

Detailed Feasibility Study Report

Pinyinyi Small Hydro Power Project

Proposed Installed Capacity – 2.0 MW

Pinyinyi River, Ngorongoro District, Arusha, Tanzania



Project Developer & Owner



Shekilango Road, Plot number 9, Block F UBUNGO, P.O.Box 31564,
Dar-es-Salaam, Tanzania

Report prepared on April 2016 by:



Report Reviewed on September 2020 by:



Gyeonggi-province, 14047, South Korea

List of Drawings

Sr. No	Title	Drawing number
1(i)	Project Layout Plan(1 of 5)	PHEP- 01(i)
1(ii)	Project Layout Plan(2 of 5)	PHEP- 01(ii)
1(iii)	Project Layout Plan(3 of 5)	PHEP- 01(iii)
1(iv)	Project Layout Plan(4 of 5)	PHEP- 01(iv)
1(v)	Project Layout Plan(5 of 5)	PHEP- 01(v)
2	Water Conductor Profile 1	PHEP- 02
3	Water Conductor Profile 2	PHEP- 03
4	Trench Weir Plan	PHEP- 04
5	Trench Weir Sections	PHEP- 05
6	Trench Weir Longitudinal Section	PHEP- 06
7	Conveyance Channel Sections	PHEP- 07
8	Desilting Tank Plan & Sections	PHEP- 08
9	Forebay Plan and Section A	PHEP- 09
10	Forebay Section B	PHEP- 10
11	Penstock Longitudinal Profile	PHEP- 11
12	Penstock Sections	PHEP- 12
13	Power House Plan	PHEP- 13
14	Power House Section A	PHEP- 14
15	Power House Section B	PHEP- 15
16	Switch Yard Plan	PHEP- 16
17	Switch Yard section	PHEP- 17
18	Single line Diagram (improved by H & W control)	PHEP- 18
19	Power House Design (improved by Gugler Turbines)	PHEP- 19

Checklist

Check List		
	Name Of Project	Pinyinyi Small Hydro Electric Project (2.0 MW)
	Location	
i).	Region	Arusha
ii).	District	Ngorongoro
	Category Of The Project	Small Hydro Power Project (SHPP)
	Planning	
	Has the overall development of the stream been prepared and stages of development discussed briefly.	Yes.
	Have the alternative proposals been studied and their merits and demerits discussed.	Yes
	Have the detailed topographical surveys been carried out for the following items and drawings prepared as per prescribed scale	Yes
i).	Stream	Yes
ii).	Head works Surveys (weir or diversion structure)	Yes
iii).	Plant site & Camp site	Yes
iv).	Power House, Switchyard, tailrace	Yes
v).	Roads, transmission line etc.	Yes
	Geology	
	Have the geological surveys for head works, power house and tail-race etc. been carried out and report on general geology of the area and on geology of the sites of principal structures appended?	This will be done at the detailed engineering stage.
	Foundation Investigation	
	Have the foundation investigations for the major civil structures and of the schemes etc. been carried out?	To be carried out during the detailed engineering & design stage leading to construction.
	Hydrological & Meteorological Investigations	
	Have the hydrological and meteorological investigations been carried out, and status of data discussed in report?	Yes Data regarding the hydrology regime of the river has been worked out at hydrometric station number 2A4 Oldoinyo Sambu by Water and Land Centre Consult Co. Ltd.
i).	Rain Fall in the catchments	Yes

ii).	Gauge and discharge data of the stream		data from the gauging station at a hydrometric station number 2A4 on Pinyinyi river at Pinyinyi village is available.
	Hydrology		
	Have hydrological studies been carried out to establish the availability of water for the benefits envisaged, and what is the dependability of the potential?		Long term hydrology series developed from the available discharge of Pinyinyi river. The 90% dependable flow power potential has been calculated based on the available data for the discharge.
	Land Acquisition & Resettlement (Wherever Applicable)		
	Have the provisions for land acquisition and resettlement been considered?		Yes
	Have the socio-economic problem involved in resettlement been considered?		Yes
	Design		
	Has the layout of the project area, viz. location of diversion structure, workshop sheds, offices, camps etc., been finalized? Have the preliminary design prepared for the following components?		Yes
i).	Diversion structure of intake etc.		Yes
ii).	Power House & Switchyard		Yes
iii).	Power House equipment, LT/HT switching		Yes
iv).	Equipment and control and protection equipment.		Yes
v).	Communication facilities		Yes
	Power Benefits		
	Have the following points been discussed?		
	Total energy production and installed capacity of the project		Yes
	How does the scheme fit into overall development of power of region? (If applicable).		The project utilizes the available potential of the river at the location. The project will result in economic development of the region through dependable electricity supply, employment creation & increased standard of living.
	Energy generation from the projects firm power, seasonal power and total power.		It is estimated that with a design discharge of 1.05 cumecs, energy generation of around 14.980 GWh based on a 90% dependable flow, with

		90% plant availability.
	Proposals for transmission and/or connection to the existing system etc. (wherever applicable).	Power generated shall be stepped up to 33 KV at the switchyard and transmitted to isolated grid network system of Loliondo and Wasso via a planned 78km long 33KV transmission line.
	Cost of project as compared to the various micro-hydro projects and various services in the region to justify the, economic viability of the scheme.	Cost of project is estimated to be USD 8.725 Million, which does not include the transmission line network because the project received a grant to construct the transmission line which is now on going activity. The levelised cost of generation is US cents 8.5 per kWh. The tariff allowed for the project as per Tanzanian EWURA 2019 policy is US Cents 8.95 Per kWh. Hence the project is thus economically viable.
	Construction Program	
	Are the major components of work proposed to be done departmentally or through Contractor	Through an EPC contractor
	Have the year/month-wise quantities of the following items been worked out for various components of the project?	
i).	Excavation-soft and hard strata	Yes
ii).	Earth work in filling (wherever applicable)	Yes
iii).	Stone masonry	Yes
iv).	Coarse aggregate for concrete	Yes
v).	Steel of various sizes and types of reinforcement	Yes
vi).	Cement	Yes
vii).	Other materials, electricity, fuel etc.	Yes
	Cost Estimate	
	Is the estimate prepared? Have the analysis of rates for various major items of works for the major components of the project been furnished, with the basis of analysis and the price index at which the estimate is based.	Yes. The estimate has been prepared based on the analyzed rates from the relevant markets for material and skilled/ Semi skilled worker's applicable wages in the project area.
	Ecological & Environmental Aspects	
	Is the area likely to have any environmental and ecological problems due to the altered	Not applicable as it is a run-of-river project without submergence.

	surface water pattern and preventive/corrective measures discussed? (Wherever applicable).		
	Camps And Buildings		
	Has the planning of the camps/buildings been done?		Yes
	Soil conservation		
	Has the planning of the soil conservation measures in the project been discussed?		Yes

Employment and training				
a).	Yearly employment during construction (approx.) by categories			
Year	Unskilled Workmen	Workmen	Technical	Skilled Services
First Year	40	5	5	5
Second Year	40	5	5	5
b).	Personnel required to be retained under above categories after completion of the project (approx.).			10% of above

Executive Summary

Pinyinyi Small Hydro Power Project (hereafter referred to as "the Project") is a proposed run-of-the-river development on the left bank of Pinyinyi River in Ngorongoro District, near Lake Natron (Soda Lake) within the United Republic of Tanzania. The proposed total installed capacity for the Project is **2.0 MW**, comprised of Two Pelton turbine generator sets of 1.0 MW each. The gross head available for power generation is ~236m, and the proposed design discharge is ~1.05 cumecs. The electricity generated is to be delivered to an isolated grid network system of Loliondo and Wasso via a 33 KV transmission line of 78 Km. The construction of the Transmission line is 85 % towards completion.

The proposed site is located on the Pinyinyi River around 7 km west of the shoreline of Lake Natron, close to the village of Pinyinyi. The location is approximately 57 km to the south-east of Loliondo Township. The site is around 150 km from Mto wa Mbu town towards the North.

Pinyinyi Power Project is developed and owned by Ninety Two Ltd, a registered company in Tanzania, with offices at Shekilango Road, Plot number 9, Block F UBUNGO, P.O.Box 31564 Dar-es-Salaam, Tanzania. Strategic Consulting Group (SCG), a hydro power consulting firm from India was hired in 2016 as technical consultant for the project and Yujin Energy Consulting Co from South Korea has been hired to review the project feasibility study.

Tanzania has an estimated hydro power potential of around 4,700 MW but only 561 MW of it has been developed so far. In the recent years, the Ngorongoro region has seen increasing demand for electricity due to the development in economic activity such as tourism, as well as population growth. Given the low access to electricity, heavy dependence on fossil fuels, low installed capacity and potential available, the Pinyinyi SHP is justified from all angles.

The river Pinyinyi originates from Kenya and flows into Lake Natron in the Arusha region of northern Tanzania. The Pinyinyi River has a total catchment area of 1380 sq. km and 40% of the catchment is in Kenya. A significant portion of the catchment does not contribute to the run off.

As per previous studies, the region is semi-arid and the rainfall is scanty. A long rain season from March to May & a short rain season in November-December are expected. Although the precipitation of the catchment is fairly distributed throughout the year substantial amount of it occurs during months of April & May.

A team of Senior Engineers from the consultants visited the site and did a preliminary reconnaissance of the project site. The principal components of the project were identified and placed on the map. Subsequently, visits were conducted for carrying out detailed topographical surveys to freeze the layout of the site and establish the feasibility of the project. The Survey sheet for the project area is 27/4.

From the available geological information for the site, the site is considered satisfactory for the construction of structures involved in a small hydro power project. The bearing capacity of all the proposed locations is adequate and no major problems are expected at this stage. Construction material such as aggregates, sand, boulders are available at locations near the site.

The hydrology data for the river Pinyinyi for the years 1980 to 2019 was obtained from the Gauging and discharge station maintained by the ministry of water at a hydrometric station number 2A4. The information that is available from the gauging station at Oldonyo Sambu and from one near the Pinyinyi Village indicates that a dependable flow of 0.90 to 1.0 cumecs would be available at the river with 90% dependability. Based on this assumption, we have calculated the power generation potential of the project at around 14.980 GWh per year for 90% plant availability.

The major civil structures involved in the project are:

1. A trench weir with shingle flushing conduit.
2. An intake structure to collect water from the weir & direct it to the conveyance channel.
3. A free flow conveyance channel to carry the water to the desilting tank.
4. A desilting tank to separate all silt particles up to 0.20 mm size.
5. A free flow water conductor system consisting of D Shaped head race Channel (HRC) to carry the water to the forebay.
6. A surface forebay (with storage of water equivalent to 2.5 minutes of operation) & penstock.
7. A powerhouse at the base of the penstock to house the machines.
8. Tail race Channel.

The design for civil structures was carried out in accordance with civil design principles & the estimated 100 years flood values.

Two horizontal axis Pelton turbine, each of 1.0 MW capacity and two numbers of jets, have

been proposed for the project. The turbine and generating units with other associated equipment will be accommodated in a surface powerhouse on the left bank of the river. The generation voltage is proposed to be 3.3 kV. This voltage will be stepped up to 33 kV level by two generator step-up transformers, rated (1.3 MVA), 3.3 kV/33 kV. On the LV side, the transformer will be connected to the generator by means of 3.3 kV isolated phase bus duct. On the HV side, the transformer will be connected to a 33 kV outdoor conventional type switchyard by a 33 kV overhead transmission line (link lines). Power will be evacuated through 33 kV Outdoor Switch Yard through single/double circuit 33 kV transmission line to the Wasso Town in Loliondo to the TANESCO Local grid station at a distance of 78 km.

The main items of work for civil works have been estimated on the basis of drawings prepared after carrying out the designs of civil components. Surveys have been conducted to assess the availability and suitability of construction materials in the vicinity of the project area. The construction of Pinyinyi HEP will have to be supported by relevant infrastructure works such as permanent and temporary colonies, office, roads and bridges, workshops, etc. situated within the project area. The project is planned to be completed in a construction period of 18 months and a 3 months period will be devoted for mobilization and creation of infrastructure facilities such as roads, housing, shelters, storage areas etc. The construction of the project is proposed to be carried out through contracting agencies entrusted with suitable contract packages. Suitable work force will be hired by the developer to execute the project in a judicious manner.

The following activities including permits, license, study reports have already been completed.

1. Environmental Impact Assessment Certificate (EC/EIA/3378)
2. Permanent Water Use Permit, No: 62100316
3. Provisional Electricity Generation License, No: PEGE-2018001
4. Letter of Intent from Tanesco (site reference no: Pinyinyi/Hydro/SPP/2019/90)
5. Land ownership from Ngorongoro District Council.
6. Load Flow Study report for the 33 kV Transmission Line.
7. Letter of No Objection from the Ministry of Energy.
8. Tanzania Investment Centre, letter of Incentives for Tax Exemption of Imported Electrical and mechanical Equipment.

The Environmental & Social Impacts Assessment EIA have been conducted in accordance with the terms of reference granted by the appropriate authority and Certificate has been granted by NEMC for this project. This is a run-of-river type small hydro power project and is an environment friendly activity without any adverse impacts on the ecology of the area.

In order to arrive at an estimate for the Project Cost, the major activities involved in the construction of the project have been identified and rates determined for the same. Also, the market rates & working rates for the major commodities involved in the construction of the project have been calculated.

Based on these estimates, an estimate for the project cost is arrived at. Various activities involved during development of the project, cost of land, & other items are factored in. A financial model is built to calculate the financing cost, working capital requirement etc. After adding all these costs, the total project cost is calculated to be around USD 8.725 Million or USD 4.3625 Million per MW of capacity installed. This exclude the 78 km long transmission line which the project received a grant for its construction and therefore is within the accepted range of costs for such projects.

The tariff for the project as per the EWURA 2019 policy is USD 8.95 c/kWh, while the levelized cost of electricity generated is around USD 8.5 c/kWh.

The financial projections are found to be encouraging. Sensitivity analysis is carried out for the project, varying the assumptions for critical variables such as project cost, hydrology, operational costs, etc. The sensitivity analysis indicates that the project has sufficiently robust cash flows to absorb variation in these inputs. Thus, the project is found to be technically feasible and economically viable.

In conclusion, the Pinyinyi SHP is an economically & technically viable project and so, further steps for detailed engineering design and SPPA procedures should follow next. After securing an SPPA with Tanesco, thereafter, preparation for EPC tendering documents and Financial closure will proceed ready for construction.

Chapter 1 - Introduction

1.1 Introduction to the Project

Pinyinyi Small Hydro Power Project (hereafter referred to as "the Project") is a proposed run-of-the-river development on the left bank of Pinyinyi River situated at Ngorongoro District, near Lake Natron (Soda Lake) within the United Republic of Tanzania. The proposed total installed capacity for the Project is **2.0 MW**, comprised of two Pelton hydro turbine generator sets of 1.0 MW each. The gross head available for power generation is ~236m, and the proposed design discharge is ~1.05 cumecs. The electricity generated is to be delivered via a 33 kV transmission line to an isolated grid network system of Loliondo and Wasso whose construction is 80% towards completion.

1.2 Promoters of the Project

Pinyinyi Power Project is developed and owned by Ninety Two Ltd, a registered company in Tanzania, with offices at Shekilango Road, Plot number 9, Block F UBUNGO, PO Box 31564, Dar-es-Salaam, Tanzania.

1.3 Technical Consultants - Strategic Consulting Group, India (SCG) and Yujin Energy Technology Co. Ltd, South Korea.

Yujin Energy Technology Co. Ltd from South Korea has been selected as the technical consultants to review the existing Feasibility study and bring it to a realistic and bankable level for the implementation of the project. Yujin Energy Technology Co. Ltd will also work on the Detailed Engineering Design drawings for construction and preparation of tendering documents for EPC contractors. Strategic Consulting Group (SCG), a hydro power consulting firm from India was previously hired as technical consultants to prepare the initial Feasibility Study which was completed in 2016. Yujin Energy Technology Co. Ltd is providing services such as site identification, feasibility assessment, detailed survey and investigation, DPR, Design and engineering and PPA advisory.

1.4 Site Accessibility

The project intake is located at an elevation of about $\pm 868\text{m}$ (above mean sea level), before the Pinyinyi river falls down an escarpment on its way to Lake Natron. The proposed Powerhouse for the Project will be located at $\pm 630\text{m}$ elevation, about 7.0 km upstream from shores of Lake Natron, and about 1.0 km away from the Pinyinyi village settlement. The project components are located on the left bank and include a 21m long trench weir, intake structure, desilting tank, about 1550m long free flow head race channel, forebay, penstock and powerhouse on the left bank of the river. New road of about 2-3 km and a bridge would also be required to connect the intake site. The intake site may also be connected by means of a ropeway to transport construction material and equipment.

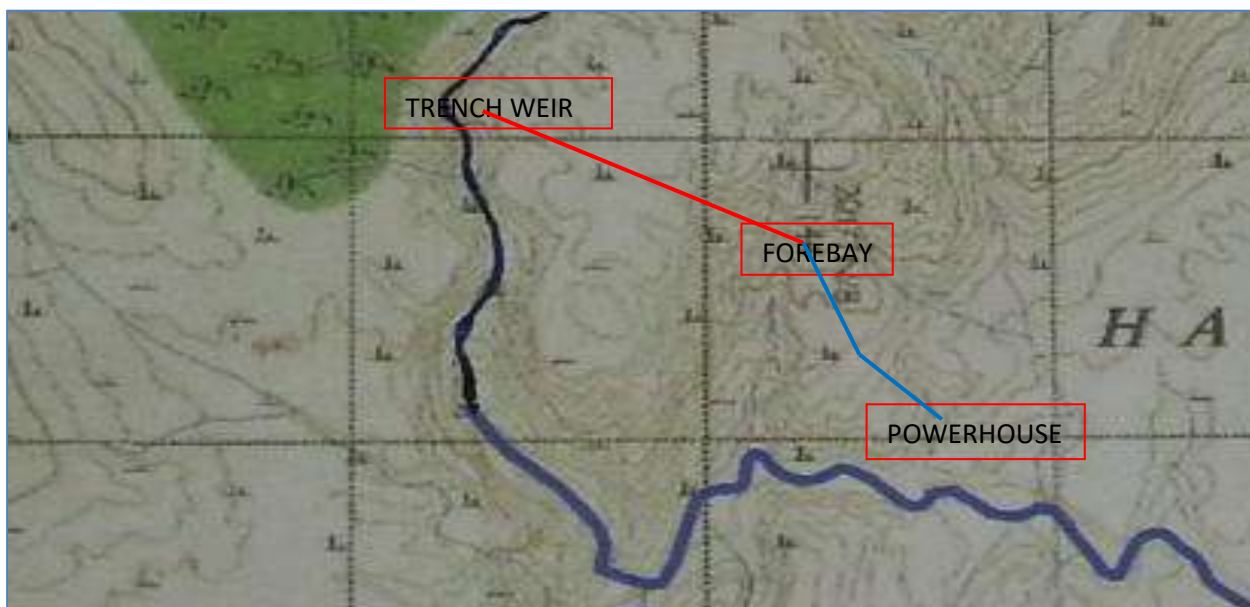
Also, the dirt roads would need to be reinforced and made ready for use by heavy trucks transporting machinery, equipment and supplies to the site during construction. The proposed powerhouse site would have to be connected through new black top road for easy movement of equipment and machinery.



Rocky road with very steep slope on the right bank of Pinyinyi River near the Site is drivable only in an all-wheel drive (4x4) vehicle that too with some difficulty.

1.4.1 Site location

The project area is located approximately 150 km to the North of *Mto Wa Mbu* town (literally, River of Mosquitoes) & around 60 km to the East of Loliondo town. Pinyinyi River has a catchment area of $\sim 1,380$ square kms, out of which $\sim 40\%$ lies in Kenya. The river joins the Lake Natron, a large soda water lake at an elevation of around 600m (above mean sea level).



Project layout shown in red line (tunnel) & blue line (penstock) on topographic map of Project Area (Sheet 27/4)

1.4.2 General climatic conditions in the area

The general climate in the area is subtropical, and changes as per the altitude: the temperatures are mild to warm during the day and mild to cold at night. The climate is warmer from September to April and slightly colder from May to August, although the difference in temperatures throughout the year is not significant. The Ngorongoro average temperatures are as follows:

Ngorongoro	J	F	M	A	M	J	J	A	S	O	N	D
Min (°C)	10	10	10	11	10	8	8	8	8	9	10	10
Max (°C)	23	23	22	21	20	19	19	20	21	22	22	22

Annual average precipitation in the region is around 600-1000 millimeters, and varies with the altitude. The areas in the lower altitudes are more arid as well as warmer. There is a dry season from June to September, thus corresponding to the coolest period, and a rainy season from October to May. The rainy season can be divided into a long rains season (from March to May) and a shorter rains season (from October to December). However, some rainfall is experience even in January and February. In the dry period, however, from June to September or October (until the short rains begin) there is very little rain.

The average monthly precipitation at Ngorongoro is as follows:

Ngorongoro	J	F	M	A	M	J	J	A	S	O	N	D	Year
Prec. (mm)	110	90	135	215	100	20	10	15	10	55	115	135	1010
Days	15	14	18	22	15	6	5	5	4	7	16	17	144

1.4.3 Topography and Geology

Essential topographical surveys were carried out to decide upon the general layout of the project and to identify the exact location of the various components of the scheme. This is described in detail in Chapter Number 4, Survey & Investigation. Generally, the project site is located in a mountainous zone in which the topography is composed of undulating hill and valleys. The project site is located at an elevation of about 868 m a.m.s.l, before Pinyinyi River descends into escarpment as it flows to lake Natron. The proposed power house for the project will be located at an elevation of about 630 m a.m.s.l. Therefore, the topographic nature of the project site provides the gross head of about 236 m between the proposed intake and powerhouse, which clearly shows that the site has a potential for the proposed power generation. Details of Preliminary surface geological assessment conducted for the project area are also given in the same Chapter. The area is mainly composed of the volcanic products of old and now extinct volcanoes, a notable exception from that is oldoinyo lengai volcanic mountain, which is still an active volcano in the region. Lake Natron is a soda ash lake situated in the bottom of the rift valley basin (Gregory Rift) surrounded by rift valley escarpments and volcanic mountains. The lake flats are surrounded by steep sloping hills with plio-pleistocene sediments rich in important fossils and artefacts as discussed below Detailed Geological investigations including soil test, core logging, sample testing shall be conducted at the Detailed Engineering stage.

1.5 Present Proposal

The proposed layout of the project consists of trench weir structure & intake on the Pinyinyi River with a full supply level (FSL) of 867.07m, which will divert the flow towards the water conductor. A 25m long surface desilting tank has been proposed as the silt load in the Pinyinyi River is significant. After the desilting tank, water will flow through an 1550 m head race channel to the forebay designed to have 2.5 minutes of water storage. Water will flow through a penstock to two numbers of Pelton turbines generator sets of 1.0 MW each. Water from the tail race will be released back into the Pinyinyi River at an elevation of ~630m. The gross head available for power generation is ~236m, and the proposed design discharge is ~1.05 cumecs. Suitable environmental flow will be maintained in the river

stretch between the intake & the powerhouse outfall. The electricity generated is to be delivered to an isolated grid network system of Loliondo and Wasso via a planned 78Km long transmission line.

1.6 Alternative Studies

Alternative schemes encompassing different positioning of various components have been studied. The most cost beneficial scheme has been finally proposed.

1.7 Socio Economic Aspects

According to the population census of 2002, Ngorongoro district had a population of close to 130,000 and the population density was lower as compared to the National average. The main populated areas of the region are the Soitisambu village and the townships of Loliando and Wasso.

The project area is remote (with the distance from the regional capital of Arusha being close to 220 km). The main business of the people in the Ngorongoro area is tourism, livestock & agricultural farming. The area is developing rapidly because of connectivity and people are using new techniques in their business. Small scale industrial activities such as milling, handicrafts and furniture making can be found sporadically. There is clearly improvement of basic infrastructure such as electric power, roads, telephone connectivity etc that will contribute towards the development of the area.

1.8 Land Requirement

The Pinyinyi Small Hydro Project is a run-of-river scheme and will not result in submergence or reservoir creation. A total of 48.5 Acres has already been approved and issued by Ngorongoro district council for the construction of the project structures.

