower Project, comes out to be 21.65%.

- Financial analysis indicates a Financial Internal Rate of Return (FIRR) as 14.34 % and the project is adjudged viable.

12.2 Recommendations

Engineering, economic and financial studies have classified Patrak Shringal Hydropower Project as viable. Hence the project is recommended for detailed engineering design and execution.

The successful completion of the project will turn into job opportunities and uplift in the socio economic well being of the adjoining areas. This will result into economic activities in the locality.

Table 1: Salient Features

Hydrology	
Catchment Area	1498 km^2
Design Discharge	35 m^3/s
Working Head	
Normal Head Water Level	1475 masl
Tailrace Water Level	Varied according to tail water rating curve
Gross Head	79 m
Net Head	73 m
Power Intake	
Type of Intake	Gated
No. of Gates	2
Size of Gates	4m x 4m
Height Above River Bed	6 m
Width of Intake Crest	20.86 m
Diversion Weir	
Type of Weir	3 Sections (Overflow, Gated, Under Sluice)
Width and Height of Overflow section	30m x 13m
Length of Overflow section	65.31 m (Including Stilling Basin)
Width and Length of Gated Section	30m x 105.91m (Including Stilling Basin)
Type of Gates	3 Radial Gates (8m x 7m)
Sluicing Section	2 Vertical Gates (4.5m x 3.0m)
Type of Energy Dissipater	Stilling Basin USBR Type-II

Length of Sluice Section	65.31 m (Including Stilling Basin)
Connecting Channel	
Type of Channel	Rectangular (4.5m x 4.3m)
Total Length	122 m (25m before and 97m after headrace tunnel)
Headrace Tunnel	
Type of Tunnel	Horseshoe shaped, Concrete lined
Length	5.00 km
Diameter	4.5 m
Forebay and Sand Trap Structure	
Number of Chambers	One chamber, 2 Hopper-shaped compartments
Width of Combined Structure	22 m
Total Length of Structure	113 m
Max. Depth of Structure	15.5 m
Overflow Spillway	
Type of Spillway	Cascade Type
Crest Level on Forebay	1467.85 masl
Width of Spillway Steps	20 m
Penstock	
Penstock Material	Steel
No. of Penstocks	2
Length	215 m
Diameter	2.35 m

Power House	
Type	Surface
Size (L x W x H)	40m x 20m x 36m
No. and Type of Turbines	2x Vertical-Francis
No. of Generators	2
Crane	40 Ton
Tailrace Channel	
Type	Concrete Lined, Free Flow
Channel Section	Rectangular
Length of the Channel	40 m
Power Potential	
Gross Power	22 MW
Annual Energy	109.01 GWh
Plant Factor	56.6 %
Project Cost & Economic Viability	
Total Project Cost	8,434.62 Million Rs.
Benefit / Cost Ratio	1.48
Unit Cost Generated	9.96 Rs. / kWh
Unit Cost Generated	10.06 US cent / kWh