While a separate 62 Ha of land has already been issued for the 33 kV Transmission line of 78 Km which is now under construction.

1.9 Population Affected

This project is a run-of-river scheme, has no storage reservoir and hence no submergence of the area. No rehabilitation or relocation issues are envisaged.

1.10 Environmental Aspects

This Project is located in a rural and ecologically sensitive area surrounded by multiple national parks. The development of the project has taken into account the environmental impacts and mitigations through the Environmental Impact Assessment which was conducted and completed in 2017. The project will play an important role in changing the living standards of the people of the area and shall contribute substantially towards positive environmental impacts. Small hydro power projects are non-polluting and no adverse environmental impact of any nature has been envisaged. This Project is economically viable, socially equitable, culturally acceptable, ecologically compatible and environmentally sustainable.

In consultation with the National Environment Management Council (NEMC) of Tanzania, & in accordance with the laws & regulations, an environmental flow has been provided for the river stretch between the intake & the powerhouse outlet (tailrace). This flow will ensure that the aquatic ecosystem in the given stretch of the river will remain intact.

1.11 Inter-State / Inter-National Aspects

The project area is located near the international boundary of Tanzania with Kenya, but no critical issues related to the boundary are envisaged currently. All project components are located well within Tanzania, and the transmission line is also located within the country. So no major international issues are expected to be encountered in the project.

1.12 Construction Program

Available working season in a year in the project area shall be the whole year and the work can be executed throughout the year. Short interruptions during long rains (April & May) may be experienced due to heavy downpour. The project is not well connected by motor able roads. The construction material and equipment would need to be transported keeping this in mind. The construction program, methodology have been planned with the aim of commissioning the project in 18 months excluding the mobilization period.

1.13 SALIENT FEATURES

1 LOCATION

Region	Africa, South of Sahara
Country	The United Republic of Tanzania
City/ Town	Mto Wa Mbu, Loliondo, Wasso
Geographical co-ordinates of project	
At Weir Site	2° - 17' – 16.75” S - 35° - 54' – 56.81” E
At Power House Site	2° - 17' – 57.02” S - 35° - 55' – 46.43” E
Access	150 km from Mto Wa Mbu town towards the North & around 60km from Loliondo town (towards East).
Nearest Airport	Arusha, Dar es Salaam
Nearest Port	Tanga Port
Distance from Capital	860 km from Dar es Salaam
River / Stream	Pinyinyi River which joins lake Natron (Soda lake), 7 km downstream of the project area.
Basin	Lake Natron basin
Proposal	Weir site on Pinyinyi River at El. ± 868m, power house at EL ± 630 m on left bank.

2 HYDROLOGY AND CLIMATE

Catchment area	1380 Sq km
Average Runoff	A large portion of the catchment may not be Contributing to the runoff to any significant degree The river joins lake Natron a large soda water lake At an elevation of around 600m above mean sea level
Design Flood	The flood level of 2m above the river banks for safe design
Design Discharge assumed	1.05 cumecs

3 PROJECT COMPONENTS

3.1 DIVERSION WEIR

Type	Drop type trench weir
River bed level	EL ± 868 m
HFL	870m
Size	21 m long * 16 m wide
Diversion design discharge	1.67 cumecs
Shingle flushing discharge	0.278 cumecs

3.2 CONVEYANCE CHANNEL

Type	Closed rectangular shaped
Size	1 m * 1 m
Length	35m
Slope	1 in 103
Velocity	2.78 m/s

3.3 DESILTING TANK

Type	Surface
Size (L*B*D)	15 m * 4 m * 2.6 m
Particle Size to be excluded	All particles down to 0.20mm size
Silt Flushing Duct Size	0.7 m * 1 m
Silt Flushing Discharge	0.23 cumecs

3.4 HEAD RACE CHANNEL

Type & Size	D – shaped, 1.1 m x 1.8 m preferably pipes
Length	1550 m

3.5 FOREBAY

Type	Surface
Size	15 m * 4 m * 3 m
FSL	EL 860.94 m
MDDL	EL 857.94 m
C/L of penstock intake opening	EL 855.99 m

3.6 PENSTOCK

Type	Circular, surface steel penstock
Size	1 number, 650 mm dia, plate thickness (6-10) mm, bifurcating at lower end near power house into 500 mm diameter each.
Length	± 1019m
Velocity	3.17 m/sec.

3.7 POWER HOUSE

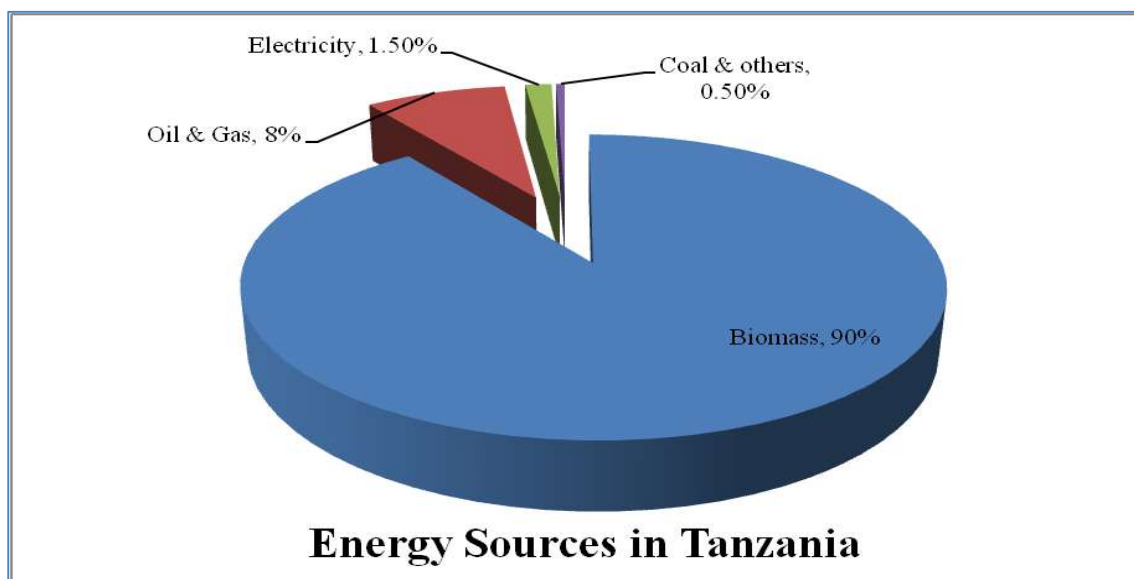
Type	Surface
Location	Left bank of Pinyinyi River at EL ±630 m
Installed capacity	2.0 MW
Size of Power House:	
Length	25 m

Width	13 m
Height	14 m
Normal Tail Water level	EL 629.91 m
Type of Turbine	2 nos. Horizontal axis Pelton
Type of Generator	Synchronous, brushless
Power factor	0.8 lag
Overload capacity continuous	10 %
Gross Head	± 236 m
Net head	± 217 m
3.8 TAIL RACE	
Type & Size	Rectangular section, 1.14 m x 1.5 m
Length	± 60 m
3.9 Electricity Generation	
Pant load factor (PLF) assumed	90%
Electricity generation in GWh	14.980 GWh
3.10 Project Cost in Million USD	
Civil construction works	3.430
Electromechanical equipment	1.350
Project Development costs	1.804
Other Direct costs	1.044
Interest During Construction	0.255
CRDB Facility Fee	0.114
Debt Service Reserve Account	0.478
TIC charges	0.001
VAT payment	0.001
Working Capital	0.225
Working Capital fee	0.003
Cash Balance at end of construction	0.020
Total Project Cost	8.725 million
Cost per MW	4.3625 million

Chapter 2 – Justification for the Project

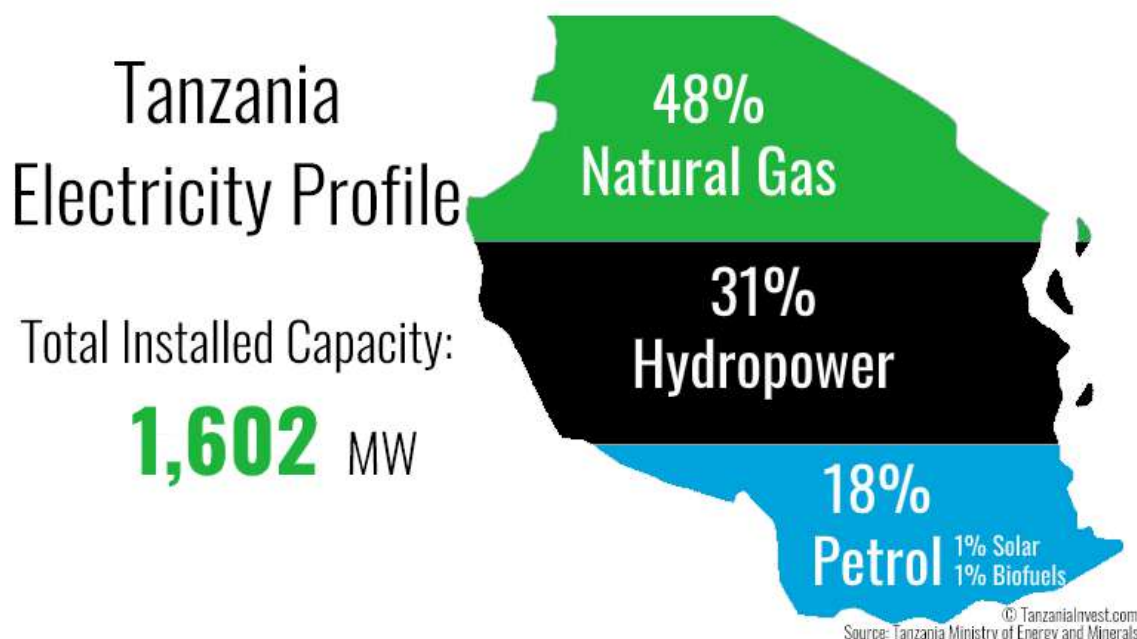
2.1 Energy Sector Overview of Tanzania

Tanzania is gifted with diverse energy sources most of which are untapped. These include biomass, hydro, uranium, natural gas, coal, geothermal, solar and wind. The primary energy supply includes biomass (90%); petroleum products (8%); electricity (1.5%), and the remaining (0.5%) is contributed by coal and other renewable energy sources. More than 80% of energy delivered from biomass is consumed in rural areas. Heavy dependence on biomass as the main energy source contributes to deforestation. Import of oil costs about 25% to 35% of the nation's foreign currency earnings. Only about 21% of the country's population has gained access to electricity (as of January 2014). Extending the National Grid into many parts of the country, including rural areas, is not economically feasible.



2.2 Power Sector Overview

The total installed power capacity in Tanzania is about 1602 MW, out of which around 48% is Natural Gas with hydro power coming in at 31%. The power sector comes under the Ministry of Energy (ME) and ME acts as a representative of the Government of Tanzania (GoT) while dealing with the IPPs regarding power projects. TANESCO is the single vertically integrated national utility, wholly owned by the GoT & regulated by ME. The power sector is regulated by the Energy and Water Utility Regulatory Authority (EWURA). EWURA awards licences to IPPs, approves and enforces tariffs and approves terms and conditions of the power purchase agreements (PPAs).



2.3 Power Scenario- Present and Future

The demand for electricity, which is considered as prime mover of growth, is expected to grow at an exponential rate in the country due to the overall economic development as well as the growth in population. It has been estimated that the country needs to add about 10%-15% of its installed capacity every year in next decade or so to meet the ever increasing power demand. However, the capacity addition program has not been meeting targets.

The power supply has been largely dependent on Gas and Hydro Power dams which have proven to be insufficient to meet the demand. The thermal projects depend on imported fuel which is a drain on the valuable & meagre foreign exchange resources of the country.

The country has a target of generating 10,000 MW and providing electricity access to 75% of the population by 2025. If this target is to be met meaningfully, the installed capacity must rapidly be scaled up to meet the electricity demands of this connected population. Investments in transmission and distribution infrastructure is also required to reduce losses, and take electricity to the currently unserved regions.

2.4 Justification of the Project from Power Supply Angle

Tanzania has an estimated hydro power potential of around 4,700 MW but only 561 MW of it has been developed so far. A number of large hydro power projects have been identified by the Government as well as by IPPs and are currently being investigated. This leaves a vast potential still to be harnessed. The small hydro power potential is also being investigated by many IPPs. Given the low access to electricity, heavy dependence on fossil fuels, low installed capacity and potential available, the Pinyinyi SHP is justified from all angles.

2.5 Need for the Project

As of now, there is no existing renewable energy source or any public infrastructure for grid connectivity in northern part of Ngorongoro district, other than a 4.8 MW diesel power generator owned by the TANESCO. Recently through the REA phase III Electrification program, a new mini-grid of 33 Kv Transmission and distribution line is being constructed in Loliondo. Meaning the proposed Pinyinyi project will be feeding 2 MW of renewable electricity to the new transmission line.



Diesel Power Generators in Loliondo, operated by Tanesco

Most of the electricity needs of private individuals and organizations are met through their own diesel generators or solar power systems (PV). Most large electricity consumers such as hospital, government offices, and small businesses use diesel generators (or Solar PV systems) and could turn out to be future customers for the power from Pinyinyi Hydro Project.

Based on the tariffs approved by EWURA in 2019, the Pinyinyi project will sell electricity to Tanesco for USD 8.95 c/kWh, this tariff is very low compared to what Tanesco is using to operate and maintain the Diesel generators plant in Loliondo. It is estimated that once the Pinyinyi will be operational, Tanesco will be saving Tsh 6.0 Billion annually from fuel and other operating expenses being consumed by Loliondo Diesel generators.

According to the strategic location of the Pinyinyi project, a lot of transmission losses will be reduced when evacuating power to existing and new customers. Presently, a large portion of the energy is being generated from fossil fuels. Their polluting and fast depleting nature has become a cause of concern for the country's energy and environmental security. Given the above mentioned circumstances, Micro/Mini/small hydro power projects are attractive renewable sources of decentralized power. These projects possess additional advantages, such as being economically viable, socially equitable, culturally acceptable, environmentally compatible and geologically stable.

2.6 Objectives of the Scheme

Pinyinyi HEP, being a small hydro power scheme, brings together all the benefits associated with renewable energy & small hydro power mentioned above. The main objectives of the Project are:

- i. To contribute to improvement of quality, stability & reliability of power supply in the northern Tanzanian regions of Loliondo and Wasso.
- ii. To conserve kerosene, oil products and wood used for space heating, cooking, lighting and other purposes by local people.
- iii. To conserve forest that is being cut down at an alarming rate to meet rural energy needs.
- iv. To increase productivity and output in rural areas by reducing the cost of energy thereby increasing efficiency and profitability.
- v. To add to the standard of living in village communities by promoting small enterprises at the local level.
- vi. To create employment opportunities during construction of the project and operations stage and thus help check rural migration to urban areas.
- vii. To reduce emission of greenhouse gases and earn carbon credits
- viii. To preserve biological diversity.
- ix. To arrest the pollution of water.
- x. To preserve ozone layer.

Chapter 3 – Basin Development

3.1 The origin and course of the River

The river Pinyinyi originates from Kenya and flows into Lake Natron in the Arusha region of northern Tanzania. The Pinyinyi River has a total catchment area of 1380 sq. km and 40% of the catchment is in Kenya. However, a large portion of the catchment may not be contributing to the runoff to any significant degree.

The Pinyinyi (2.0 MW) small hydro power project has been proposed on Pinyinyi River between elevations 868m & 630m. The project area for Pinyinyi SHPP is located approximately 150 Km to the north of Mta wa Mbu & around 60 Km to the east of Loliondo town.

The Pinyinyi river is characterized by a perennial flow of water. The flow of water has been gauged from around 1977 (till around 1984) and then in 1990. As per a study conducted by Sweco in 2005, a 90% dependable flow of 0.9 cumecs has been estimated. Flood flow estimates are not available.

The main topographic feature of the river in the project area is the escarpment over which it drops suddenly with a fall in elevation of close to 200m. The slope or gradient of flow is very gradual (except for the steep fall over the escarpment). On both banks in the project area, the banks are almost flat with an elevation of close to 630m.

3.2 Power Potential of the Basin

Various studies done over the years have estimated the potential of the Pinyinyi River site to produce around 2.0 MW. The proposals have been evaluated, but no other project has come up. The Pinyinyi SHP is a cost effective and technically feasible solution to harness the power potential of the Pinyinyi River between elevations 868m and 630m and to supply the clean energy to the mini grid of Loliondo and Wasso.

3.3 Trans-Basin Diversion of Water

The Pinyinyi SHPP is a run of river scheme and no trans-basin diversion of water is involved. The water from Tail Race Pool will be fed back to the river Pinyinyi.

3.4 Fitment of the Scheme in the overall basin development

The drop in the Pinyinyi River between elevations 868m and 630m, provides an opportunity to harness the energy of the flowing water. The gross head generated will be about 236m, and the capacity installed will be 2.0 MW. It is imperative that only the most cost beneficial and economically viable projects are constructed. The Pinyinyi SHPP proposes to utilize such a potential available on the Pinyinyi River. The proposed design discharge of the scheme is 1.05 cumecs. The project utilizes the available head and the discharge to generate 2.0 MW of peak power at an estimated plant load factor of nearly 90%.

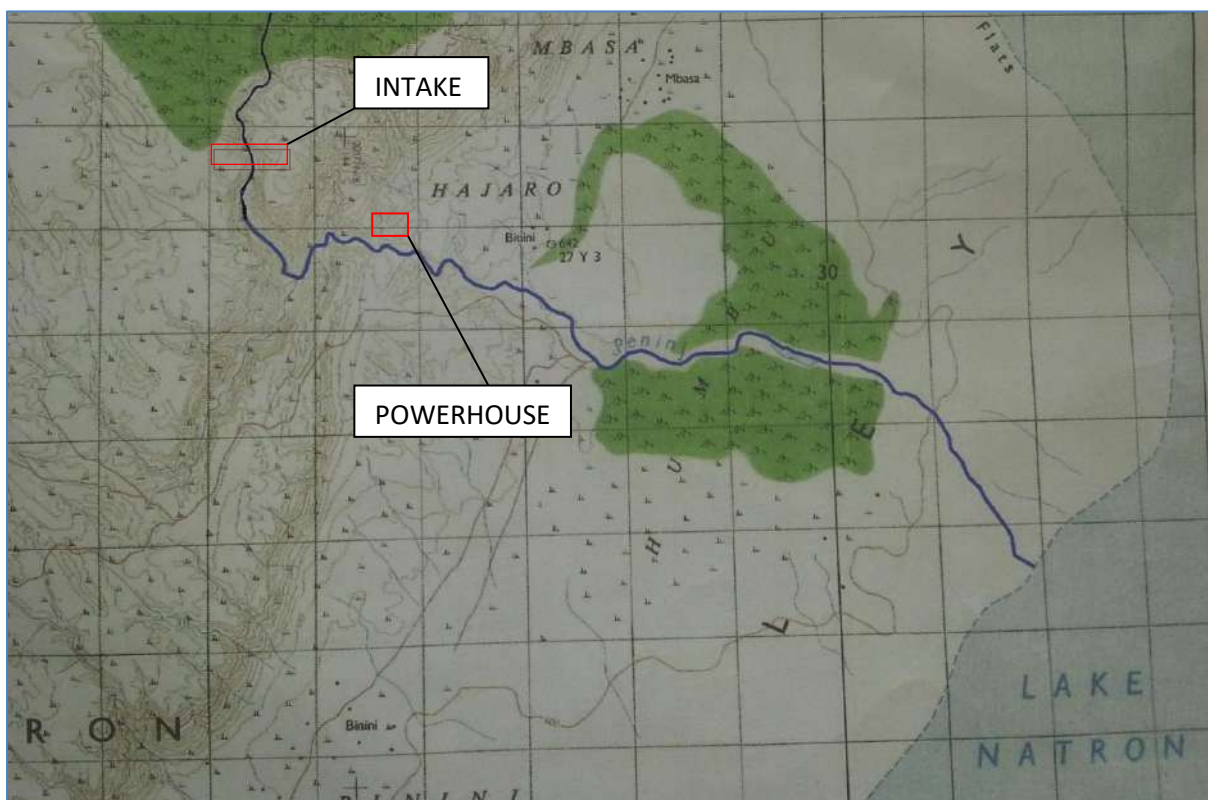
3.5 Effect of future upstream/downstream developments on the potential of proposed scheme

The Pinyinyi SHPP does not interfere with any other schemes proposed on the Pinyinyi River. This scheme shall not have any impact on any future scheme. Rather it shall set a precedent and encourage the development of more such schemes in the future.

Chapter 4 – Survey & Investigation

4.1 Topographic Survey

A team of Senior Engineers from the consultants visited the site and did a preliminary reconnaissance of the project site. The principal components of the project were identified and placed on the map. Subsequently, visits were conducted for carrying out detailed topographical surveys to freeze the layout of the site and establish the feasibility of the project. The Survey sheet for the project area is 27/4. The extract of the project area from the topo sheet is shown below:



Project location area with respect to Pinyinyi village and Lake Natron (Sheet 27/4)

The detailed topographical survey was carried out by a surveyor agency 'Albani Shirima', PO Box 3838, Dar Es Salam, over a period of 4 days in March 2015. The team consisted of five people, and the survey was carried out with the help of GPS receivers & Total Stations. The description of survey carried out for various components of the project is as follows:

4.2 General Layout

Detailed topographical surveys were carried out for contour interval of 2m using a total station. Different alternatives have been studied and general layout of the various components of the project has been marked indicating the proposed location of the Diversion Structure, Desilting tank, water conductor, forebay, penstock, Power House, Tail Race Channel, Switch Yard, etc. The description of the project components surveyed has been included below:

4.2.1 Diversion Structure along with Channel

The survey of the area 300m upstream of the proposed intake location has been carried out. The survey of the alignment of the water conductor, including Conveyance channel, Desilting tank & Head race channel has been carried out.

4.2.2 Forebay

Detailed topographic survey of the proposed forebay area in the scale of 1:2000 with contour interval of 2 m has been carried out.

4.2.3 Power House Area

The detailed topographic surveys of the proposed power house area in the scale of 1:2000 with contour interval of 2 m covering tail race channel has been done. Water level marks in the river have also been recorded.

4.2.4 Tail Race Channel

From tail race pool, water will be carried to the tail race channel. The structure is envisaged on the left bank of the river with a length of ~60 m meters carrying water discharge after power generation.

4.2.5 Switch Yard

An outdoor switchyard has been proposed after conducting the survey. The dimensions of the proposed switch yard are 23 meters long and 14 meters wide. The Switch Yard will be next to the power house building on the same bank. It will accommodate the main transformer and other equipment.

4.2.6 Foundation Investigations

Detailed geological investigations & drilling shall be conducted at the Detailed Engineering stage. Sub-soil explorations will be carried out by drilling cores and testing samples in a laboratory.

Surface Geological Report of the project area is as follows.

4.3 Regional Geology

The area is mainly composed of the volcanic products of old and now extinct volcanoes, a notable exception being that of Oldonyo Lengai, which is an active volcano in the region.

4.3.1 Geology of Intake Area

From the available geological information for the site, the site is considered satisfactory for the construction of structures involved in a small hydro power project. Since the impoundment of water is not very large, no significant problems related to slips or settlements are expected in the Intake area.

4.3.2 Geology of the Channel

Properties of the geology along the alignment indicate that the alignment of the channel runs through rock mass and there is very little risk of debris or loose soil falling into the channel. The bearing capacity of all the proposed locations is adequate and no major problems are expected at this stage.

4.4 Construction Material Surveys

Grit, concrete aggregate can be made available by installing a stone crusher at the site. Bricks will have to be procured from the nearby townships. Sand can be derived from the river at number of places in the vicinity.

4.5 Hydrological and Meteorological Investigations

4.5.1 Hydrological Investigations

The hydrological evaluation is the basis of plant design, as they affect the choice of the plant layout, the dimensioning of the waterways, the type of turbine and the relevant

electromechanical equipment There is measurement discharge series available for the river for long period to firm up the hydrology and power potential of the site.

4.5.2 Meteorological Investigations

The region generally has two rainy seasons. A long rain season from March to May & a short rain season in November-December. Although the precipitation of the catchment is fairly distributed throughout the year substantial amount of it occurs during months of April & May.

Chapter 5 – Hydrology

5.1 Hydrological Inputs for the Project Planning

This chapter describes the water flow characteristics of the Pinyinyi River and the methodology applied for arriving at the design discharge for the Pinyinyi Small Hydro Power Project. The 2005 Tanzania Rural Electrification Study (Sweco, 2005a) briefly outlines the hydrology also the discharge of Pinyinyi river was obtained from the gauging station number 2A4 a site nearby Oldoinyo Sambu, with coordinates Lat 2° 22' S and Long 35° 54' E has been gauged from around 1977. The obtained data was subjected to rearrangement and statistical analysis was made. The hydrometric data record collected during the station's operational period shows that the river is a **PERENNIAL RIVER**. The details of the same have been shared in this chapter.

5.2 Effect of Project Development on Hydraulic Regime

Pinyinyi Small HPP is a run of river project with no storage. There is no consumptive use of water either. Hence there is no effect of the project development on the hydraulic regime of the river.

5.3 Catchment Description & Characteristics

The proposed Pinyinyi small Hydropower is situated on the main river channel of Pinyinyi river system which originates from Kenya and flows into Lake Natron in the Arusha region of northern Tanzania which its basin is a sub-basin of within the Internal Drain Basin. The Pinyinyi River has a catchment area of 1380 sq. km at the proposed intake site and 40% of the catchment is in Kenya. The Pinyinyi River is characterized by perennial flow of water. The project area is remote with poor road access in the rainy season but those roads are now getting improved to the project location. It is in an environmental sensitive area with Serengeti National Park in the west, Ngorongoro conservation area in the south, and Lake Natron in the east.

5.4 Flood estimation

The flood discharge of Pinyinyi River has been estimated for the safe design of the weir and intake components, as well as the safe location of the powerhouse above the flood level. To estimate the 100 year return flood value, with the hydrology data series obtained and the

conclusion for Pinyinyi river to have water flow as Perennial river, we have assumed a flood level of 2 m above the river banks for safe design.

5.5 Climate

The general climate in the area is subtropical, and changes as per the altitude: the temperatures are mild to warm during the day and mild to cold at night. The climate is warmer from September to April and slightly colder from May to August, although the difference in temperatures throughout the year is not significant.

5.6 Rainfall

The region generally has two rainy seasons. A long rain season from March to May & a short rain season in November-December. Although the precipitation of the catchment is fairly distributed throughout the year substantial amount of it occurs during months of April & May. Annual average precipitation in the region is around 600-1000 millimeters, and varies with the altitude. The areas in the lower altitudes are more arid as well as warmer.

5.7 Sediment Load

As per observations during site visits and information from earlier studies, the river is likely to carry significant sediment loads during rains, and hence further sampling and analysis of sediment loads is required to be done. Preliminary reconnaissance studies have shown that there is no significant danger of sedimentation to the intake or the project. But silt load volumes during flood season would have to be analysed at the detailed engineering stage of the project.

5.8 Existing Water Uses

The existing uses of water in the project area are limited to the daily use requirements of the local population for their ablutions, cattle & drinking purposes.

5.9 Discharge Data for Pinyinyi

The existing discharge data for the river at one gauging station by relating the available data at this station with those at adjacent station and as per the information given in earlier studies, a 90% dependable flow of 0.9 cumecs has been adopted for the purpose of this study.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	1.561	1.425	1.289	0.424	1.860	1.266	0.533	0.386	0.296	0.259	0.285	0.115
1981	0.071	0.039	0.824	10.988	1.535	1.149	0.303	0.529	0.460	0.193	0.297	0.623
1982	1.008	0.960	0.912	0.864	1.209	1.032	0.074	0.672	0.624	0.128	0.309	1.131
1983	0.880	0.808	0.029	0.187	0.225	0.853	0.802	0.902	0.406	0.136	0.228	3.623
1984	1.167	1.057	0.947	0.837	0.716	0.674	0.507	0.397	0.188	0.144	0.147	6.116
1985	0.652	0.680	0.708	0.736	1.109	0.995	0.820	0.848	0.395	0.172	0.254	2.322
1986	0.890	1.762	1.018	0.918	0.818	0.718	0.194	0.346	0.418	0.318	0.146	0.450
1987	2.202	1.739	1.533	1.357	1.181	1.005	0.273	0.407	0.477	0.301	0.038	0.465
1988	2.178	1.716	1.536	1.367	1.198	1.029	0.352	0.468	0.522	0.353	0.112	0.480
1989	2.154	1.693	1.540	1.378	1.216	1.054	0.431	0.529	0.566	0.406	0.186	0.495
1990	2.130	1.670	1.543	1.388	1.233	1.078	0.510	0.590	0.613	0.458	0.260	0.510
1991	2.106	1.647	1.546	1.398	1.250	1.102	0.589	0.651	0.658	0.510	0.334	0.525
1992	2.082	1.624	1.550	1.409	1.268	1.127	0.668	0.712	0.704	0.563	0.408	0.540
1993	2.058	1.601	1.553	1.419	1.285	1.151	0.747	0.773	0.749	0.615	0.482	0.555
1994	2.034	1.578	1.565	1.401	1.237	1.073	0.826	0.834	0.581	0.417	0.253	0.089
1995	2.010	1.555	1.566	1.417	1.268	1.119	0.905	0.895	0.672	0.523	0.374	0.225
1996	1.986	1.532	1.567	1.433	1.299	1.165	0.984	0.956	0.763	0.629	0.495	0.361
1997	1.962	1.509	1.568	1.449	1.330	1.211	1.063	1.017	0.854	0.735	0.616	0.497
1998	1.938	1.486	1.569	1.465	1.361	1.257	1.142	1.078	0.945	0.841	0.737	0.633
1999	1.914	1.463	1.570	1.481	1.392	1.303	1.221	1.139	1.036	0.947	0.858	0.769
2000	1.890	1.440	1.571	1.497	1.423	1.349	1.300	1.200	1.127	1.053	0.979	0.905
2001	1.866	1.417	1.572	1.513	1.454	1.395	1.379	1.261	1.218	1.159	1.100	1.041
2002	1.842	1.394	1.573	1.529	1.485	1.441	1.458	1.322	1.309	1.265	1.221	1.177
2003	1.818	1.371	1.574	1.545	1.516	1.487	1.537	1.383	1.400	1.371	1.342	1.313
2004	1.794	1.348	1.573	1.558	1.543	1.528	1.616	1.444	1.483	1.468	1.453	1.438
2005	1.770	1.325	1.574	1.574	1.574	1.574	1.695	1.505	1.573	1.573	1.573	1.573
2006	1.746	1.302	1.572	1.586	1.600	1.614	1.774	1.566	1.656	1.670	1.684	1.698
2007	1.722	1.279	1.573	1.602	1.631	1.660	1.853	1.627	1.747	1.776	1.805	1.834
2008	1.698	1.256	1.574	1.618	1.662	1.706	1.932	1.688	1.838	1.882	1.926	1.970
2009	1.674	1.233	1.575	1.634	1.693	1.752	2.011	1.749	1.929	1.988	2.047	2.106
2010	1.650	1.210	1.576	1.650	1.724	1.798	2.090	1.810	2.020	2.094	2.168	2.242
2011	1.626	1.187	1.577	1.666	1.755	1.844	2.169	1.871	2.111	2.200	2.289	2.378
2012	1.602	1.164	1.578	1.682	1.786	1.890	2.248	1.932	2.202	2.306	2.410	2.514
2013	1.578	1.141	1.579	1.698	1.817	1.936	2.327	1.993	2.293	2.412	2.531	2.650
2014	1.554	1.118	1.580	1.714	1.848	1.982	2.406	2.054	2.384	2.518	2.652	2.786
2015	1.530	1.095	1.581	1.730	1.879	2.028	2.485	2.115	2.475	2.624	2.773	2.922
2016	1.529	1.093	1.583	1.736	1.881	2.031	2.492	2.118	2.479	2.632	2.784	2.935
2017	1.516	1.091	1.592	1.742	1.887	2.062	2.498	2.123	2.484	2.648	2.793	2.961
2018	1.502	1.078	1.597	1.756	1.894	2.071	2.521	2.142	2.496	2.682	2.811	2.989
2019	1.498	1.062	1.631	1.768	1.897	2.074	2.546	2.169	2.498	2.683	2.824	2.992
2020	1.494	1.061	1.657	1.772								
Mean	1.676	1.328	1.420	1.642	1.399	1.343	1.201	1.129	1.130	1.056	1.021	1.419

Monthly Mean Flows for Pinyinyi River at Station. No. 2A4 - (cumecs) for the Period 1980-2020

Month	Discharge of Pinyinyi River (cumecs)
Jan	1.676
Feb	1.328
Mar	1.420
Apr	1.642
May	1.399
Jun	1.343
Jul	1.201
Aug	1.129
Sept	1.130
Oct	1.056
Nov	1.021
Dec	1.419
Mean	1.314

The minimum monthly mean flow discharge for Pinyinyi River is 1.021 Cumecs which occurs in November while maximum monthly mean flow discharge is 1.676 Cumecs which occurs in January. The maximum flow is attributed to surface runoff increase resulting from rainfall during rainy season. The average flow discharge is **1.314** Cumecs.

Therefore, the drop in the Pinyinyi River between 868m and 630m provides a potential for harnessing the energy from the flowing water. The gross head of about 236 will generate power with the installed capacity of 1.90MW of peak power at an estimated plant load factor of nearly 90%. It is imperative that only the most cost beneficial and economically viable projects are constructed. The proposed design discharge of the scheme is 1.05 cumecs. The project developing company has obtained a permanent water use permit from The Ministry of water through the Internal Drainage Basin Water Office (IDBWO).

The discharge was computed using the arithmetical mid-section method involves essentially of the following steps; 1 dividing the total area of the cross section into partial sections and determining the area and mean velocity of each partial section separately, 2 computing the discharge in each partial section as the product of the velocity and the area, and 3 summing up the partial discharges to obtain the total discharge.

The measured flow discharge for Pinyinyi River was $0.619\text{m}^3/\text{s}$. This measured flow discharge is higher than the plant minimum discharge design. Hence the Pinyinyi River is an adequate water source and it is therefore very suitable for the proposed project.



Discharge measurement (Source: Study team, July, 2016)

Chapter 6 – Power Potential

6.1 Type of Power Plant

The Pinyinyi Small hydro power project is a run of river small hydro power project on the Pinyinyi River. Utilizing a gross head of 236m and a design discharge 1.05 Cumecs, it is envisaged that the project will have an installed capacity of 2.0 MW.

The assessment of amount of power that could be generated at the project and the related determination of generating capacity to be installed at this site have been made in accordance with the best technical practices, recommendations and guidelines generally followed in the design of hydro power projects.

6.2 Assessment of Power Potential of the Scheme

Analysing the power potential of the project is a principal step towards deriving the parameters of technically and economically suitable project considering the expected water availability over the years, the variation in water flow in different seasons, the available head and the other related factors influencing the project dimensions.

The principal factors for this assessment are:

- a) As per the 2005 Tanzania Rural Electrification Study (Sweco, 2005a) a site nearby has been gauged from around 1977 and there are some data available for the period 1980 to 2020. From the gauging station of number 2A4.
- b) The appropriate availability of gross & net head based on the Topography of the area & losses in the system.
- c) The placement of the appurtenant structures of the project on the available topography.

6.3 Capacity Sizing

Capacity sizing for the project was done on the basis of the estimated 90% dependable flow of 0.9 cumecs for the Pinyinyi river. For the given flow and head combination, an installed capacity of 2.0 MW is found to be suitable.

We have suggested a configuration consisting of 2 units of Pelton turbines each of 1.0 MW which will provide a higher reliability & flexibility of maintenance.

Chapter 7 – Design of Civil Structures

7.1 Introduction

Pinyinyi Small Hydro power project is a run of river based hydro power project on the Pinyinyi River. The major civil structures involved in the Pinyinyi project are as follows:

1. A trench weir with shingle flushing conduit.
2. An intake structure to collect water from the weir & direct it to the conveyance channel.
3. A free flow conveyance channel to carry the water to the desilting tank.
4. A desilting tank to separate all silt particles up to 0.20 mm size.
5. A free flow water conductor system consisting of high density pipes, head race channel (HRC) to carry the water to the forebay.
6. A surface forebay (with storage of water equivalent to 2.5 minutes of operation) & penstock.
7. A powerhouse at the base of the penstock to house the machines.
8. Tail race Channel.

The salient features of the civil structures are shown below:

DIVERSION WEIR

Type	Trench weir with shingle flushing conduit
River bed level	EL ± 868 m
HFL	870 m
Full Supply Level	802 m
Waterway	21 m

INTAKE STRUCTURE

Design Discharge	1.67 cumecs
FSL at intake	867.07 m
Full Supply Depth	0.5 m
Sill Level of Intake	866.57 m

CONVEYANCE CHANNEL

Type & Size	Rectangular 1.0 m x 1.0 m
-------------	---------------------------

Length	35 m
Slope	1 in 103
Design Discharge	1.39 cumecs

DESILTING TANK

Type	Surface
Size	25 m x 3.5 m x 2.6 m
FSL	El 866.73 m
Top RL of Tank	El 867.23 m

HEAD RACE CHANNEL

Type	D shaped
Full Supply Depth	0.55 m
Base Width	1.10 m
Length of HRC	1550 m

FOREBAY

Type	Surface
Full Supply Level	0.55 m
Length	15 m
Width	4 m

PENSTOCK

Diameter	0.65 m
Velocity	3.17 m/s
Length of main	1019 m
Length of each branch	23 m

POWER HOUSE

Type	Surface
Length	25 m
Width	13 m
Height	14 m

TAIL RACE

Type	Rectangular Shaped
Base Width	1.14 m
Full Supply Depth	0.31 m
Length	60 m

SWITCHYARD

Type	Surface
Length	30.8 m
Width	15.5 m

The design for these structures is explained in the following sections.

1. Water Conductor and Losses

Project Capacity	=	2.0	M.W	
River Bed level at diversion site	=	868.00	m	
Ground Level at power house site	=	630.00	m	
Full supply level at diversion site	=	867.50	m	
Center line of turbine at Power House	=	631.50	m	
Gross head	=	236.00	m	
Assumed head loss for calculation	=	19.00	m	
Net head	=	217.00	m	216.99
Considering turbine & generator efficiency	=	0.85		
Required discharge at turbine	=	Capacity (kW)/ $\eta\eta H$		
η (Overall efficiency of turbine and generator)	=	0.85		
γ (Unit weight of water)	=	9.81	kN/m ³	
	=	1.05	cumecs	
Design discharge at diversion site	=	1.67	cumecs	
(20% Shingle Flushing at intake+20% silt flushing at desilting tank+10% overloading)				
Design discharge at conveyance channel	=	1.39	cumecs	
Design discharge for HRC	=	1.16	cumecs	
(1) Trash Rack Losses at Trench Weir	=	$kv^2/2g$	m	
k (trash rack loss coefficient)	=	$1.45-(0.45*R)-R^2$		
Net area through trash rack / gross area of rack and supports (R)	=	0.25		
Area of trash rack opening (50% area is covered by trash rack bars)	=	10.5	sqm	
Net Area of trash rack (assuming 50% opening clogged)	=	5.25	sqm	
Velocity at trash rack	=	0.32	m/s	
k	=	1.275		
Trash rack loss	=	0.01	m	
(2) Losses in Conveyance Channel				
Length in conveyance channel	=	35	m	
Discharge in conveyance channel	=	1.39	cumecs	
Bottom width	=	1	m	
Full supply depth	=	0.5	m	
Area provided	=	0.5	sqm	
Velocity of flow	=	2.78	m/s	
(which is within permissible limit)				
Wetted perimeter	=	2.00	m	
Hydraulic Radius	=	0.25	m	

Applying Manning 's formula				
n for concrete	=	0.014		
Slope	=	$(Vn/R^{2/3})^2$		
Slope 1 in	=	103	m	
Head loss in conveyance channel	=	0.34	m	
(3) Losses in Desilting Tank				
(3).(i) Transition Loss in Tank	=	$K_e*((V_1^2 - V_2^2)/2g)$		
where, V1	=	velocity at upstream end		
	=	2.78	m/s	
V2	=	velocity at downstream end		
	=	0.15	m/s	
	=	$(1-a_1/a_2)*\sin\theta$		
a1	=	area on upstream		
	=	0.50	sqm	
a2	=	area on downstream		
	=	9.27	sqm	
θ	=	One half of the flare angle.		
	=	9.2	degrees	
k	=	0.152		
He	=	0.053	m	
Losses due to gradual contraction is neglected as the value of k is usually very small even for large values of the angle of convergence. As per ' <i>Hydraulics of Fluid Mechanics</i> ' by Dr. P.N. Modi & Dr. S.M. Seth (P- 407), Published by Standard Book House, Edition no. 18 (2011).				
(3).(ii) Friction Losses in Tank	=	$V^2 n^2 L / R^{4/3}$		
Velocity of flow (V)	=	0.15	m/s	
n	=	0.014		
Width of tank	B	=	3.5	m
Length of tank	L	=	25	m
Equivalent depth	D_e	=	1.99	m
Area of chamber	A	=	9.27	sqm
Perimeter of chamber	P	=	7.47	m
Hydraulic radius	R	=	1.24	m
Friction loss	=	0.0001	m	
Total losses in desilting tank	=	0.05	m	
(4) Losses in HRC				
Length of tunnel	=	1100	m	
Providing a H.R.C				
Flow will occur in H.R.C				
Discharge in H.R.C	=	1.16	cumecs	

Bottom width provided	=	1.1	m	
Full supply depth	=	0.55	m	
Area Provided	=	0.6	sqm	
Velocity of flow	=	2.20	m/s	
Wetted perimeter	=	2.20	m	
n for concrete	=	0.014		
Hydraulic radius	=	0.28	m	
Slope	=	$(Vn/R^{2/3})^2$	0.0052	
Slope one in	=	192.00		
Head loss in H.R.T	=	5.73	m	
(5) Losses in Penstock				
(5).(i) Entrance Losses				
(5).(i).(a) Trash Rack Losses	=	$kv^2/2g$	m	
k (Trash rack loss coefficient)	=	0.3		
(Assuming 25% bar area and slightly rounded corner trash rack)				
<i>(Refer fig 10 for cwc manual for penstock)</i>				
Assuming velocity at trash rack	=	0.6	m/s	
Trash rack loss	=	0.01	m	
(5).(i).(b) Bellmouth Entrance Loss	=	$Kv^2/2g$	m	
K (for bell mouth opening)	=	0.1		
Velocity of flow at bellmouth	=	2.5	m/s	
(Assuming 20% less than that of the penstock)				
Head loss	=	0.03	m	
(5).(ii) Friction loss				
(5).(ii).(a) Friction loss in Penstock main				
Length of main penstock	=	996	m	
Length of branches	=	23	m	
Discharge at penstock main	=	1.05	cumecs	
Diameter of penstock provided	=	0.65	m	
Velocity of flow at penstock	=	3.17	m/s	
Hydraulic radius	=	0.16	m	
Manning's n for steel	=	0.01		
Friction loss	=	$LV^2n^2/R^{4/3}$	m	
	=	11.22	m	
(5).(ii).(b) Friction Loss in Penstock Branches				
Length of branches	=	23	m	
Diameter of branches	=	0.5	m	
Velocity of flow	=	3.17	m/s	
(Same as main penstock)				
Hydraulic radius	=	0.125	m	

Manning's n for steel	=	0.01		
Friction loss	=	$LV^2n^2/R^{4/3}$	m	
	=	0.37		
Total friction loss	=	11.59	m	
(5).(iii) Bend Loss (Vertical Bends)				
No of bends in main	=	5 vertical	3 horizontal	
No of bends in branches	=	1 vertical	1 horizontal	
Bend angle for first vertical bend	=	28	degrees	
Bend angle for second vertical bend	=	20	degrees	
Bend angle for third vertical bend	=	13	degrees	
Bend angle for fourth vertical bend	=	17	degrees	
Bend angle for fifth vertical bend	=	11	degrees	
Bend angle for branch	=	14	degrees	
Bend loss	=	$\epsilon V^2/2g$	m	
€	=	Bend loss coefficient, depends upon (R/D and bend angle)		
Where R	=	Radius of curvature		
D	=	Diameter of penstock		
R/D	=	5		
€	=	0.05		
For 28 degrees bend				
€	=	0.04		
For 20 degrees bend				
€	=	0.02		
For 13 degrees bend				
€	=	0.03		
For 17 degrees bend				
€	=	0.02		
For 11 degrees bend				
€	=	0.03		
For 14 degrees bend				
<i>(As per fig-14, C.W.C manual for Penstock)</i>				
Total bend loss	=	0.1	m	
(5).(iv) Bend Losses (Horizontal Bend)				
Bend angle for first horizontal bend	=	26	degrees	
€		0.05		
Bend angle for second horizontal bend	=	33	degrees	
€		0.06		
Bend angle for third horizontal bend	=	27	degrees	
€		0.05		
Bend angle for branch	=	30	degrees	

€			0.06		
Total bend loss	=		0.11	m	
(5).(v) Losses at Wyes					
Wyes loss	=	$kv^2/2g$		m	
k	=	wyes loss coefficient			
It depends upon bifurcation angle and V_b/V					
Where V_b	=	Velocity at bifurcated unit			
V	=	Velocity at main unit			
Considering V_b/V	=	1			
Assuming bend angle	=	60		degrees	
k	=	0.5			
<i>(As per fig 18 of CWC manual)</i>					
Velocity	=	3.17		m/s	
Wyes loss	=	0.26		m	
(5).(vi) Reducer Loss					
6. Reducer Loss					
Reducer loss	=	$0.25v^2/2g$			
Diameter of reducer	=	0.3		meters	
Area of reducer	=	0.07		sqm	
v	=	d/s velocity at reducer			
		7.43		m/s	
Head loss	=	0.70		meters	
(5).(vii) Valve Loss					
Valve loss	=	$0.25v^2/2g$			
	=	0.70		m	
Total Losses in Penstock					
Actual Calculated Head Loss (Total)					
(Penstock+H.R.C)					
Summary					
Full Supply Level at Diversion	=	867.5		m	
Turbine -Centerline	=	631.5		m	
Gross Head	=	236		m	
Net Head (At Full Supply)	=	216.99		m	
Head Loss	=	19.01		m	
Length of Conveyance Channel	=	35		m	
Slope in Conveyance Channel (1 in	=	103			
Length of H.R.C	=	1550		m	

Slope of H.R.C (1 in	=	192		
Total Length of Penstock	=	1019	m	
Length of Penstock Main	=	996	m	
Length of Penstock Branch	=	23	m	
No of Bends in Main Penstock	=	5 vertical	3 horizontal	

2. Hydraulic Design of Trench Weir

Design Data								
The trench plan size	=	21 m × 7 m						
Design discharge	=	1.05	cumecs					
River Bed Level	=	868.00	m					
Highest Flood Level	=	870.00	m					
Water Level in trench weir at start	=	867.55	m					
Width of river	=	21	m					
Length of trench trough	=	21	m					
Depth of trench weir trough (at end)	=	1.87	m					
Width of trench weir trough	=	1	m					
Length of upstream apron	=	3	m					
Length of downstream apron	=	3	m					
Slope of upstream and downstream apron	=	01:10						
Slope of trench weir trash rack	=	01:10						
Design Calculations:								
Width of trench weir at top	=	B						
	=	$Q/(E1E2C_dL(2gE)^{1/2})$						
where,								
B	=	Width of trash rack (Width of trench weir at top) in m						
Q	=	Diverted discharge in cumecs						
E1	=	Ratio of area of opening to total area of trash rack surface over trench						
E2	=	Ratio of opening in trash rack likely to be clogged						
C _d	=	Coefficient of discharge through opening = 50%						
L	=	Length of trench trough						
g	=	Acceleration due to gravity						
E	=	Specific energy at any section of stream in the trench weir						
C	=	Coefficient of discharge for broad crested weir						
Diverted discharge Q	=	Design discharge						
		+ 20% extra for flushing at D - tank						

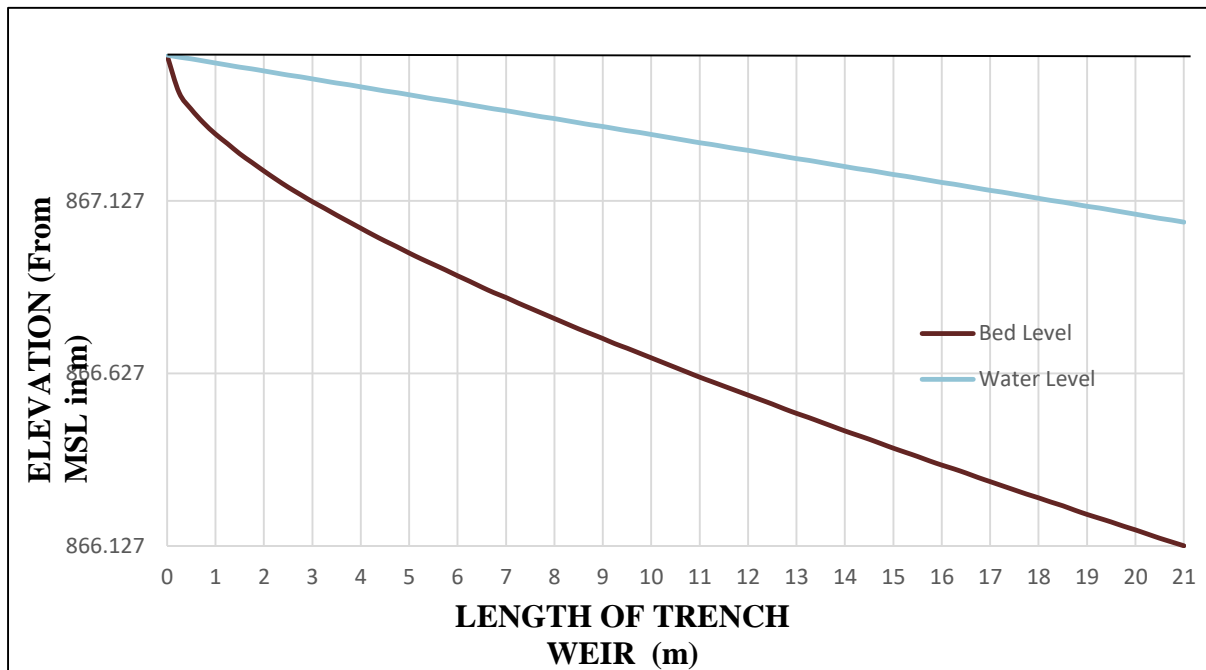
		+ 20% extra for flushing at intake				
		+ 10% for overloading				
	=	1.67	cumecs			
Length of trench trough L	=	21	m			
C_d	=	0.5				
g	=	9.8	m/s ²			
C	=	1.53				
E1	=	0.5				
E2	=	0.5				
Specific energy at any section of stream in the trench weir E	=	$(Q/CL)^{2/3}$	=	0.14		
<i>Refer: Page 339, Open Channel Hydraulics: Ven T Chow. Also refer design of broad crested weir</i>						
Therefore, width of trench weir at top B	=	0.39	m			
Let us provide width as	=	1	m			
Width by Considering Velocity						
Allowable velocity through trashrack opening v	=	0.4	m/s			
Width of trash rack	=	$Q/(Lv)$				
	=	0.2	m			
Width required for steel grating + clogging criteria	=	0.80	m			
which is less than provided, hence safe						
Calculation for Trench Weir Bed Slope & Depth						
River Bed Level	=	868.00	m			
Top level of downstream trough wall of trench weir	=	867.95	m			
Required free board	=	0.4	m			
Water level at the start of the trench	=	867.55	m			
Length of the rack	=	21	m			
Design discharge for the weir Q	=	1.67	cumecs			
Width of the trench B	=	1	m			
<i>The bed and water surface profile is computed by Hind's method with assumption that the concentration of the discharge is uniform at the crest of weir.</i>						

<i>Ref:-Ch- 12,Pg :327 , Open Channel Hydraulics ; Ven T. Chow</i>							
Let the water depth at any section along the channel be 'd'							
Therefore area, A	=	Bd =	1d				
For the section at end of the trench, the velocity head, h_v	=	$[\frac{n}{n+1}] * [A/(2 B)]$					
<i>Constant "n" depends on the bottom profile of the channel</i>							
n	=	0.5	(for rectangular channel)				
Therefore:							
Velocity head at end of collector, h_{v21}	=	0.17	d				
Q	=	$A(2gh_{v21})^{1/2}$					
From here, d	=	0.94	m				
Therefore, A	=	0.94	m^2				
Velocity end of trench weir V	=	1.78	m/s				
Velocity distance relation along the trench is given as follows:							
V	=	ax^n					
a	=	V/x^n					
a	=	0.388					
Therefore , V	=	0.388	$x^{0.5}$				
The ordinate y of the water surface curve measured downwards from the datum (FSL) is given by							
y	=	$h_v(n+1)/n$					
y	=	3	h_v				
y	=	3	$V^2/2g$				

S. No.	x	Q	x^n	$V = ax^n$	$A = Q/V$	$d = A/B$	$y = [(n+1/n)*V^2/2g]$	d +y	Bed Level of Trench 867.55-(d+y)	Water Level 867.55-y
1	0	0							867.55	867.55
2	0.25	0.02	0.5	0.19	0.103	0.103	0.006	0.109	867.441	867.544
3	0.5	0.04	0.707	0.27	0.146	0.146	0.011	0.157	867.393	867.539
4	0.75	0.06	0.866	0.34	0.179	0.179	0.017	0.196	867.354	867.533
5	1	0.08	1	0.39	0.206	0.206	0.023	0.229	867.321	867.527
6	1.25	0.099	1.118	0.43	0.228	0.228	0.029	0.257	867.293	867.521
7	1.5	0.119	1.225	0.48	0.251	0.251	0.035	0.286	867.264	867.515
8	1.75	0.139	1.323	0.51	0.271	0.271	0.04	0.311	867.239	867.51
9	2	0.159	1.414	0.55	0.29	0.29	0.046	0.336	867.214	867.504
10	2.25	0.179	1.5	0.58	0.308	0.308	0.052	0.36	867.19	867.498
11	2.5	0.199	1.581	0.61	0.325	0.325	0.058	0.383	867.167	867.492
12	2.75	0.219	1.658	0.64	0.341	0.341	0.063	0.404	867.146	867.487
13	3	0.239	1.732	0.67	0.356	0.356	0.069	0.425	867.125	867.481
14	3.25	0.258	1.803	0.7	0.369	0.369	0.075	0.444	867.106	867.475
15	3.5	0.278	1.871	0.73	0.383	0.383	0.081	0.464	867.086	867.469
16	3.75	0.298	1.936	0.75	0.397	0.397	0.086	0.483	867.067	867.464
17	4	0.318	2	0.78	0.41	0.41	0.092	0.502	867.048	867.458
18	4.25	0.338	2.062	0.8	0.423	0.423	0.098	0.521	867.029	867.452
19	4.5	0.358	2.121	0.82	0.435	0.435	0.104	0.539	867.011	867.446
20	4.75	0.378	2.179	0.85	0.447	0.447	0.109	0.556	866.994	867.441
21	5	0.398	2.236	0.87	0.459	0.459	0.115	0.574	866.976	867.435
22	5.25	0.418	2.291	0.89	0.47	0.47	0.121	0.591	866.959	867.429
23	5.5	0.437	2.345	0.91	0.48	0.48	0.127	0.607	866.943	867.423
24	5.75	0.457	2.398	0.93	0.491	0.491	0.132	0.623	866.927	867.418
25	6	0.477	2.449	0.95	0.502	0.502	0.138	0.64	866.91	867.412
26	6.25	0.497	2.5	0.97	0.512	0.512	0.144	0.656	866.894	867.406
27	6.5	0.517	2.55	0.99	0.523	0.523	0.15	0.673	866.877	867.4
28	6.75	0.537	2.598	1.01	0.533	0.533	0.156	0.689	866.861	867.394
29	7	0.557	2.646	1.03	0.542	0.542	0.161	0.703	866.847	867.389
30	7.25	0.577	2.693	1.05	0.552	0.552	0.167	0.719	866.831	867.383
31	7.5	0.596	2.739	1.06	0.561	0.561	0.173	0.734	866.816	867.377
32	7.75	0.616	2.784	1.08	0.57	0.57	0.179	0.749	866.801	867.371
33	8	0.636	2.828	1.1	0.58	0.58	0.184	0.764	866.786	867.366
34	8.25	0.656	2.872	1.11	0.589	0.589	0.19	0.779	866.771	867.36
35	8.5	0.676	2.915	1.13	0.598	0.598	0.196	0.794	866.756	867.354
36	8.75	0.696	2.958	1.15	0.606	0.606	0.202	0.808	866.742	867.348
37	9	0.716	3	1.16	0.615	0.615	0.207	0.822	866.728	867.343
38	9.25	0.736	3.041	1.18	0.624	0.624	0.213	0.837	866.713	867.337

S. No.	x	Q	x ⁿ	V = ax ⁿ	A = Q/V	d = A/B	y = [(n+1/n)*V ² /2g]	d +y	Bed Level of Trench 867.55-(d+y)	Water Level 867.55-y
39	9.5	0.755	3.082	1.2	0.631	0.631	0.219	0.85	866.7	867.331
40	9.75	0.775	3.122	1.21	0.64	0.640	0.224	0.864	866.686	867.326
41	10	0.795	3.162	1.23	0.648	0.648	0.23	0.878	866.672	867.32
42	10.3	0.815	3.202	1.24	0.656	0.656	0.236	0.892	866.658	867.314
43	10.5	0.835	3.240	1.26	0.664	0.664	0.242	0.906	866.644	867.308
44	10.8	0.855	3.279	1.27	0.672	0.672	0.248	0.92	866.63	867.302
45	11	0.875	3.317	1.29	0.680	0.680	0.254	0.934	866.616	867.296
46	11.3	0.895	3.354	1.30	0.688	0.688	0.259	0.947	866.603	867.291
47	11.5	0.915	3.391	1.32	0.695	0.695	0.265	0.96	866.59	867.285
48	11.8	0.934	3.428	1.33	0.702	0.702	0.271	0.973	866.577	867.279
49	12	0.954	3.464	1.34	0.710	0.710	0.276	0.986	866.564	867.274
50	12.3	0.974	3.500	1.36	0.717	0.717	0.282	0.999	866.551	867.268
51	12.5	0.994	3.536	1.37	0.724	0.724	0.288	1.012	866.538	867.262
52	12.8	1.014	3.571	1.39	0.732	0.732	0.294	1.026	866.524	867.256
53	13	1.034	3.606	1.40	0.739	0.739	0.300	1.039	866.511	867.25
54	13.3	1.054	3.640	1.41	0.746	0.746	0.305	1.051	866.499	867.245
55	13.5	1.074	3.674	1.43	0.753	0.753	0.311	1.064	866.486	867.239
56	13.8	1.093	3.708	1.44	0.760	0.760	0.317	1.077	866.473	867.233
57	14	1.113	3.742	1.45	0.767	0.767	0.323	1.09	866.46	867.227
58	14.3	1.133	3.775	1.47	0.773	0.773	0.329	1.102	866.448	867.221
59	14.5	1.153	3.808	1.48	0.780	0.780	0.334	1.114	866.436	867.216
60	14.8	1.173	3.841	1.49	0.787	0.787	0.340	1.127	866.423	867.21
61	15	1.193	3.873	1.50	0.794	0.794	0.346	1.14	866.41	867.204
62	15.3	1.213	3.905	1.52	0.801	0.801	0.351	1.152	866.398	867.199
63	15.5	1.233	3.937	1.53	0.807	0.807	0.357	1.164	866.386	867.193
64	15.8	1.253	3.969	1.54	0.814	0.814	0.363	1.177	866.373	867.187
65	16	1.272	4.000	1.55	0.820	0.820	0.369	1.189	866.361	867.181
66	16.3	1.292	4.031	1.56	0.826	0.826	0.374	1.2	866.35	867.176
67	16.5	1.312	4.062	1.58	0.832	0.832	0.380	1.212	866.338	867.17
68	16.8	1.332	4.093	1.59	0.839	0.839	0.386	1.225	866.325	867.164
69	17	1.352	4.123	1.60	0.845	0.845	0.392	1.237	866.313	867.158
70	17.3	1.372	4.153	1.61	0.852	0.852	0.397	1.249	866.301	867.153
71	17.5	1.392	4.183	1.62	0.858	0.858	0.403	1.261	866.289	867.147
72	17.8	1.412	4.213	1.64	0.864	0.864	0.409	1.273	866.277	867.141
73	18	1.431	4.243	1.65	0.869	0.869	0.415	1.284	866.266	867.135
74	18.3	1.451	4.272	1.66	0.875	0.875	0.421	1.296	866.254	867.129
75	18.5	1.471	4.301	1.67	0.881	0.881	0.426	1.307	866.243	867.124
76	18.8	1.491	4.330	1.68	0.888	0.888	0.432	1.32	866.23	867.118

S. No.	x	Q	x ⁿ	V = ax ⁿ	A = Q/V	d = A/B	y = [(n+1/n)*V ² /2g]	d + y	Bed Level of Trench 867.55-(d+y)	Water Level 867.55-y
77	19	1.511	4.359	1.69	0.894	0.894	0.438	1.332	866.218	867.112
78	19.3	1.531	4.387	1.7	0.9	0.9	0.443	1.343	866.207	867.107
79	19.5	1.551	4.416	1.71	0.905	0.905	0.449	1.354	866.196	867.101
80	19.8	1.571	4.444	1.72	0.911	0.911	0.455	1.366	866.184	867.095
81	20	1.59	4.472	1.74	0.916	0.916	0.461	1.377	866.173	867.089
82	20.3	1.61	4.5	1.75	0.922	0.922	0.467	1.389	866.161	867.083
83	20.5	1.63	4.528	1.76	0.928	0.928	0.473	1.401	866.149	867.077
84	20.8	1.65	4.555	1.77	0.934	0.934	0.478	1.412	866.138	867.072
85	21	1.67	4.583	1.78	0.939	0.939	0.484	1.423	866.127	867.066



Trench Weir Bed Slope and Water Surface Profile			
Bed slope of trench weir,	1 in	=	14.76
Check for Adequacy of Waterways			
Average depth		=	1.111 m
Area	A	=	1.111 m ²
Wetted Perimeter	P	=	3.223 m
Slope provided	S	=	0.0678
i.e. 1 in		=	14.76

Using manning's formula with value of n	=	0.014		
Discharge Q	=	$(1/n)AR^{2/3}S^{1/2}$		
	=	10.16	cumecs	
which is > diverted discharge		OK		
Check for Adequacy of Capacity with 50 % Area Clogged				
Average depth	=	0.56	m	
Area A	=	0.56	m ²	
Wetted perimeter P	=	2.11	m	
Slope S	=	0.0678		
i.e. 1 in	=	14.76		
Using Manning's formula with value of n	=	0.014		
Discharge Q	=	$(1/n)AR^{2/3}S^{1/2}$		
	=	4.30	cumecs	
Which is greater than design discharge		OK		
Summary				
Length of Trench	=	21	m	
Width of Trench	=	1	m	
Trench Depth at Start (from RBL)	=	0.45	m	
Trench Depth at Intake (from RBL)	=	1.873	m	
Slope Provided 1 in	=	14.76		
FSL at Trench Weir Start	=	867.55	m	
FSL at Trench Weir End	=	867.07	m	
R.L. of U/S Trench Side Wall	=	868.05	m	
R.L. of D/S Trench Side Wall	=	867.95	m	
R.L. of Top of Bottom Slab at Start of Trench	=	867.55	m	
R.L. of Top of Bottom Slab at End of Trench	=	866.13	m	
Length of Trash Rack	=	21	m	
Width of Trash Rack	=	1	m	
R.L. of Abutment Top at Weir Axis	=	871	m	
Height of Abutment	=	3	m	

3. Hydraulic Design of Intake

Design Data				
Design discharge Q_{max}	=	1.05	cumec	
Discharge at intake well Q	=	1.67	cumec	
Top of trench weir bed RL at end	=	866.13	m	
Pond level at start of intake FSL	=	867.07	m	
Height of opening at entry of conveyance channel h	=	0.5	m	

Flushing velocity	V_f	=	2.1	m/sec	
Provision for bell mouth	h_b	=	0.3	m	
Silt trap depth proposed		=	0.50	m	
HFL at trench weir site		=	870.00	m	
Design Computations					
Computation of Bottom Level of Intake					
Invert level of conveyance channel at start		=	FSL in channel - FSD		
		=	866.57	m	
Sill level of bell mouth		=	Bottom of intake — h_b		
		=	866.27	m	
Bottom RL of intake well		=	865.63	m	
Bottom level of gate		=	Top of trench weir bed RL at end		
		=	866.57	m	
Computation of Dimensions of Shingle Flushing Duct					
Flushing discharge	Q_f	=	0.278	cumec	
Area required		=	Q/V		
		=	0.13	m^2	
Provide width of shingle flushing duct		=	0.70	m	
Therefore, depth of shingle flushing duct		=	0.19	m	
Provide shingle flushing duct of size 0.7*		=	1.50	m	
Wetted Area	A	=	0.13	m^2	
Wetted perimeter	P	=	1.08	m	
Hydraulic radius	R	=	0.12	m	
Using Manning's formula,	V	=	$(1/n)R^{2/3}S^{1/2}$		
	S	=	0.015		
Provide slope of	1 in	=	69		
Assuming Slope of river bed	1 in	=	25		
Invert level of shingle flushing duct at start		=	865.63	m	
HFL at diversion site		=	870.00	m	
El. diff. b/w HFL at diversion site & invert level of shingle flushing duct at start		=	4.373	m	
Length of shingle flushing duct (L)					0.02551
$(L/25)-(L/69)=870-865.63$		=	171.00	m	39.2045
Computation of Depth of Trench at Exit					
Depth of trench at exit	D	=	RL of U/S trench wall - RL of top of bottom slab at end of trench		
	(from RBL)	=	1.92	m	

Height of intake chamber	=	HFL + Free board	
	=	871.00	m
Summary			
Sill Level of Intake Opening (Service Gate)	=	866.57	m
Dimensions of Shingle Flushing D shaped duct	=	0.7*1.5	m
Sill RL of Gate	=	866.57	m
Depth of Trench at Exit	=	1.92	m
Top RL of Intake Chamber	=	871.00	m

4. Hydraulic Design of Conveyance Channel

Design Data			
Design discharge	=	1.05	cumecs
Design discharge for intake	=	1.67	cumecs
Design discharge for conveyance channel	=	1.39	cumecs
FSL at the start of conveyance channel	=	867.07	m
Rugosity coefficient	n	=	0.014
Length of water conveyance channel	=	35	m
Design Calculations:			
Computation of Bed Width & FSD			
Design discharge in conveyance channel Q	=	1.39	cumecs
Provide width of conveyance channel	=	1	m
Depth of conveyance channel	=	0.5	m
Wetted area	A	=	0.5 m ²
Velocity	V	=	Q/A
		=	2.78 m/sec
Wetted perimeter	P	=	2.00 m
Hydraulic radius	R	=	0.25 m
Computation of Slope of Conveyance Channel Bed			
Using Manning's formula,	V	=	$(1/n)R^{2/3}S^{1/2}$
	S	=	0.0096
Provide slope of	1 in	=	103
Computation of FSL at End of Conveyance Channel			
Reduced FSL at the beginning	FSL ₁	=	FSL at start
		=	867.07 m
Reduced FSL at end		=	FSL ₁ - (Length/Slope)
		=	866.73 m
Provision of Free Board			
Free board		=	0.5 m
Summary			

Base Width	=	1	m		
FSD in Conveyance Channel	=	0.5	m		
Free Board of Conveyance Channel	=	0.5	m		
Bed Slope of Conveyance Channel	1 in	=	103		
Length of Conveyance Channel	=	35	m		
FSL at Beginning of Conveyance Channel	=	867.07	m		
FSL at End of WCS	=	866.73	m		

5. Hydraulic Design of Desilting Tank

Design Data					
Propose one tank					
<i>Mosonyi's Approach</i>					
Design discharge of plant	Q_{max}	=	1.05	cumecs	
Discharge of desilting tank		=	HRC discharge + 20% silt flushing discharge		
		=	1.39	cumecs	
Discharge for desilting tank		=	1.39	cumecs	
Particle size to be removed	P_s	=	0.20	mm	
Flow through velocity required	u_f	=	$aP_s^{1/2}$		
Here a		=	0.44		
	u_f	=	0.20	m/sec	
Actual u_f provided		=	0.15	m/sec	
Fall velocity from curve (at temp. 10°C),	u_s	=	0.026	m/sec	

(Reference : Pg 39; Standard/ Manual /Guidelines for Small Hydro Development Guidelines For Hydraulic Design Of Small Hydro Plants ,AHEC, IITR

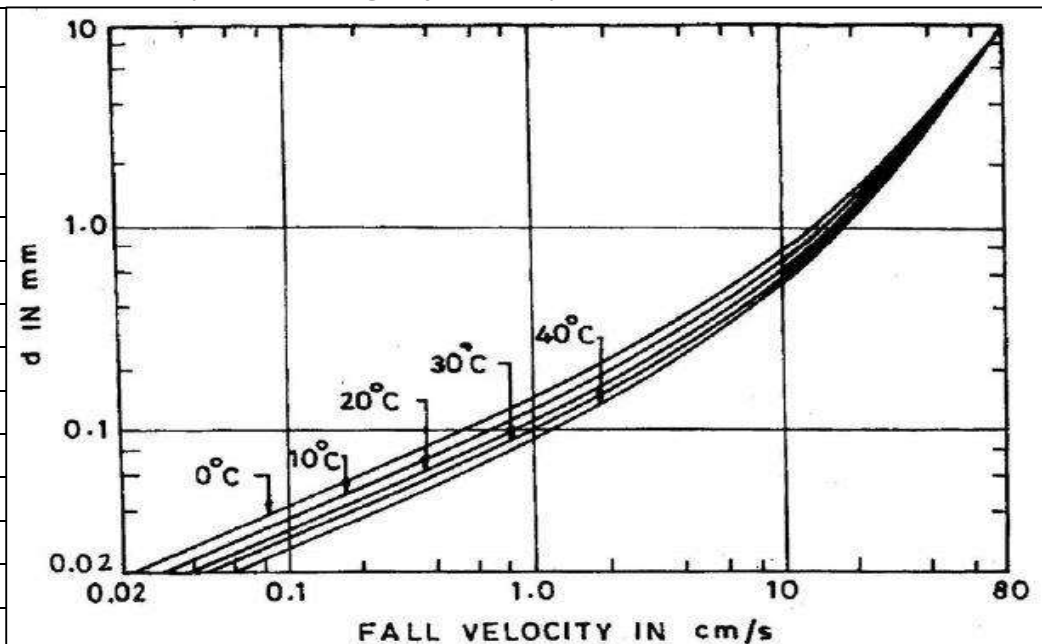


FIGURE 2.2.3.2 Fall velocity of spherical particles (relative density = 2.65) in water

Design Calculation for Tank Size				
Let width of the tank	=	3.5	m	
Depth required for tank (Equivalent depth)	=	1.99	m	
Let width of cunette	=	0.5	m	
Total depth provided	=	2.6	m	
Area required	=	9.27	m ²	
Moderate settling velocity	=	u_m		
	u_m =	$u_s - (0.132/(D))^{1/2} * u_f$		
	u_m =	0.012	m/sec	
Length of settling tank	L_s =	$((u_f/u_m)*D$		
	=	24.93	m	
Provide	L_s =	25.00	m	
<i>Reference : Pg 40; Standard/ Manual /Guidelines for Small Hydro Development</i>				
<i>Guidelines For Hydraulic Design Of Small Hydro Plants ,AHEC, IITR</i>				
Depth of cunette at start	=	0.3	m	
Depth of cunette at end	=	0.60	m	
Slope of cunette (1 in)	=	83.33		
No. of cunette provided	=	1		
Depth of hopper	=	1.5	m	
Depth at the end of silt gutter	=	3.20	m	
FSL at conveyance channel end	=	866.73	m	
FSL at desilting tank start	=	866.73	m	
FSL at desilting tank end	=	866.67	m	
Bottom R.L of gutter at the start of the tank	=	863.83	m	
Bottom R.L of gutter at the end of the tank	=	863.53	m	
Free board above F.S.L	=	0.5	m	
Top R.L of tank	=	867.23	m	
Efficiency by Camp's Curve				
$\frac{u_s D^{1/6}}{n u_f g^{0.5}}$	=	2.04		
$\frac{u_s L}{u_f D}$	=	1.00		
Settling efficiency from Camp's curve	=	97%		
<i>Reference :- Pg 279-289 , Sediment Management in water resources project</i>				
<i>Dr. B.N.Asthana , Publication. No. 301</i>				

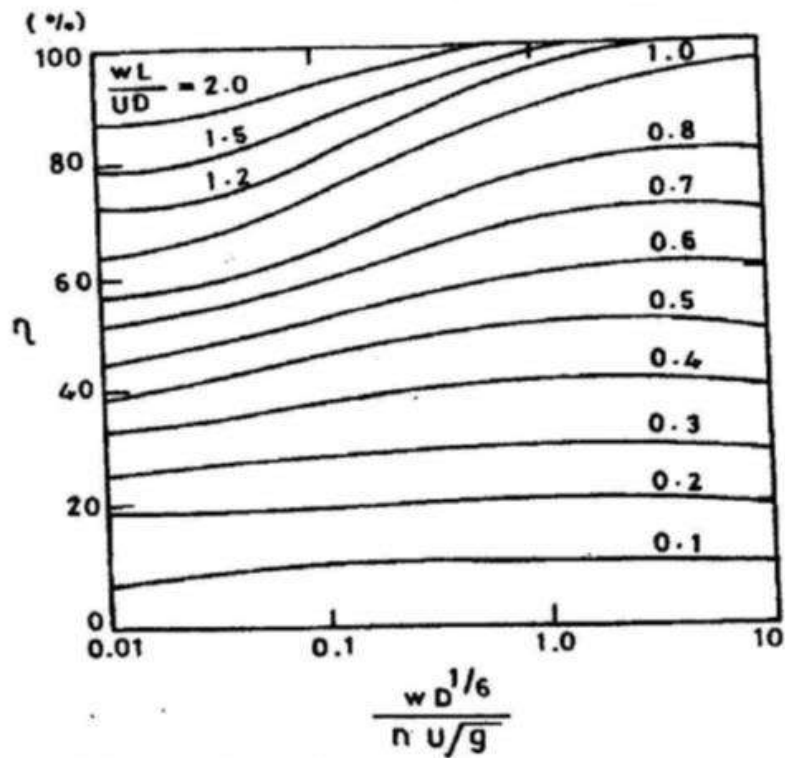


FIGURE 2.2.3.4
Camp and Dobbin's relation for efficiency of settling basin

Design of Transitions:			
Inlet Transition:			
Inlet transition length	=	3.75	m
B = width of desilting tank	=	3.5	m
b = width of conveyance channel	=	1.0	m
For the slope to be 1 : 3			
Provide inlet transition length	=	3.75	m
Outlet Transition:			
Outlet transition length	=	2.40	m
B = width of desilting tank	=	3.50	m
b = width of water conductor system	=	1.10	m
For the slope to be 1 : 2			
Provide outlet transition length	=	2.40	m
Computation of Dimensions of Silt Flushing Duct			
Flushing discharge Q_f	=	0.23	cumec
Velocity	=	3.25	m/sec
Area required	=	Q/V	
	=	0.071	m^2
Provide width of silt flushing duct	=	0.7	m
Therefore, depth of silt flushing duct	=	0.10	m
Provide silt flushing duct of size 0.7*	=	1.00	m

Wetted area	A	=	0.07	m ²	
Wetted perimeter	P	=	0.90	m	
Hydraulic radius	R	=	0.08	m	
Using Manning's formula,	V	=	$(1/n)R^{2/3}S^{1/2}$		
	S	=	0.0601		
Provide slope of	1 in	=	17		
Slope of river bed	1 in	=	25		
Invert level of silt flushing duct at start		=	863.53	m	
Invert level of silt flushing duct at end		=	860.00	m	
Length of silt flushing duct		=	60	m	
Summary					
Settling Tank - Width		=	3.5	m	
Settling Tank Length		=	25.00	m	
FSL in Desilting tank		=	866.73	m	
Bottom RL at Start of Tank		=	863.83	m	
Bottom RL of Gutter at End of Tank		=	863.53	m	
Top RL of Tank		=	867.23	m	

6. Hydraulic Design of Head Race Channel

Design Data					
Design discharge		=	1.05	cumecs	
Design discharge for intake		=	1.67	cumecs	
Design discharge for HRC		=	1.16	cumecs	
FSL at the start of HRC		=	FSL in Desilting Tank end		
		=	866.67	m	
Velocity (limited)	V	=	2.2	m/s	
Rugosity coefficient	n	=	0.014		
Length of HRC		=	1550	m	
Design Calculations:					
Computation of Bed Width & FSD					
Design discharge in HRC	Q	=	1.16	cumecs	
Area required		=	Q/V		
		=	0.6	m ²	
Provide width of HRC		=	1.10	m	
Therefore, depth of HRC		=	0.55	m	
Wetted area	A	=	0.6	m ²	
Wetted perimeter	P	=	2.2	m	
Hydraulic radius	R	=	0.3	m	
Computation of Slope of HRC Bed					

Using Manning's formula,	V	=	$(1/n)R^{2/3}S^{1/2}$	
	S	=	0.0052	
Provide slope of	1 in	=	192	
Computation of FSL at End of HRC				
Reduced FSL at the beginning	FSL ₁	=	FSL at start of HRC	
		=	866.67	m
Reduced FSL at end		=	FSL ₁ - (Length/Slope)	
		=	860.94	m
Summary				
Base Width		=	1.1	m
FSD in HRC		=	0.55	m
Bed Slope of HRC	1 in	=	192	
Length of HRC		=	1100	m
FSL at Beginning of HRC		=	866.67	m
FSL at End of HRC		=	860.94	m

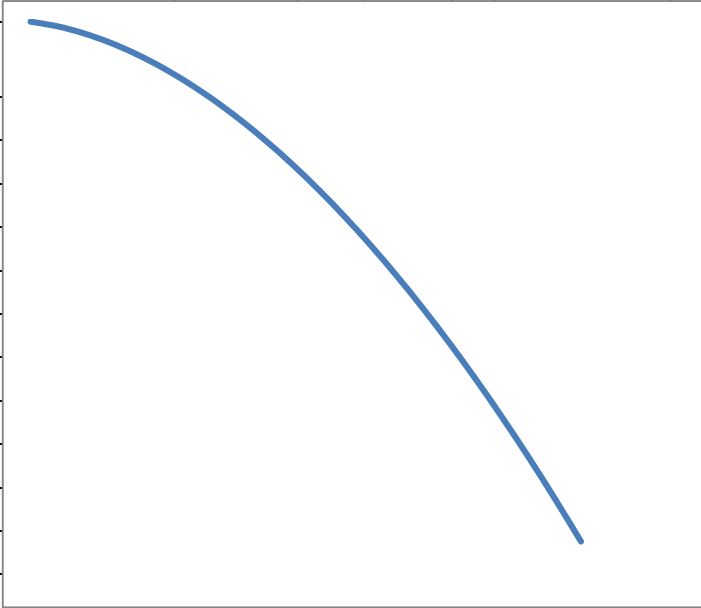
7. Hydraulic Design of Forebay

A	Design Data			
	Design discharge of plant	Q _{max}	=	1.05 cumecs
	Discharge at forebay (with overloading)		=	1.16 cumecs
	Max level in forebay	FSL	=	860.94 m
	Storage capacity (2-3 minutes)		=	2.5 minutes
B	Design Calculations			
	Drawdown Level in Forebay & MDDL Calculation			
	Discharge at forebay with 10 % overloading		=	1.16 cumecs
	Storage capacity		=	2.5 minutes
	2.5 minutes water storage		=	173.25 m ³
	Depth of forebay (assumed)		=	3 m
	Area required		=	57.75 m ²
	Take width		=	4 m
	Length required		=	15 m
	FSL at forebay		=	860.94 m
	MDDL in forebay		=	857.94 m
	Dia of penstock		=	650 mm

Velocity in penstock	V	=	3.17	m/s	
Computation of C/L of Intake Opening					
Area of penstock		=	0.332	m ²	
Angle of inclination of penstock	Θ	=	0	degrees	
Coefficient of contraction	C_c	=	0.6		
<i>Reference :- IS: 9761, Clause 5.1.2</i>					
Area of bellmouth opening		=	Penstock area / $C_c \cos\Theta$		
		=	0.55	m ²	
Diameter of opening			0.80	m	
Water cushion above C/l of bellmouth		=	$D(0.5+(2V/\sqrt{gD}))$		
		=	1.96	m	
Water cushion above bellmouth		=	$V^2/2g$		
		=	0.51	m	
Adopt water cushion		=	1.96	m	
C/L of intake opening		=	M.D.D.L.- water cushion		
		=	855.99	m	
Sill level of forebay		=	MDDL - water cushion - 0.5*dia of opening		
			855.19	m	
Freeboard		=	0.9	m	
Top RL of forebay		=	FSL fore bay + Free Board		
		=	861.84	m	
Total depth (Including depth below M.D.D.L)		=	6.657	m	
Summary					
Length of Forebay		=	15	m	
Breadth of Forebay		=	4	m	
F.S.L. at Forebay		=	860.94	m	
MDDL		=	857.94	m	
C/L of Penstock Intake Opening		=	855.99	m	
Sill level of Forebay		=	855.19	m	
Top RL of Forebay		=	861.84	m	

8. Hydraulic Design of Spillway at Forebay

Discharge, Q		=	1.16	cumecs	
Co-eff of discharge, C		=	2.2		
Effective length of spillway, L_e		=	4	m	
Total head, H_e		=	$(Q/C*L_e)^{2/3}$		
		=	0.26	m	

Height of spillway, h			=	3	m	
Slope of spillway			1V in	=	0.6	H
			dy/d x	=	1.67	
Design head, H _d			=	0.26	m	
Hence, h/H _d			=	11.54		High spillway
(h _d +d)/ H _e = (H _e +h)/ H _e			=	12.62		OK
Downstream Profile						
		y	=	(x ^{1.85})/2*(H _d) ^{0.85}		
As, 2*(H _d) ^{0.85}			=	0.64		
Hence, y			=	(x ^{1.85})/0.64		
Differentiating y w.r.t. x, we get						
			dy/d x	=	(1.85(x ^{0.85}))/0.64	
			1/0. 6	=	(1.85(x ^{0.85}))/0.64	
Hence, x			=	0.52	m	
And y			=	0.47	m	
Co-ordinates from x=0.1 to x=0.64 can be given as:						
x (m)	y=(x ^{1.85})/0.64					
	4 (m)					
0.1	0.02					
0.15	0.05					
0.2	0.08					
0.25	0.12					
0.3	0.17					
0.35	0.22					
0.52	0.47					
						
DOWNSTREAM PROFILE						
Upstream Profile						

			y	=	$(0.724(x+0.27H_d)^{1.85}/H_d^{0.85}) + 0.126H_d - 0.4315H_d^{0.375}(x + 0.27H_d)^{0.625}$					
<i>(Waterway Experimental Stations, U.S. Army Corps)</i>										
			y	=	$(0.724(x+0.27*0.26)^{1.85}/(0.26^{0.85}) + 0.126*0.26 - 0.4315*0.26^{0.375}(x + 0.27*0.26)^{0.625}$					
The curve should go upto					x	=	-0.27H _d	-0.0702		
x(m)	y(m)									
-0.02	0.001605									
-0.03	0.003781									
-0.04	0.007053									
-0.05	0.011705									
-0.0702	0.032760									
UPSTREAM PROFILE										

9. Hydraulic Design of Penstock

Economical diameter of Penstock				
(1) Moffat et al. (1990) relation				
D	=	$0.52 * p^{0.43} / H^{0.60}$		
(Penstock dia)				
Where, p	=	Rated horse power of turbine		
	=	2581.521739	metric horse power	
H	=	Rated head of turbine in meters		
	=	217	meters	
D	=	0.6	meters	
Q	=	Discharge in penstock in cumecs		
	=	1.05	cumecs	
(2) P.J Biers (1945) Relation				
Assuming 1:1 slope of hopper	=	$.176(P/H)^{.466}$		
	=	0.56	meters	
Adopting value	=	0.65	meters	

For Bifurcated Units					
Adopting same velocity in bifurcated units as that in mains					
Discharge in each unit	=	0.525	cumecs		
Velocity of flow	=	3.17	m/sec		
Diameter required	=	0.5	meters		
Hence adopting diameter	=	0.5	meters		
Calculation for the Thickness of the Steel Liner					
Full supply level at forebay	=	860.94	meters		
Center line of penstock	=	855.99	meters		
Center line of turbine at power house	=	631.50	meters		
Head available at forebay	=	229.44	meters		
Dynamic head assumed	=	22%			
(As per Recommendation in C.W.C manual for Penstock)					
1.Upto R.L 710 meters					
Grade of steel	=	IS-2002-2009 (Grade-1)			
Yield strength	=	235	N/mm ²		
U.T.S	=	420	N/mm ²		
(As per table-3 , Page-4, IS-2002-2009 , Design of steel plates for pressure vessel)					
Permissible stress	=	Lesser of 1/3 U.T.S or 2/3 Y.S			
	=	140	N/mm ²		
Dia of penstock	=	0.65	meters		
Assuming thickness of steel liner	=	6	mm		
Length of penstock	=	527	meters		
Head	=	150.9	meters		
Dynamic head assumed due to water hammer	=	22%			
<i>(Reference Manual On Design and Fabrication of Penstock (Central Water Commission))</i>					
1.1 Hoop Stress					
Hoop stress in steel	=	Pr/t			
where,					
r	=	Radius of pipe shell			
P	=	Internal pressure head			
		(Static head + Dynamic head)			
t	=	thickness of pipe shell			
		in meters			
Maximum static head	=	150.94	meters		
Dynamic head (22% static head)	=	33.21	meters		
Total Pressure head	=	184.15	meters		

Total internal pressure	=	ρgh		
	=	180.65	N/cm ²	
Hoop stress (Pr/t)	=	97.85	N/mm ²	
1.2 Other Stresses				
1.2.1 Longitudinal Stress due to Friction				
Frictional stress	=	$\mu \cdot W/A$	kg/m ²	
Considering, μ	=	0.5		
Considering saddle interval	=	7	meters	
Area	=	$2\pi rt$	sqm	
	=	0.012	sqm	
Total weight (Weight of shell + Weight of water)	=	$2\pi rtLp_s$	kg	
Weight of steel shell	=	672.9	Kg	
Weight of water	=	$\pi r^2 L p_w$	kg	
	=	2321.6375	kg	
Total weight	=	2994.5375	kg	
Frictional stress	=	122265.944	kg/m ²	
	=	1.22	N/mm ²	
1.2.2 Temperature Stresses				
Temperature stress in steel	=	$\mu P A_c / A$		
When expansion joint is provided				
Where,				
Considering μ	=	0.5		
Considering length of packing materials	=	300	mm	
A_c (Contact area between penstock shell and packing material)	=	0.61	m ²	
P (Static pressure)	=	148.08	N/cm ²	
Total temperature stress	=	37.02	N/mm ²	
1.2.3 Longitudinal Stresses due to Beam Action				
Interval between each saddles	=	7	meters	
Weight of steel for each shell	=	96.13	kg/m	
Weight of water per meter	=	331.66	kg/m	
Maximum bending stress will occur at mid span	=	WL^2/z	kg-m	
Section modulus for the section	=	$\pi d^3/32$		
	=	0.03	m ³	
Total stress due to beam action	=	777876	kg/m ²	
	=	7.78	N/mm ²	

Calculation of Principle Stresses					
Sx,Sy	=	$fx+fy/2+((fx-fy)^2/2)^{.5}$			
<i>(Principal Major and Principal Minor Stress)</i>					
fx (Total longitudinal stress)	=	Temperature Stress+Friction Stress+Stress Due to Beam Action			
	=	46.02	N/mm ²		
fy (Hoop stress)	=	97.85	N/mm ²		
Sx (Principal major stress)	=	108.59	N/mm ²		
Sy (Principal minor stress)	=	35.29	N/mm ²		
Se (equivalent)	=	$(Sx^2+Sy^2+SxSy)^{.5}$			
	=	129.88	N/mm ²		
Which is less than the permissible Stress					
2.Upto R.L 655 meters					
Grade of steel assumed	=	IS-2002-2009 (Grade-1)			
Yield strength	=	235	N/mm ²		
U.T.S	=	420	N/mm ²		
<i>(As per Table-3 , Page-4, IS-2002-2009 , Design of steel plates for pressure vessel)</i>					
Permissible stress	=	Lesser of 1/3 U.T.S or 2/3 Y.S			
	=	140	N/mm ²		
Dia of penstock	=	0.65	meters		
Assuming thickness of steel liner	=	8	mm		
Head	=	205.9	meters		
Length of penstock	=	392	meters		
Dynamic head assumed due to water hammer	=	22%			
<i>(Reference Manual On Design and Fabrication of Penstock (Central Water Commission))</i>					
2.1 Hoop Stress					
Hoop stress in steel	=	Pr/t			
where,					
r	=	Radius of pipe shell			
P	=	Internal pressure head (Static head + Dynamic head)			
t	=	thickness of pipe shell in meters			
Maximum static head	=	205.94	meters		
Dynamic head (22% Static Head)	=	45.31	meters		
Total pressure head	=	251.25	meters		

Total internal pressure	=	ρgh		
	=	246.48	N/cm ²	
Hoop stress (Pr/t)	=	100.13	N/mm ²	
2.2 Other Stresses				
2.2.1 Longitudinal stress due to friction				
Frictional stress	=	$\mu \cdot W/A$	kg/m ²	
Considering, μ	=	0.5		
Considering saddle interval	=	7	meters	
Area	=	$2\pi rt$	sqm	
	=	0.016	sqm	
Total weight (Weight of shell + Weight of water)	=	$2\pi rtLp_s$	kg	
Weight of steel shell	=	897.2	Kg	
Weight of water	=	$\pi r^2 L \rho_w$	kg	
	=	2321.64	kg	
Total weight	=	3218.84	kg	
Frictional stress	=	98568.03	kg/m ²	
	=	0.99	N/mm ²	
2.2.2 Temperature Stresses				
Temperature stress in steel	=	$\mu P A_c / A$		
When expansion joint is provided				
Where,				
Considering μ	=	0.5		
Considering length of packing materials	=	300	mm	
A_c (Contact area between penstock Shell and packing material)	=	0.61	m ²	
P (Static pressure)	=	202.03	N/cm ²	
Total temperature stress	=	37.88	N/mm ²	
2.2.3 Longitudinal Stresses due to Beam Action				
Interval between each saddles	=	7	meters	
Weight of steel for each shell	=	128.17	kg/m	
Weight of water per meter	=	331.66	kg/m	
Maximum bending stress will occur at mid span	=	WL^2/z	kg-m	
Section modulus for the section	=	$\pi d^3/32$		
	=	0.03	m ³	
Total Stress due to beam action	=	836142.96	kg/m ²	
	=	8.36	N/mm ²	

Calculation of Principle Stresses					
Sx,Sy	=	$fx+fy/2+((fx-fy)^2/2)^{.5}$			
<i>(Principal Major and Principal Minor Stress)</i>					
fx(Total longitudinal stress)	=	Temperature stress+Friction stress+Stress due to beam action			
	=	47.23	N/mm ²		
fy (Hoop stress)	=	100.13	N/mm ²		
Sx (Principal major stress)	=	111.09	N/mm ²		
Sy (Principal minor stress)	=	36.27	N/mm ²		
Se (equivalent)	=	$(Sx^2+Sy^2+SxSy)^{.5}$			
	=	132.99	N/mm ²		
Which is less than the permissible Stress					
3.Upto R.L 638 meters					
Grade of steel assumed	=	IS-2002-2009 (Grade-1)			
Yield strength	=	235	N/mm ²		
U.T.S	=	420	N/mm ²		
(As per Table-3 , Page-4, IS-2002-2009 , Design of steel plates for pressure vessel)					
Permissible stress	=	Lesser of 1/3 U.T.S or 2/3 Y.S			
	=	140	N/mm ²		
Dia of penstock	=	0.65	meters		
Assuming thickness of steel liner	=	10	mm		
Head	=	222.9	meters		
Length of penstock	=	77	meters		
Dynamic head assumed due to water hammer	=	22%			
<i>(Reference Manual On Design and Fabrication of Penstock (Central Water Commission))</i>					
3.1 Hoop Stress					
Hoop stress in steel	=	Pr/t			
where,					
r	=	Radius of pipe shell			
P	=	Internal pressure head (Static head + Dynamic head)			
t	=	thickness of pipe shell in meters			
Maximum static head	=	222.94	meters		
Dynamic head (22% Static Head)	=	49.05	meters		

Total pressure head	=	271.99	meters		
Total internal pressure	=	ρgh			
	=	266.82	N/cm ²		
Hoop stress (Pr/t)	=	86.72	N/mm ²		
3.2 Other Stresses					
3.2.1 Longitudinal stress due to friction					
Frictional stress	=	$\mu \cdot W/A$	kg/m ²		
Considering μ	=	0.5			
Considering saddle interval	=	7	meters		
Area	=	$2\pi rt$	sqm		
	=	0.02	sqm		
Total weight	=	$2\pi rtL\rho_s$	kg		
(Weight of shell + Weight of water)					
Weight of steel shell	=	1121.5	Kg		
Weight of water	=	$\pi r^2 L\rho_w$	kg		
	=	2321.64	kg		
Total weight	=	3443.14	kg		
Frictional stress	=	84349.28	kg/m ²		
	=	0.84	N/mm ²		
3.2.2 Temperature Stresses					
Temperature stress in steel	=	$\mu P A_c/A$			
When expansion joint is provided					
Where,					
Considering μ	=	0.5			
Considering length of packing materials	=	300	mm		
A_c (Contact area between penstock Shell and packing material)	=	0.61	m ²		
P (Static pressure)	=	218.71	N/cm ²		
Total temperature stress	=	32.81	N/mm ²		
3.2.3 Longitudinal Stresses due to Beam Action					
Interval between each saddles	=	7	meters		
Weight of steel for each shell	=	160.22	kg/m		
Weight of water per meter	=	331.66	kg/m		
Maximum bending stress will occur at mid span	=	WL^2/z	kg-m		
Section modulus for the section	=	$\pi d^3/32$			
	=	0.03	m ³		
Total Stress due to beam action	=	894409.47	kg/m ²		

	=	8.94	N/mm ²	
Calculation of Principle Stresses				
Sx,Sy	=	$fx+fy/2+((fx-fy)^2/2)^{.5}$		
<i>(Principal Major and Principal Minor Stress)</i>				
fx(Total longitudinal stress)	=	Temperature stress+Friction stress+Stress due to beam action		
	=	42.59	N/mm ²	
fy (Hoop stress)	=	86.72	N/mm ²	
Sx (Principal major stress)	=	95.86	N/mm ²	
Sy (Principal minor stress)	=	33.45	N/mm ²	
Se (equivalent)	=	$(Sx^2+Sy^2+SxSy)^{.5}$		
	=	116.25	N/mm ²	
Which is less than the permissible Stress				
4.Upto R.L 635.5 meters (Bifurcated Units)				
Grade of steel	=	IS-2002-2009 (Grade-1)		
Yield strength	=	235	N/mm ²	
U.T.S	=	420	N/mm ²	
(As per Table-3 , Page-4, IS-2002-2009 , Design of steel plates for pressure vessel)				
Permissible stress	=	Lesser of 1/3 U.T.S or 2/3 Y.S		
	=	140	N/mm ²	
Dia of penstock	=	0.5	meters	
Assuming thickness of steel liner	=	8	mm	
Head	=	225.4	meters	
Length of penstock	=	23	meters	
Dynamic head assumed due to water hammer	=	22%		
<i>(Reference Manual On Design and Fabrication of Penstock (Central Water Commission))</i>				
4.1 Hoop Stress				
Hoop stress in steel	=	Pr/t		
where,				
r	=	Radius of pipe shell		
P	=	Internal Pressure head		
		(Static head + Dynamic head)		
t	=	thickness of pipe shell		
		in meters		
Maximum static head	=	225.4	meters	
Dynamic head (22% Static head)	=	49.60	meters	

Total Pressure head	=	275.04	meters		
Total internal pressure	=	ρgh			
	=	269.82	N/cm ²		
Hoop stress (Pr/t)	=	84.32	N/mm ²		
4.2 Other Stresses					
4.2.1 Longitudinal Stress due to Friction					
Frictional stress	=	$\mu \cdot W/A$	kg/m ²		
Considering, μ	=	0.5			
Considering saddle interval	=	7	meters		
Area	=	$2\pi rt$	sqm		
	=	0.013	sqm		
Total weight	=	$2\pi rtLp_s$	kg		
(Weight of shell + Weight of water)					
Weight of steel shell	=	690.2	Kg		
Weight of water	=	$\pi r^2 L \rho_w$	kg		
	=	1373.75	kg		
Total weight	=	2063.95	kg		
Frictional stress	=	82163.61	kg/m ²		
	=	0.82	N/mm ²		
4.2.2 Temperature Stresses					
Temperature stress in steel	=	$\mu P A_c / A$			
When expansion joint is provided					
where,					
Considering μ	=	0.5			
Considering length of packing materials	=	300	mm		
A_c (Contact area between penstock shell and packing material)	=	0.47	m ²		
P (Static pressure)	=	221.16	N/cm ²		
Total temperature stress	=	41.47	N/mm ²		
4.2.3 Longitudinal Stresses due to Beam Action					
Interval between each saddles	=	7	meters		
Weight of steel for each shell	=	98.60	kg/m		
Weight of water per meter	=	196.25	kg/m		
Maximum bending stress will occur at mid span	=	WL^2/z	kg-m		
Section modulus for the section	=	$\pi d^3/32$			
	=	0.01	m ³		
Total Stress due to beam action	=	1177881.60	kg/m ²		

	=	11.78	N/mm ²		
Calculation of Principle Stresses					
Sx,Sy	=	$fx+fy/2+((fx-fy)^2/2)^{.5}$			
<i>(Principal Major and Principal Minor Stress)</i>					
fx(Total longitudinal stress)	=	Temperature stress+Friction stress+Stress due to beam action			
	=	54.07	N/mm ²		
fy (Hoop stress)	=	84.32	N/mm ²		
Sx (Principal major stress)	=	90.58	N/mm ²		
Sy (Principal minor stress)	=	47.81	N/mm ²		
Se (equivalent)	=	$(Sx^2+Sy^2+SxSy)^{.5}$			
	=	121.75	N/mm ²		
Which is less than the permissible Stress					
Summary					
Penstock Length	=	1019	meters		
Length of Main Penstock	=	996	meters		
Length of Branches	=	23	meters		
Diameter of Main	=	0.65	meters		
Velocity of Flow	=	3.17	m/sec		
Diameter of Branches	=	0.5	meters		
Summary of Penstock Profile					
	Length	Head	Grade	Thickness	
	527	150.94	Grade-1	6	
	392	205.94	Grade-1	8	
	77	222.94	Grade-1	10	
	23	225.44	Grade-1	8	
	1019				
Details of Vertical Bends					
		Angle			
Bend-1	=	28			
Bend-2	=	20			
Bend-3	=	13			
Bend-4	=	17			
Bend-5	=	11			
Bifurcation Bend	=	14			
Details of Horizontal Bends					
		Angle			
Bend-1	=	26			
Bend-2	=	33			

	Bend-3	=	27			
	Bifurcation Bend	=	30			

Chapter 8 – ELECTRO MECHANICAL EQUIPMENTS

8.1 Introduction

Pinyinyi Small Hydro power project is a run of river based hydro power project on the Pinyinyi River. Two turbine-generator units of 1.0 MW each have been proposed for the project. The project shall utilize a gross head of 236 m and rated design discharge of 1.05 cumecs. The turbine and generating unit with other associated equipment will be accommodated in a surface powerhouse on the left bank of the river. The generation voltage is proposed to be 3.3 kV. This voltage will be stepped up to 33 kV level by two generator step-up transformers, located near the power house. It is proposed that two numbers three-phase step-up generator transformer (GT) rated (1.3 MVA), 3.3 kV/33 kV will be used. On the LV side, the transformer will be connected to the generator by means of 3.3 kV isolated phase bus duct. On the HV side, the transformer will be connected to a 33 kV outdoor conventional type switchyard by a 33 kV overhead transmission line (link lines). The switchyard will be located on left bank of the river.

The electricity generated is to be delivered to an isolated grid network system of Loliondo and Wasso via a planned 78km long 33KV transmission line.

8.2 Drawings

The following drawings may be referred

Sl. No.	Item Description	Drawing No.
1	Plan of Power House	PHEP-15
2	Section of Power House	PHEP -16 & 17
3	Switchyard Plan	PHEP-18
4	Switchyard Section	PHEP-19
5	Single Line diagram	PHEP-20

In collaboration with an Austria company (Gugler), who are turbine manufactures have closely worked with our team of consultants to improve the Power house drawings, while H&W controls have also closely worked with our team of consultants to improve the Single Line MV Diagram.

8.3 Main Electro-Mechanical Components

The major Electro-Mechanical components have been described below:

8.3.1 Main Inlet Valve (MIV)

A Main Inlet Valve (MIV – Butterfly type) shall be provided for controlling the flow of discharge to the turbine. The MIV is also required to regulate flow and start/stop the discharge during the maintenance of the unit.

8.3.2 Hydraulic Turbines

Turbine-Pro software provides a definitive and technical output for the suitable turbine type for a particular head-flow combination. The characteristics for Pinyinyi SHP site were input in the software, and for the given head and flow combination, a configuration of two units of Pelton type of turbine has been found to be suitable. A typical arrangement of Pelton turbine is shown in the diagram below. Pelton turbines are used primarily for high head and low discharge applications. Since it works under high heads, comparatively less quantity of water is required.

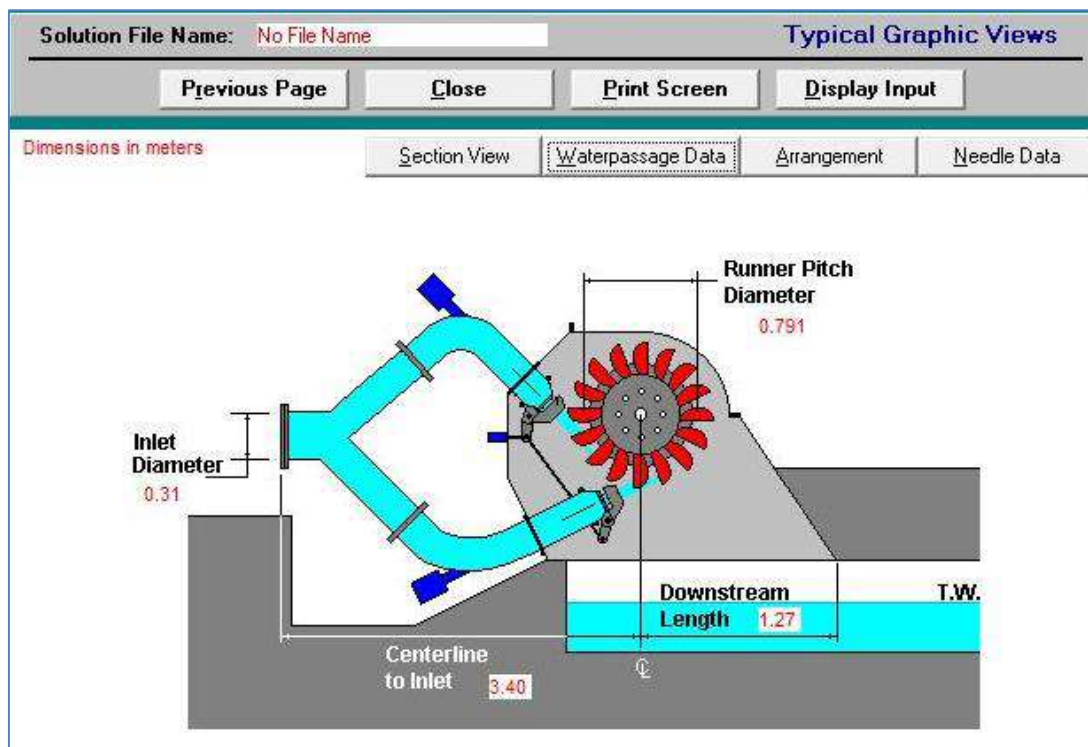


Figure - Sectional view of the Pelton Turbine

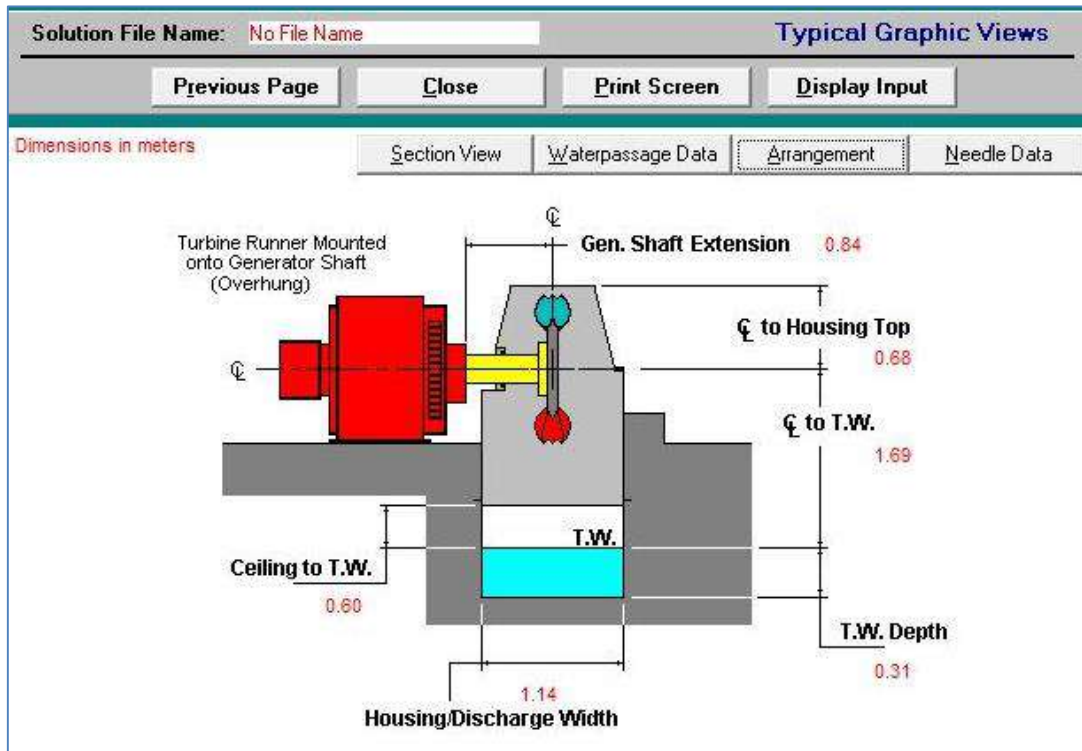


Figure – Arrangement of Pelton Turbine

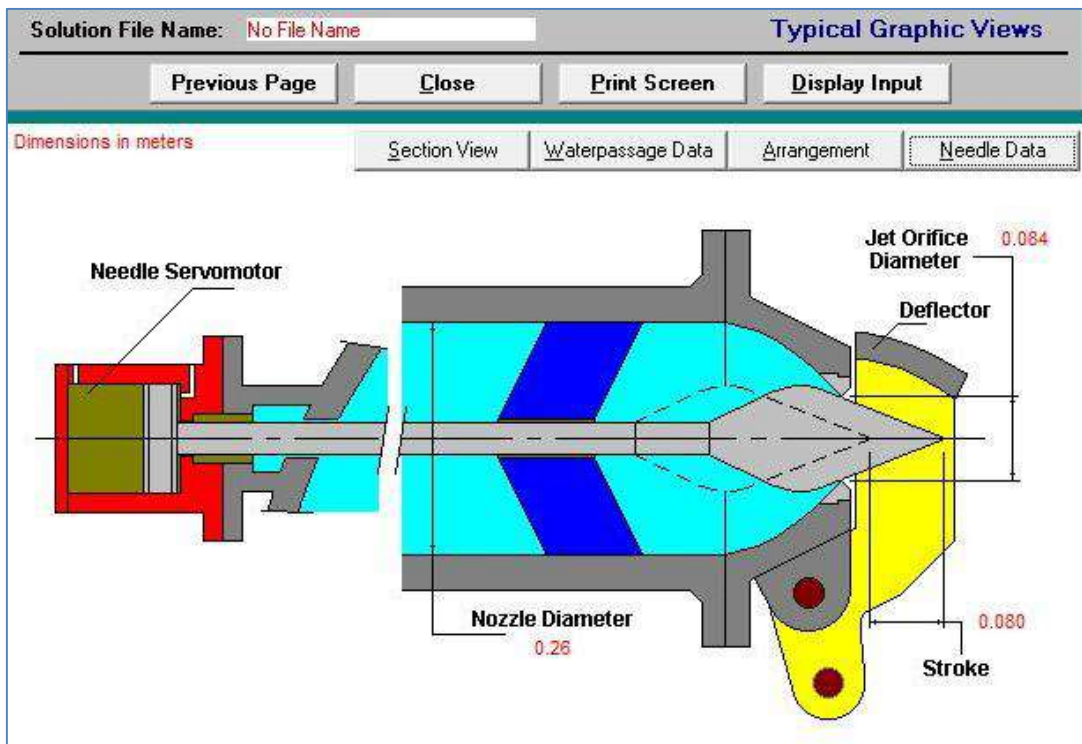


Figure – Needle Data for each Jet of Pelton Turbine

8.3.2.1 Turbine Specifications

Notes: *All information listed below is based on preliminary calculations. Detailed characteristics will vary on turbine manufacturer’s actual designs at the time of procurement.*

i	Rated Discharge (in m ³ /s)	0.525	Limits
i	Net Head at rated discharge (in meters)	217	Limits
i	Site Gross Head (in meters)	236	Limits
i	Efficiency Priority at max output (0 to 10)	8.5	Limits
i	System Frequency (50 Hz or 60 Hz)	50	Limits
i	Minimum Net Head (in meters)	217	Limits
i	Maximum Net Head (in meters)	217	Limits

Input Data for turbine design

Solution	Runner Diameter	Runner Diameter	Unit Speed	Specific Speed/Jet	Number of Jets
Number	Millimeters	Inches	rpm	NS	Qty
1	1192	46.9	500.0	19.0	1
2	1402	55.2	428.6	16.3	1
3	791	31.2	750.0	20.1	2
4	1002	39.5	600.0	16.1	2
5	801	31.5	750.0	16.4	3
6	1011	39.8	600.0	13.1	3
7	596	23.5	1000.0	19.0	4
8	806	31.7	750.0	14.2	4
9	600	23.6	1000.0	17.0	5
10	810	31.9	750.0	12.7	5
11	602	23.7	1000.0	15.5	6
12	813	32.0	750.0	11.6	6

Preliminary Output: **999 KW**

Enter Size Selection:

Different possible turbine configurations

Runner Pitch Diameter: mm
 Speed: rpm

1) Axis Orientation

Horizontal
 Vertical

2) Shaft Arrangement

With Turbine Shaft/Bearings
 Overhung Runner on Generator Shaft

3) Efficiency Modifier (User Option)

Multiplier - (0.98 to 1.02)
 Flow² Function - (-0.01 to +0.01)

2 - Jet Pelton Turbine

Comments:

The selected arrangement for Pelton turbine – Horizontal axis Pelton turbine with overhung runner on Generator Shaft.

Solution File Name: **Turbine Performance Data - Typical**

2 - Jet Pelton Turbine

Performance at rated net head of: meters

m ³ /s	% Eff	KW	% Rated
0.71	89.0	1335	134.5
0.53	89.7	1002	100.0
0.50	89.7	964	96.2
0.39	89.3	748	75.0
0.26	88.8	496	50.0
0.13	86.6	242	25.0

** Overcapacity * Best Efficiency Condition at Rated Net Head
 Efficiency Modifiers: Multiplier: Flow² Function:

Maximum Output Performance

At maximum net head of m

<input type="text" value="1337"/> KW	<input type="text" value="1337"/> KW
<input type="text" value="88.9"/> % Eff	<input type="text" value="88.9"/> % Eff
<input type="text" value="0.71"/> m ³ /s	<input type="text" value="0.71"/> m ³ /s

Runner Pitch Diameter: mm
 Bucket Width: mm
 Speed: rpm

Minimum Distance from Runner Centerline to Tailwater: meters

Maximum Runaway Speed (at the Maximum Net Head above): rpm

D/B Ratio (Runner Pitch Dia. / Bucket Width):

Specific Speed under Rated Net Head at:

Peak Efficiency: 100% Output

Total Turbine	<input type="text" value="28.0"/>	<input type="text" value="28.5"/>
Per Jet	<input type="text" value="19.8"/>	<input type="text" value="20.2"/>

Turbine efficiency at different flows & other performance data

Solution File Name: No File Name		Turbine Dimensional Data - Typical	
Previous Page	Next Page	Close	Display Input
Definitions			
Runner Pitch Diameter:	791 mm	Orientation:	HORIZONTAL
Intake Type - 2-Jet		Housing/Discharge Geometry -	
Inlet Diameter:	0.31 meters	Centerline to Housing Top:	0.68 meters
Jet to Jet Included Angle:	70 to 90 degrees	Housing Width:	1.14 meters
Centerline to Inlet:	3.40 meters	Discharge Width:	1.14 meters
Nozzle Diameter:	0.26 meters	Tailwater Depth:	0.31 meters
Jet Orifice Diameter:	84 mm	Discharge Ceiling to T.W.:	0.60 meters
Needle Stroke:	80 mm	Centerline to Tailwater:	1.69 meters
		Downstream Length:	1.27 meters
Shaft Arrangement - OVERHUNG ON GEN SHAFT		Miscellaneous -	
Generator Shaft Extension:	0.84 meters	Runner Outside Diameter:	1068 mm
Approximate Shaft Diameter:	218 mm	Hydraulic Thrust per Jet:	2310 kg
		Maximum Total Hydraulic Thrust: (under the Maximum Net Head)	3950 kg
		Estimated Axial Thrust:	197 kg
		Estimated Runner Weight:	554 kg

Typical turbine sizing data

8.3.2.2 Turbine Description

The horizontal axis Pelton Turbine package will comprise the two jets, with self-lubricating type bushes and protective seals. The turbine shall be capable of giving output higher than the rated output to match the 10% overload capability of the generator. Turbine shall be capable of delivering a power output (at turbine shaft) 1.0 MW at generator terminals at rated net head.

8.3.2.3 Runner

The runner shall be of high grade cast 13/4 Cr-Ni Stainless steel casted with integral buckets completely finished grinded and dynamically balanced. The runner shaft shall be fastened to the turbine shaft by means of frictional locking devices, which securely transmits the torque generated by the runner to the turbine shaft.

8.3.2.4 Turbine Housing

The turbine shall be made of welded construction. The removable upper section of the housing is shaped and constructed in such a way to minimize the wind age losses caused by the rotating runner.

The turbine housing is furnished with suitable opening for inserting and alignment of nozzles with the turbine runner and to support the rocker shaft bearing for the deflectors. At both side

of turbine housing is furnished with support for the bearings. The lower part of the turbine casing is designed for embedment in concrete.

8.3.2.5 Turbine Shaft

The turbine shaft shall be forged carbon steel or alloy steel confirming to European standard or equivalent International standard and shall be supported by two bearing located externally of the turbine housing. If required runner can also be mounted to generator shaft directly. All bearing shall be antifriction type with a life expectancy of 100,000 hrs or approximately 12 years of pedestal type.

8.3.2.6 Nozzle and Inlet Pipe

Needle operated nozzle by means of separate hydraulically operated servomotors. The nozzle bend is flanged to the pipe and an oil pumping unit shall operate nozzle servomotor.

The nozzle consists of nozzle head made of cast steel with a replaceable nozzle seat ring of stainless steel, needle tip of 13-4 Cr-Ni steel, needle stem is provided with replaceable needle tip of stainless steel.

8.3.2.7 Jet Deflectors

For nozzle a jet deflector shall be provided, which will be actuated by common servomotor. The jet deflector is provided with deflector edges of stainless steel. The deflector shaft is made of stainless steel and each shaft will be supported by two bearings provided in turbine casing.

8.3.2.8 Valves

Water from the penstock after bifurcation shall pass to turbine through valves. Valves are necessary for the closing as well as isolating the plant from the water conductor system.

8.3.2.9 Butterfly Valve

The main inlet valve for each generating unit shall be Butterfly valve. This will act as closure device. The valve shall be operated by oil (hydraulic power pack) or by electric actuator and shall have the tendency of closing. Suitable by pass arrangement shall be provided for equalising pressure on both side of valve so as to reduce torque during opening of valve.

8.3.2.10 Turbine Control & Governing System

Electronic PLC based digital governor shall be provided. It shall control the speed as well as load of TG set in grid connection system. It shall detect speed/load from the reference valve and convert these into the main servomotor stroke deviation in a characteristic manner. The

electronic speed governor shall be linked to the mechanical hydraulic part of the governing system i.e. by servo valve. The governing system will consist of the following main parts:

1. Speed Transducers.
2. Position Transducers.
3. Microprocessor based governor unit.
4. Oil Pumping Unit etc., as per the system requirement.

8.3.3 Mechanical Auxiliaries

8.3.3.1 Cooling Water

A pumping system would be provided to supply adequate quantity of water from the tail race for cooling of the turbine and generator bearings, generator air coolers and selected plant services.

8.3.3.2 Fire Protection System

Water for fire fighting would be taken from the river providing both reliable operation and ample capacity to fight fire in the power house.

8.3.3.3 Oil Purification

A portable oil purifier is envisaged for purification of lubricating and transformer oil.

8.3.3.4 Material Handling in the Power House

In order to expedite the completion of various construction activities of the power house, one EOT of 10/5 tonnes capacity would be installed in the power house. This crane shall primarily be used for erection, maintenance and repair of generating units.

8.3.3.5 Crane and Hoists

Electrically operated overhead double girder crane with main hook capacity 10 Tons and auxiliary hook of 5 Tons will be provided in the power house for lifting of equipment like T-G components and other equipment for erection and maintenance. Electrically operated lifting device for the gates and stop logs will be provided.

- Type : Double girder EOT
- Crane capacity : 10/5 T
- Max. height of lift : ~12 m
- Longitudinal traverse : ~25 m
- Cross travel : ~10 m

8.3.3.6 Ventilation

The Power House will be provided with suitable ventilation system. Control room and office areas will have window/package air-conditioners

8.3.3.7 Compressed Air System

A compressed air plant would be installed to meet the requirements of the governor oil system and the oil pressure system spherical valves at 120 bar pressure.

Electrical Equipment, Control and Protection Equipment

8.3.4 Generator

To convert mechanical energy achieved through turbine to electrical energy, generators shall be provided. Generator should be able to supply 3 phase, 50 Hertz A.C. at 3.3 KV level. Generator shall be synchronous, brushless type having 0.8 power factor (lag). The rated output of generator shall be 950 kW each and it shall be coupled to the turbines. The above capacity of generators ensures 110% load output at 0.8 p.f. for a plant capacity of 2.0 MW. The generator manufacturer shall coordinate with the turbine manufacturer to match the speed, Runway speed, moment of inertia, overloads capacity and coupling arrangements etc.

8.3.4.1 Synchronous Versus Induction Generator

For small capacity projects, line excited induction generators can be preferred over synchronous generators because of their low initial cost, ease of operation and maintenance simplicity. The induction generator uses excitation power supplied from an external source, which is normally the grid. However, in case of grid failure, black start of machines will be difficult. Dependability on grid could result in loss of power due to standstill generator. Hence, synchronous generators are proposed with the following protections:

- Stator - phase to earth faults
- Stator - phase to phase faults
- Over load
- Single phasing
- High/low voltage
- Loss of load and over speeding
- Reverse power flow
- Poor power factor
- Stator overheating
- Rotor overheating

➤ Bearing overheating

The electromechanical equipment manufacturer has to co-ordinate with the control panel manufacturer to provide necessary protections.

8.3.4.2 Stator Frame

The stator frame is made of Welded Steel Construction and has adequate thickness to prevent distortion under operation. The frame is robust and rugged, designed to withstand bending stresses and deflections due to its self-weight and weight of the complete core to be supported by it. The design takes care of safe transmission load of all types and minimizes vibration and noise level, Stator bore is circular to ensure uniform air gap between the stator and rotor, thereby minimizing the unbalance magnetic pull. The Frame is rugged and strong to withstand stresses during normal operation and extreme stresses due to short circuits.

8.3.4.3 Stator Core

The stator core is built-up of thin, high quality, low loss non oriented grains, cold rolled Silicon steel Laminations. Each punching is carefully deburred and laminations are insulated on both sides with high quality insulating varnish to minimize eddy current losses. Ventilation ducts are provided at intervals along the stator core, being formed by means of steel spacing bars securely welded to adjacent punching. The laminations are securely held in place by clamping flanges at each end. The clamping flanges are made up of mild steel.

8.3.4.4 Stator Winding

The stator winding has class “F” insulation system. The stator winding is of multi-turn type, insulated throughout with epoxy resin, mica paper tape and glass tape insulation system. Each coil is made up of number of strands of glass braided copper of electrolytic quality, and of rectangular cross section, to minimize eddy current losses. The coils are provided with class “F” epoxy resin, mica paper tape and glass tape insulation. The coils are treated to eliminate void to ensure high factor of safety against breakdown. An anti-corona shield consisting of a butt layer of asbestos tape and a semi conducting graphite tape / paint is applied to the straight portion of each bar. The overhang portions of the winding is braced together with packing blocks and securely laced to support rings made of molded synthetic resins bonded fabric carried on brackets adjacent to the stator core end plate. Sufficient gap is provided in the top and bottom coils for good ventilation and to avoid hot spots. The coils are held in place in open type slots by wedges of non-shrinking material of class F Epoxy glass laminates.

The whole stator is Vacuum Pressure Impregnated (VPI). After the impregnation and curing process, the whole unit forms a rigidly supported fully consolidated, void free winding. The resin fills all the voids in the stator winding and results in better heat transfer from conductor to stator core.

8.3.4.5 Terminal Arrangement

The three main leads and three neutral leads of the generator windings are brought out of the stator frame, in two separate Terminal Boxes. The Phase and Neutral end of the windings are brought out with suitable insulating enclosure where they pass through the generator housing. The main and neutral leads are provided with terminals suitable for connection with XLPE cables.

8.3.4.6 Cooling System

The generator is natural air cooled. Rotor radial/ axial fans are designed to give a smooth and quiet flow of air. Air is drawn from one / both ends and discharged at the other end / top of the machine. Combined action of rotor poles and fans are sufficient to extract the heat generated in the generator.

8.3.4.7 Temperature Detectors

Resistance type temperature detectors of simplex/ duplex type are arranged symmetrically in the stator winding to indicate the temperature obtained during operation. An Auxiliary Terminal box having suitable terminal blocks are mounted on the generator frame to terminate the resistor element connections. The temperature detectors leads are kept flexible to facilitate disconnecting them without breakage.

8.3.4.8 Rotor Core

The Rotor Core is made up of Rotor stampings, skip notched to form cylindrical poles and directly stacked on to the rotor shaft. Ventilation ducts are provided at intervals along the rotor core, being formed by means of steel spacing bars securely welded to adjacent punchings. The rotor is designed to safely withstand all mechanical stresses imposed by the maximum runaway speed. The rotor core clamp is securely shrink-fitted on main shaft taking care of requirements both at normal operating speed and at maximum over speed conditions. The dynamic balancing of the complete rotor is carried out at plant to keep values of rotor vibrations within allowable limits.

8.3.4.9 Shaft

The generator shaft is made of a high quality medium carbon steel, properly heat treated and accurately machined all over and polished at the bearing surfaces and at all accessible points for alignment checks. The shaft will have ample strength and stiffness at all speeds to resist vibration or twisting on short circuits. The entire shaft is properly tested to ensure that it is free from cracks, blowholes, slag formation or any other defects. A complete set of test reports covering metallurgical strength, & ultrasonic tests performed on each shaft will be furnished.

8.3.4.10 Cylindrical Poles with Field Windings

The cylindrical poles are provided with adequate damper windings to improve stability under fault conditions, to reduce voltage distortions under conditions of single phase to ground fault.

8.3.4.11 Field Winding

The field winding is Multi-layer type, insulated with class “F” insulation and consists of copper strips formed into concentric winding. All pole winding overhangs & connections between adjacent field coils are made mechanically strong and firmly secured to the rotor by Res-I-glass banding. The whole Rotor winding is Roll Dip Impregnated with resin & cured. The field poles are provided with adequate damper winding of the low resistance type to improve stability under single-phase fault conditions. The damper winding bars are of circular copper section embedded in pole faces. The ends of damper bars are short circuited together by copper stampings.

8.3.4.12 Balancing

All rotating parts of the generator unit shall be well balanced dynamically so as to run perfectly true, smoothly and within vibration limits specified and provision is made for readily and effectively compensating any out of balance that may occur upon erection at site or subsequently.

8.3.4.13 Bearings

The generator is provided thrust / guide bearing, on DE side and guide bearing on NDE side. The bearings are forced oil lubricated White metal lined journal type pedestal / end shield mounted Sleeve bearings. Bearings are designed to take the required axial / radial load. The NDE bearing is insulated to prevent any harmful circulating current from passing through the bearings surfaces.

8.3.4.14 Brakes

Generator will be provided with Hydraulic operated brakes of sufficient capacity to bring rotating parts of generator and turbine to stop from 20 % of rated speed.

8.3.4.15 Brushless Excitation System

The Brushless Excitation System consists of a three phase AC Exciter having armature winding on rotor & field winding on stator and a full wave Rotating Rectifier Bridge, mounted on same exciter rotor / shaft. Three phase AC voltage from exciter armature is fed to the Rotating Rectifier Bridge & the DC voltage output of the rectifier bridge is directly fed to main field Winding of the generator, mounted on the same shaft. Main Field winding in turn generates three phase voltage in main generator armature winding, which is housed in main stator

8.3.5 Governor

The Governor shall be PLC based with electronic speed transmitters, feedback transmitters, frequency adoption transmitters etc. The design of governor should be quite compact and is suitable for operation of the unit from one place only. This arrangement requires only one operator in the power station, who can start synchronize and load the unit from one place only by controlling various controls provided on the governor panel. The governor receives signal from a toothed disc mounted on the main shaft and amplifies it and feeds it to servo-mechanism, which in turn controls the guide vane opening-closing stroke.

Digital Electronic governor with Oil Pressure Unit (OPU) is proposed to be housed in one of the corners of the power house. This system will serve the purpose of sequential control of the unit and the status indication for peripheral mechanical devices.

- Indication
- Control

All the indications such as butterfly valve On/Off status, breaker on/off status etc. will be indicated on the unit control board incorporated in the Electronic Governor. 220 Volt D.C. lamps of different color codes will be used for this purpose.

8.3.6 Controls provided on Governor

- Speed control for grid frequency adaptation
- Speed control for isolated load operation
- Droop setting points for permanent droop and temporary droop
- Basic control

➤ Over speed Protection

With this arrangement the turbine shall operate smoothly and efficiently under any operating conditions.

Turbine shall be equipped with suitable PLC based electronic type of governor. The PLC should monitor and control following items

1. Plant power output
2. Plant rated circuit breakers
3. Reactive power control

The governor shall be of proven design capable of maintain control of speed under all conditions of heads and loads. Such a governing system shall be complete with actuator unit comprising speed responsive element, restoring mechanism having adjustable temporary and permanent droop setting, load limiting device, speed control, oil pressure units etc.

8.3.7 Metering System

Power generated shall be metered at the proposed interconnection point through metering CTs and PTs. The power transferred to 33 kV feeders shall also be metered through CTs and PTs. The metering instruments shall be provided on relevant panels. The digital multifunctional meters shall be provided on each generator control panel suitable for indicating following parameters continuously rolling with selection facility.

8.3.8 Protection

The following protections will be provided by using integrated numerical protection relays for generator, generator transformer and feeders.

a) Generator Electrical Protections

- 1) Generator Differential Protection
- 2) Negative Phase Sequence Protection
- 3) Generator Reverse Power Protection
- 4) Voltage Restrained Over Current Protection
- 5) Stator Earth Fault Protection
- 6) Loss of Excitation Protection
- 7) Over Speed (Electrical) Protection
- 8) Rotor Earth Fault Protection
- 9) Over Voltage Protection
- 10) Fuse Failure Protection

11) Under Voltage Protection

Master tripping relays for controlled action shutdown, immediate action shutdown, critical shutdown, emergency shutdown etc. shall be used separately in the system.

b) Mechanical Protections

- 1) RTQ (PT-100) in stator winding/core and in bearing for indication, alarm, recording and shutdown of the unit.
- 2) Governor oil pressure low.
- 3) Over speed mechanical for normal and emergency shutdown.

c) Generator Transformer

- 1) Overall differential protection
- 2) Over current and earth fault protection with high Inst. Element
- 3) Stand by earth fault protection
- 4) T/F Winding Temperature High Alarm/Trip.
- 5) T/F Oil Temperature High Alarm/Trip.
- 6) Buchholtz relay - Alarm/Trip.

d) 33 kV Line Protection

- 1) Digital over current and earth fault relay with high set unit.
- 2) Under voltage
- 3) Over / Under frequency

e) Station Aux. Transformer Protection

- 1) Fuse set on 3.3 kV side
- 2) Digital over current and earth fault relay with high set unit on L.T. side.

8.3.9 D.C. Equipment

Float and boost type 220 Volt, 200 AH battery charger and tabular battery will be provided for feeding power to indication lamps, protection relay coils, initial impulse to the self-excitation system by means of field flashing and to operate few emergency lights.

8.3.10 Auxiliary Power Supply

1 Nos. 3 Phase, 3.3 KV/415V, Dyn11, 63 KVA step down Unit Auxiliary transformer will be used for feeding the station lighting and heating load for power house, staff colony, illumination for approach road and switch yard.

Emergency lights on important places will be operated by D.C. battery provided in the power house. 63 KVA diesel generator set will also be provided for illumination in power house, staff colony, street lights & switch yard during shut down of machines.

8.3.11 Cables and Terminations

XLPE type H.T. cables/ Bus Ducts shall be used connecting generator to generation transformer, neutral grounding end.

8.3.12 Switchyard

A comparatively flat terrace is available near power house where step-up transformer will be kept on plinth. Earth mat will be laid underground. Proper fuse sets, switches etc. will be mounted on M.S. poles. The total area will be strongly fenced as per electrical safety rules. High voltage cable will be laid underground in cable trenches. The power cable will connect low voltage side of the step-up transformers. One number 3.3KV/33KV, YNd11 step up transformer is used to carry the power generated to the bus duct. The transformer would be ONAN type in accordance with IEC standards.

8.3.13 Grounding Systems

8.3.13.1 General

The following equipment/systems are required to be earthed:

- a. Neutral points of different voltages
- b. Equipment frame work and other metallic parts
- c. Boundary fence, steel structures etc.

8.3.13.2 Design

The grounding system shall conform to IS 3043-1987 or latest local standards. The voltage between any two earthed points shall not exceed 32 volts. The resultant value of earthing resistivity shall not exceed 1.82 ohm-m. Earthing electrodes shall be uniformly distributed and located adjacent to fencing of switchyard and power house. Three earthing connections to lightning arrestor shall be made directly.

Earth mats for switch yard and power house will be made with the help of 50mmx6mm G.I. strips buried underground. Earthing electrodes may be 19mm dia., 2m long M.S. rods driven straight into the ground with the help of sledge hammers. Alternatively G.I. plate of size 600mmx600mm may be used along with G.I. strip and G.I. pipe with funnel to achieve better results.

8.3.14 Transmission System for Evacuation of Power

The powerhouse, switchyard and its equipment up to the outgoing double pole structure shall be in the scope of the developer. The single line diagram and station switchyard layout

are provided in the drawing no. PHEP-20. For evacuating the power, it has been proposed to transmit the power from the switchyard to an isolated grid network system of Loliondo and Wasso via a planned 78km long 33KV transmission line. However, load flow studies have been completed so as to finalize the transmission voltage and interconnection arrangement.

8.3.15 Diesel Generating Set

Diesel generator of 63 KVA, 415 V shall be provided at the project along with its accessories, control panel, battery and cooling systems, indicating/measuring instruments, protection and alarm systems etc.

Chapter 9 – Construction Material & Planning

9.1 General

The main items of work for civil works have been estimated on the basis of drawings prepared after carrying out the designs of civil components. Surveys have been conducted to assess the availability and suitability of construction materials in the vicinity of the project area. The construction of the project is proposed to be completed within 18 months from the start if planned judiciously. Construction activity may be disrupted during long rain for a few days. This chapter describes the estimated quantity of main construction materials, their suitability for construction purposes and their availability along with the construction plan.

9.2 Quantity of Work Involved

The civil components for Pinyinyi SHP include the trench weir, intake, desilting tank, Water conductor consisting of channel, Forebay, Power house building, Tail race channel, Switchyard, Approach roads and other appurtenant works. The major items of work involved in construction of these components include excavation, lean concrete, reinforced cement concrete, stone/brick masonry, gabions, boulder protection, and structural steel fabrication.

The materials required for construction viz., coarse aggregate, fine aggregate, cement, reinforcement steel, structural steel, rubble, bricks shall be procured in required quantities to match the construction schedule.

9.2.1 Cement

Cement can be ordered in bulk from the factory in Tanga (700km from site). Rail & road transport (via Trucks) of cement can be arranged from Tanga. Cement bags shall be stored in cement stores at site as per specification.

9.2.2 Steel

Steel will be procured in bulk from Tanga (700 km from project site). Required quantities of reinforcement and structural steel shall have to be stored at site from time to time in advance of construction to avoid any hindrance in project construction. Penstock steel plates, however, will have to be procured by the contractor directly from the manufacturers as per design specifications.

9.2.3 Coarse Aggregate

Coarse aggregate and stones shall be bought from nearby quarries. A stone crusher shall be installed at appropriate position along the length of the project which shall cater to the requirements of coarse aggregates. The material will be screened and transported to the project site by mules, head loads, ropeway, conveyor system and/or small trucks.

9.2.4 Other Materials

Explosives, CGI sheets, industrial gas and other materials required for the project will be procured from Tanga or from Dar-es-Salaam, which is about 850 km from the project site.

9.3 Pre-Construction Activities

The activities proposed to be undertaken during Pre-construction work include the following:

- Additional testing for construction materials
- Tie-up for supply of construction materials
- Site office
- Power Purchase Agreement
- Contractor's camp and colony.
- Detailed design and preparation of tender documents for Civil, Electro-mechanical, Hydro mechanical components
- Financial closure of bank loan, equity.
- Construction power
- Construction of Approach roads
- Construction / Strengthening of bridges
- Transmission line planning including interconnection agreement with Tanesco
- Tendering of the project and selection of contractors, vendors & suppliers
- Mobilization of Project team.

It is proposed that critical activities like construction power, preparation of tender documents and Financial closure to be started immediately after signing of Power Purchase Agreement with Tanesco.

9.4 Construction Activities

9.4.1 Civil Works

The civil works of Pinyinyi SHP include:

1. Approach Roads
2. Trench weir & Intake structure
3. Desilting Tank and Conveyance Channel
4. Head Race Channel (HRC)
5. Forebay
6. Powerhouse
7. Tail race
8. Switchyard foundations

9.4.1.1 Approach Roads

The construction of required approach roads to the intake, forebay & powerhouse locations will be the first work to be executed at site, as approach roads will be required for transporting materials to site. The strengthening of existing roads & bridges will also be taken up in the first few months.

9.4.1.2 Diversion Weir & Intake Structure

The construction of diversion weir will be undertaken during the lean season (low water flow) & will be completed before the long rains. Diversion of river water through a narrow section can be achieved while construction on the rest of the river cross section is going on. The construction will be started in the first month and will be completed by the 6th month of construction.

9.4.1.3 Water conductor (Conveyance Channel, Desilting Tank and HRC)

The water conductor from the intake to the forebay will consist of Conveyance Channel, Desilting Tank and Head Race Channel. This work will be taken up in parallel with other civil works and will be opened up for flow only after construction of other related civil structures. This work may be completed in about 8 months, starting from 1st month of construction

9.4.1.4 Forebay & penstock civil works

Forebay & penstock civil works will be carried out simultaneously with the works in the powerhouse area.

9.4.1.5 Power House & Tail Race Channel

The construction of powerhouse falls on the critical path. The excavation for powerhouse will be taken up first and will be completed in 3 months' time. The concreting for powerhouse is estimated to be completed in another 6 months. After receiving the details of embedded parts of turbine and generator and valves, the concreting for powerhouse raft will be carried out. Powerhouse walls and columns will then be completed up to service bay level. There after the construction work for powerhouse columns and crane beam will be done to enable erection of roof truss and roofing material. The construction of tailrace channel will be done simultaneously with powerhouse construction. The crane beam is proposed to be made available to the turbine manufacturers before 2 months of erection of turbine and generator. Finishing works for powerhouse will be carried out in parallel with machine erection. The complete civil works for powerhouse are expected to be completed in 14 months from start of construction. Work at powerhouse may be disrupted for a month or so due to climatic conditions. Tail Race Channel & Tail Pool is expected to be completed in 3 to 4 months.

9.4.2 Electro-Mechanical Works

Tendering and Order Placement: For timely completion and efficient monitoring of project, complete electro-mechanical works shall be awarded to single contractor on the basis of Limited International Competitive Bidding process or any other competitive process that is feasible and time efficient. Tenders for the Electro-Mechanical works shall be floated during pre-construction stage and order shall be placed to match the progress of work of civil works. Procurement, Fabrication & supply of Hydro Generator Unit are estimated to take 8 months and Erection of Hydro Generator Unit is estimated to take another 3 months, starting from 15th month of construction period.

9.4.3 Transmission Lines

The project developer, Ninety Two Ltd received a grant from REA, under Rural Electrification Phase III to construct the project 33 Kv Transmission line for a total of 78 km including its distribution network. As a condition the company had to carry out the detailed topographic survey for ascertaining its details, the route, length and number of poles and other materials for construction of Transmission Line and all the results was submitted to REA offices. In its letter dated 5th July 2016 with reference number BC86/134/35/15 REA confirmed to give a grant to construct the Transmission line with the electrification of all 29 villages along the line.

Through REA tender number G10/1 a construction company was chosen for this purpose. Nipo Group Ltd of P. O Box 1109 Dodoma with contact number +255765127666 and email address nipojv@gmail.com was awarded this contract and the construction is ongoing process towards 80% completion. The line will come to the project site to assist for construction power and when completed the line will be used to evacuate the generated electricity. The load Flow study for the 33 Kv Transmission line was also completed.

9.4.4 Engineering

Immediately on confirmation of the order, the electro-mechanical supplier shall start their detail engineering and shall be asked to submit the first stage embedment drawing and other drawings to consultant for approval. Consultant shall give comments / approval of drawings within 10 days of submission of drawings. All manufacturer drawings shall be submitted within three months of award of work.

9.4.5 Manufacturing & Supply

Supplier shall be asked to submit the complete quality assurance and quality control program for consultant approval. After approval of quality plan, supplier shall start their manufacturing and erection- work. The first stage embedment viz., drainage water pipes, draft tubes embedment etc., shall be supplied during 9th month of construction period. The supply of other equipment shall start latest by 5th month from the placement of order and entire supply shall be completed by the 12th month from award of supply order.

9.4.6 Erection & Commissioning

The crane shall be made available for electro-mechanical erection during 11th month and powerhouse shall be handed over to contractor thereafter for erection of equipment. The switchyard foundations shall be made available to contractor during 14th month. Contractor shall complete erection work of powerhouse and switchyard in all respect before 16th month.

After completion of erection works, pre-commissioning test of all equipment shall be completed within one month and commissioning of first units shall be done in 15 days and 2nd shall be commissioned in another 15 days. Thus, the project shall start generating by the end of 18th month after award of work to the contractor.

9.4.7 O&M Manual & As Built Drawings

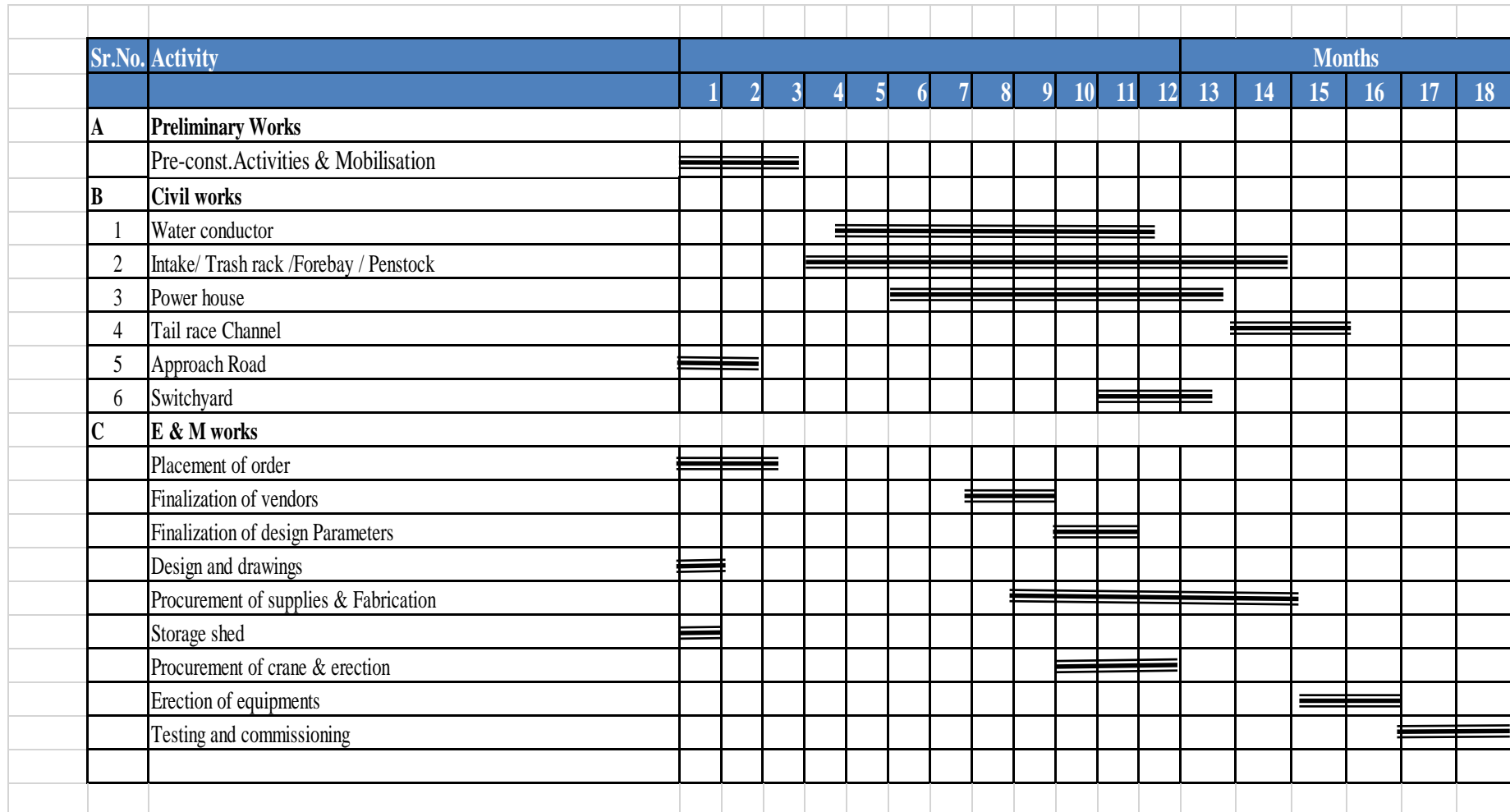
Soon after commissioning of project equipment, manufacturer shall submit the complete sets of as built drawings for consultant / developer record. The E&M equipment supplier shall also furnish a detailed operation and maintenance manual to the consultant for approval.

9.4.8 Handing Over

After commissioning of project and successful operation of plant, project shall be taken over by the developer. However, a team of contractor engineers shall be at project site for another two months for any trouble shooting and training of personnel. The next page shows a graphic representation of the construction planning.



Chart 9.1 - Construction Activities Bar Chart



Chapter 10 – Project Organization

10.1 General

The construction of Pinyinyi HEP will have to be supported by relevant infrastructure works such as permanent and temporary colonies, office, roads and bridges, workshops, etc. situated within the project area. The project is planned to be completed in a construction period of 18 months, including a short period which will be devoted for mobilization and creation of infrastructure facilities. The construction of the project is proposed to be carried out through contracting agencies entrusted with suitable EPC contract packages.

Package I:

Infrastructure: Access road, Colonies, transmission line, temporary housing, storage.

Package II:

Intake, Weir, Channel, Desilting Tank, Channel, Forebay, Penstock, Power House, Tail race and Switchyard.

Package III:

Hydro mechanical works viz. Trash Racks, Gates, valve etc.

Beside above civil packages, the following packages have been envisaged for the Electro-Mechanical works. (This scope can be further sub-divided into parts to be allotted to different contractors.)

Package IV:

Turbine, Generators, Spherical valve, auxiliary, equipment, Cranes and 33kv switchyard equipment.

It is also proposed that the contracts relating to preparation of detail designs, technical specifications and construction drawings for various components of the project is now being executed through a separate contract package by a competent consultant. Keeping in view the quantum of design and construction work involved, close coordination would have to be maintained to avoid time and cost over-runs. The organization of the project has been planned keeping the above in the view. Broad features of this organization structure are described in the following paragraph.

10.2 Project Organization

The works of Pinyinyi hydro-electric project would be looked after by a project team set up for the purpose by the developer. The unit is proposed to be headed by Project Manager for the overall management of the project. All engineering and project services would be accountable to the Project Manager. The Project Manager would be assisted by separate departments to look after the planning, material procurement, construction management, quality control, administration, financial and accounts aspects of the projects. The organization set up above will be supported by the necessary complimentary staff.

10.2.1 Organization for Construction of Civil and Electrical Works

The proposed organization for peak construction period will comprise of the following:

- One Project Manager, responsible for the overall execution of the works.
- Three/ four engineers, out of which one each for civil, mechanical, electrical along with one material testing engineer shall assist the Project Manager.
- One Financial Controller/Admin along with necessary complimentary staff for ensuring proper financial control. This job can be handled by the project manager.
- One Human Resource Manager with necessity complementary staff to look after personnel & administration, public health, liaison work, etc. This job can be handled by the project manager for such a small project.

The above mentioned officers shall be overall in-charge of their respective offices and shall function as an integrated team, every member of which will not only be conversant with his duties and responsibilities, but will also get necessary report/feedback regularly from his respective division for taking timely corrective measures wherever required. Each Division will have technical and secretarial supporting staff as per requirement. The team has the bandwidth to support more than one project, in the same vicinity, especially at the senior managerial level.

10.3 Functions and Responsibilities of Project Team Members

10.3.1 Project Manager (Complete Project)

They will be responsible for complete Infrastructure works, construction of all civil and electrical activities as stated in Package I to IV except for the Transmission line which is now

ongoing process. They will also be responsible for pre-construction investigations, material testing, quality control and control survey.

They will be assisted by Three (3) engineers for execution of these works and one material testing engineer. The key responsibilities of the team members attached to the Project Manager will be as under.

10.3.2 Engineer Civil

Responsible for construction of infrastructure works and shall be officer in-charge for civil works relating to construction activities under Package I, Package II & Package III

10.3.3 Engineer Mechanical

Responsible for the execution of all the mechanical works involved in Package III & Package IV.

10.3.4 Engineer Electrical

Responsible for execution of Package IV.

10.3.5 Material Testing Engineer

Responsible for organizing testing of materials and quality control for the entire civil works and would be in charge of up keep and maintenance of all laboratories. In addition, he will be responsible for control survey of the whole project. For this purpose, he will be assisted by supporting staff.

10.3.6 Need Based Units

The numbers of units headed by one Project Manager as proposed above are based on the function and physical requirements of the works. The works between all team members have been so distributed that progress is achieved for the critical items of the works without affecting progress on other works.

10.3.7 Finance and Accounts

The Project Manager will have a Financial Controller (F.C.) supported by one Accounts Officer (AO) attached to his office. The FC & AO will deal with working on accounts, costing regular and work-charged staff establishment etc.

10.3.8 Project Administration

Regarding project administration including maintenance of colonies, public relations, welfare etc., the Project Manager will be assisted directly by a Manager (Admin.) posted in his office. The Manager (Admin.) will be assisted by a Security Officer along with supporting staff to look after the vigilance and security aspects of the project areas. The organization structure will be reviewed and firmed up as part of the detailed planning in the pre-construction stage.

The developer will ensure adequate review of project activities, and provide financial and administrative approvals and render policy guidance to the Project Manager.

10.3.9 Technical Advisory Committee

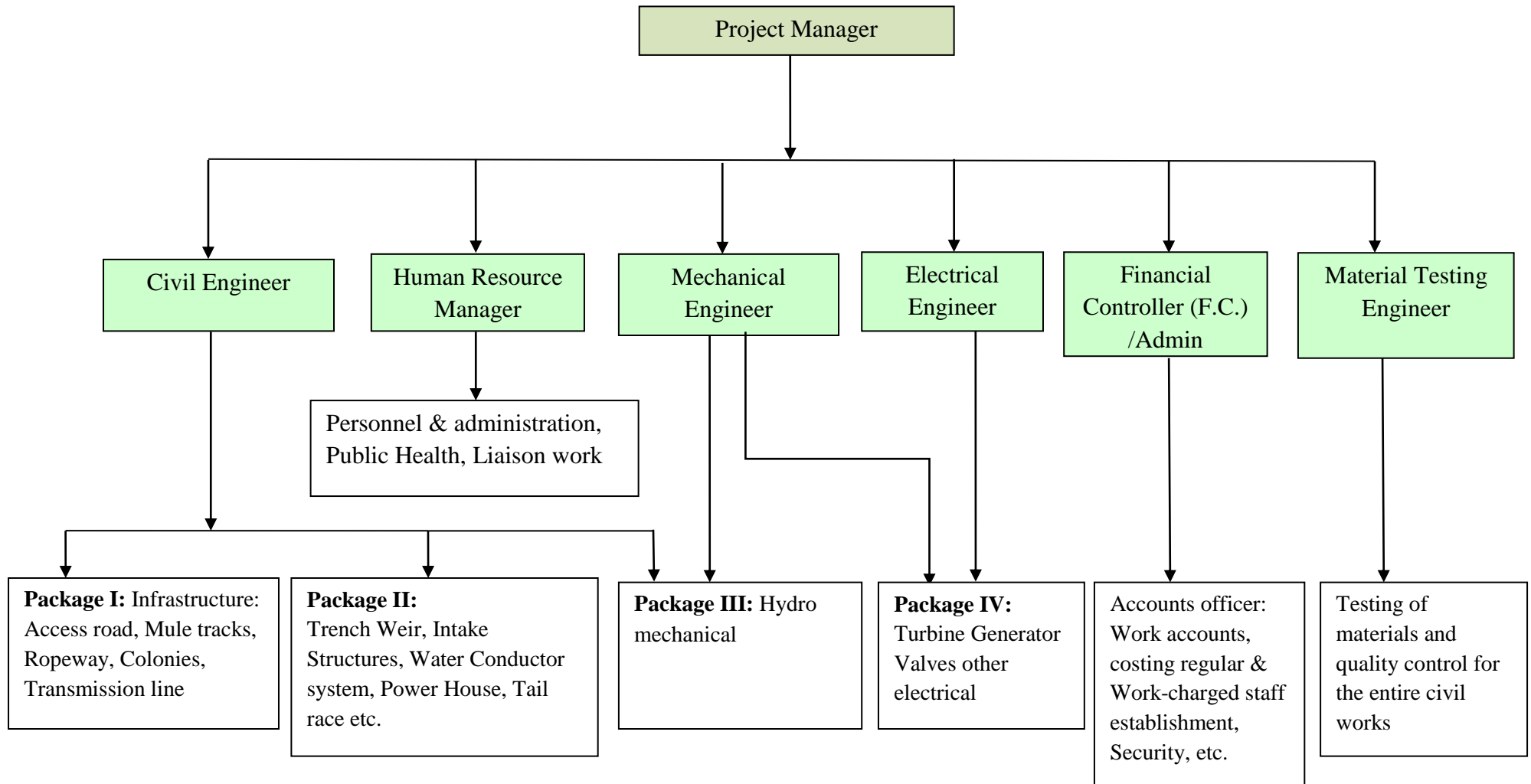
Developer will constitute a technical advisory committee comprising of renowned experts. This committee will advise the project team through Project Manager on all critical aspects of project planning, design and construction activities.

10.4 Consultants

M/s Strategic Consulting Group (SCG), India have been appointed as consultants for the project for Survey & Investigation, DFSR Preparation and finalizing the project components. Other consultants/ service providers will be hired by the Board of Directors at an appropriate time as per requirements of the project.

10.5 Reporting / Reviews

The project will be subject to monthly reviews so that all concerned are aware of the progress to date. The monthly report will give details of manpower, productivity, schedule and costs. The purpose of these reviews will be to highlight the problem areas and provide the required additional supervision and action to resolve the problem. The reports will be prepared using inputs from consultants, contractors, construction supervisors, procurement officers etc. so that a realistic picture of the project is available for review and report.



Chapter 11 – Infrastructure Facilities

11.1 Introduction

Infrastructure developments are pre-requisite for the timely completion of any project. The Pinyinyi project is located approximately 150 km to the North of *Mto Wa Mbu* town (literally, River of Mosquitoes) & around 60 km to the East of Loliondo town. The project area is remote with rough road connectivity which is now been improved for tarmac level.

11.2 Access Roads & Rail Connectivity

The project intake is located at an elevation of about $\pm 868\text{m}$ (above mean sea level), before the Pinyinyi river falls down an escarpment on its way to Lake Natron. A dirt road exists near the Pinyinyi village but the powerhouse site would need to be connected by constructing ~ 1.0 km of road. New road of about 2-3 km and a bridge would also be required to connect the intake site. The intake site may also be connected by means of a ropeway to transport construction material and equipment.

Also, the dirt roads would need to be reinforced and made ready for use by heavy trucks transporting machinery, equipment and supplies to the site during construction. The length of roads to be strengthened would be around 6 km. The proposed powerhouse site would have to be connected through new black top road for easy movement of equipment and machinery.

11.3 Construction Power

Pinyinyi is a small hydro power project and construction power requirement would have to be met through the supply from the Transmission line which is now under construction towards the project location. But a number of suitable diesel generating sets shall be installed at site as a backup supply of power for construction purpose.

11.4 Telecommunication Facilities

Cellular networks coverage is now available in the project area following the erection of communication tower close to the project location which will be used for communication during the implementation of the project. The project developer may come up with the additional telecommunication facilities that may become available in the near future.

11.5 Colonies/ Buildings

Temporary accommodation shall be constructed for housing the skilled workers. However, during the operation & maintenance of the project a few permanent quarters are proposed near power house. Water supply will be drawn from the river itself. Drinking water plant will be set up to provide clean drinking water. To carry out the pre-construction activities, rented accommodation is available in nearby towns. Shelter accommodation for the labour shall be made at the site.

11.6 Workshop

A workshop to carry out fabrication work is proposed near the power house. This will work as a temporary arrangement during execution. Ultimately a workshop in the power house building service bay shall be established during operation of the project. The necessary stockyards for the steel and other materials and storage facilities for the cement shall be provided at the location near power house location.

Chapter 12 – Environmental & Ecological Aspects

12.1 Introduction

Small hydro projects are considered to be pollution free projects and environment friendly. The Environmental & Social Impacts Assessment have been carried out by the developer in accordance with the terms of reference granted by the National Environment Management Council (NEMC) of Tanzania and has fulfilled all relevant requirements of the World Bank Safe Guard Policies. EIA consultant was hired to carry out the studies on 29th April 2016 and the agreement was signed between Ninety Two Ltd and Water Land Centre Consultant Company. The studies were completed and the project has already been awarded with an EIA Certificate, with registration number **EC/EIA/3378**, which was issued by Vice President's Office – Union and Environment. This is a run -of-river type small hydro power project and is an environment friendly activity without any adverse impacts on the ecology of the area.

The proposed hydro power project is a run of river based project and has no adverse impacts as stated above. However, the project will benefit the local grid users as the same will get strengthened, will supplement the power in the already starving grid. Further the project will generate employment for the local people, workers, and skilled labour. The project will also promote agricultural development and production. This is the only project of this kind in the nearby 5 km periphery of the project area and therefore will be of great help to the local people.

The environmental significance for the proposed Pinyinyi SHPP was determined using an impact assessment matrix shown on Table 12.1, through assigning the matrix at the intersection a value based on the scenarios of Very Severe Impact (not acceptable) for a score of -3 to an acceptable (very good) impact with a score of +3. Table 12.2 below depicts the Impacts Correlation Matrix for Proposed Pinyinyi SHPP in Pinyinyi Village, Pinyinyi Ward, Ngorongoro District, Arusha Region:

Table 12.1 Summary of the Impacts associated with the Pinyinyi SHPP

Key identified Impact	Direct	Indirect	Reversible	Irreversible	High magnitude	Medium	Low magnitude	Long term	Medium term	Short term	Significance
Impacts during mobilization and construction phase											
Noise pollution	✓		✓			✓			✓		-1
Air pollution	✓		✓			✓			✓		-1
Loss of Vegetation, land use and property	✓		✓			✓				✓	-2
Increased soil erosion and land slides	✓			✓	✓				✓		-2
Increase of accidents due to increased traffic	✓			✓	Variable		Variable			Variable	
Increased waste generation and haphazard disposal	✓		✓			✓		✓			-2
Occupational accidents at the work place	✓		✓				✓			✓	-2
Increased sediments that might reduce water velocity	✓			✓	✓				✓		-1
Increased turbidity in the stream water	✓		✓				✓			✓	-2
Impacts on aquatic ecology and downstream water users due to impaired water quality	✓		✓				✓			✓	-2
Widespread of oil spillage	✓			✓			✓			✓	-1
Increased soil and water contamination	✓			✓			✓			✓	-1
Intensification of HIV/ AIDS, STDs and other communicable diseases		✓		✓		✓		✓			-2
Visual impacts	✓		✓				✓			✓	-2
Benefits to communities resulting from employment opportunity and other economic activities	✓		✓			✓				✓	+3
Increased government revenue	✓		✓			✓				✓	+3
Impacts during operation phase											
Noise pollution	✓		✓			✓			✓		-2
Reduced surface water flow	✓		✓			✓			✓		-1
Increased waste generation and haphazard disposal	✓		✓			✓		✓			-2

Increased soil and water contamination	✓			✓			✓		✓		-1
Widespread of oil spillage	✓			✓			✓		✓		-1
Impacts on aquatic ecology and downstream water users due to impaired water quality	✓		✓				✓		✓		-2
Intensification of HIV/ AIDS, STDs and other communicable diseases		✓		✓		✓		✓			-2
Increased social conflicts and crimes		✓	✓		✓				✓		-1
Health and safety risks due to electric hazards		✓		✓		Variable		Variable			Variable
Benefits to communities resulting from employment opportunity and other economic activities	✓		✓			✓			✓		+3
Improved environmental management of Pinyinyi River ecosystem	✓		✓			✓			✓		+2
Increased government revenue	✓		✓			✓			✓		+3

Table 12.2: Impact Correlation Matrix for the Proposed Pinyinyi Small hydro Power Project

CATEGORY OF IMPACT	MOBILIZATION & CONSTRUCTION PHASE											OPERATION PHASE						DECOMMISS IONING PHASE		
	Recruitment of labour force	Site clearing	Establishment of workers' camp and delivery of construction equipments	Excavations for the foundation of intake structures and canal	Water use	Energy use	Construction of power plant and housing units	Installation of transmission/distribution lines	Solid waste management	Liquid waste management	Laying off construction labour force	Liquid waste management	Solid waste management	Water use	Energy use	Recruitment of workforce	Power generation by SHPP	Transmission	Demolition of structures and management of debris	Laying off the labour force
POSITIVE IMPACTS																				
Improved environmental management of Pinyinyi River ecosystem	+2	0	+2	+1	0	0	2	0	0	0	+1	-1	0	0	0	+	+	+1	+2	-2
Employment opportunities	+2	0	+2	+1	0	0	2	0	0	0	+1	-1	0	0	0	+	+	+1	+2	-2
Availability of electricity	-1	0	0	0	0	+1	0	0	0	0	+1	0	0	0	0	+	+	-2	-1	-1

																1	1			
Increase of community income and livelihood	+2	0	+1	+2	0	0	+2	0	0	0	-1	0	0	0	+	+	+		-1	-1
Increase of gvt revenue	+1	0	+1	+1	0	0	+1	0	0	0	-1	0	0	0	+	+	+	+2	-1	-1
NEGATIVE IMPACTS																				
Loss of vegetation, existing land use and property	0	-1	-1	-1	0	0	-1	-1	0	0	0	0	0	0	0	0	0	-1	0	0
Soil and water pollution	0	-1	0	-2	0	0	-2	0	0	0	+1	0	-1	0	-1	-1	-1	-1	0	0
Air pollution	0	-1	0	-2	0	0	-2	0	0	0	+1	0	-1	0	-1	-1	-1	-1	0	0
Increased noise level	0	-1	-1	-2	-1	-1	-2	0	0	0	+1	0	0	0	-1	0	-1	-1	0	0
Increased soil erosion and land slide	0	-1	0	-2	0	0	-2	0	0	0	+1	0	-1	0	-1	-1	-1	-1	0	0
Increased sediments in the river bed	0	-1	0	-2	0	0	-2	0	0	0	+1	0	-1	0	-1	-1	-1	-1	0	0
Reduced surface water flow	0	-1	0	-2	0	0	-2	0	0	0	+1	0	-1	0	-1	-1	-1	-1	0	0
Impairment of surface water quality	0	-1	0	-1	0	0	0	0	-1	-1	0	-2	-2	0	0	0	-1	0	0	0
Increased traffic accidents	0	-1	0	0	0	0	-2	-1	0	0	0	0	0	0	0	-1	0	-1	0	0

Intensification of HIV/AIDS, STDs and other communicable diseases.	-2	-2	0	0	0	0	-2	0	-1	-1	-1	-1	-1	-1	0	-1	-1	-1	-2	-2
Health and safety risks to workers and community	-1	-2	-1	0	0	-1	-2	0	0	0	0	-1	-1	-2	0	-1	-1	-1	-1	-1
Increased waste generation and haphazard disposal	0	-1	0	0	0	0	-2	-1	-2	-1	0	-1	-1	-2	0	0	-2	0	-1	0
Impacts to aquatic ecology and downstream water users	0	-1	0	-2	0	0	-2	0	0	0	+1	0	-1	0	-1	-1	-1	-1	0	0
Impaired aesthetic and scenic quality	0	-1	0	-1	0	0	-1	-1	-1	0	+1	0	0	-2	0	0	-1	-1	-1	0
Increased crime level and social conflicts	0	-1	-1	0	0	0	-1	0	0	0	-1	0	0	0	0	-1	-1	0	0	-1

Key

+3 = Very High Positive Impact -1 = Minor Negative Impact 0 = No Impact
 +2 = High Positive Impact -2 = Highly Negative Impact
 +1 = Minor Positive Impact -3 = Very Highly Negative Impact

12.2: Impact Management plan

The Environmental and Management Plan for the implementation of mitigation measures for the proposed hydro power project provided, indicates the institutional responsibilities, time at which the action will be undertaken and estimated costs. However, the proposed costs are only indicative, should the proposed development proceed with the suggested changes, the developer will work out the actual costs and reflect them in the overall cost of the project. Based on the EMA, (URT 2004), NEMC is required to ensure compliance of all the agreed conditions for authorization. The measures are given in Table 8.1 within the Environmental Impact Assessment Report. Pinyinyi Small Hydro Power Project Management is committed to implement the mitigation measures as suggested by the Environmental and Social Impact management Plan (ESMP).

12.3: Implementation of the Management Plan

The Environmental and Social mitigation measures incorporated in the detailed engineering design shall be handed over to the contractor during construction period. The Contractor/ developer shall take stock of the contents of the Environmental and Social Management Plan of the Project. The contractor/ developer shall implement the ESMP during the construction period under close supervision of the Pinyinyi Small Hydro Power Project Management and also during the Operation Phase.

During Environmental Assessment Study it has been observed that the proposed Pinyinyi Small Hydro Power Project is anticipated to cause potential environmental and social impacts during mobilization, construction, operation and decommissioning phases as shown in this report. However, the recommended mitigation measures for negative impacts and enhancement measures for positive once have been proposed for implementation of the proposed project. Thus, the potential negative impacts associated with the proposed development can be reduced, limited and eliminated by the application of appropriate mitigation measures as stipulated in this document.

Therefore, it is concluded that, the potential negative impacts associated with the proposed development can be reduced, limited and eliminated if appropriate mitigation measures as stipulated in the Management Plan are implemented by Ninety Two Ltd in collaboration with other stakeholders especially for the conservation of natural environment in the upstream catchment of Pinyinyi River.



Chapter 13 – Analysis of Rates

13.1 Introduction

In order to arrive at an estimate for the Project Cost, the major activities involved in the construction of the project are to be identified and rates determined for the same. Also, the market rates & working rates for the major commodities involved in the construction of the project are to be determined.

13.2 Labour Wage Rates

Labour wages form a part of the cost for all activities associated with the Project. Skilled, semi-skilled and unskilled labour and technicians are required for the project. The wages are taken as per prevalent rates of labour wages in East Africa.



Table 13.1 – Labour wage rates for cost estimation**Detail of wages of Regular Staff**

S No	Name of Post	Daily rate USD	Days	Monthly
1	Operator	13	30	390
2	Driver	13	30	390
3	Mechanic	13	30	390
4	Foreman	13	30	390
5	Electrician	13	30	390
6	Supervisor	13	30	390
7	Mason	10	30	300
8	Watchman	7	30	210
9	Other Misc	7	30	210
10	Medical Attendant	13	30	390
11	Staff nurse	13	30	390
12	Cook/ Peon	13	30	390

Detail of wages of skilled workers

S No	Name of Post	Daily rate USD	Days	Monthly
1	Helper	7	30	210
2	Black-Smith	13	30	390
3	Watchman	7	30	210
4	Other Misc	7	30	210
5	Jumper-Man	7	30	210

Source: Rates expected & encountered in Project in East Africa

3.3 Market Rates for commodities

Basic or market rates for commodities are obtained from the local markets/ suppliers of materials from the area. The working rates are derived by adding transport, handling, storage, wastage & other costs to the basic rates. Basic rates and derived working rates for various commodities are provided below. Construction power rate & diesel fuel rate are the rates as obtained from the market.

BASIC RATES USED FOR ANALYSIS

			Working rates , USD		Basic Rate USD	
A	<u>Material rates(including all taxes)</u>					
	1	Reinforcement steel	USD	2,127	per MT	1,429 per MT
	2	Structural steel (plates, angles etc)	USD	3,098	per MT	1,667 per MT
	3	Penstock steel (IS-2002-2009)	USD	3,574	per MT	1,905 per MT
	4	Cost of cement at supply store	USD	8	per bag	6.4 per bag
	5	Cost of sand	USD	18	per cum	per cum
	6	Cost of coarse aggregate	USD	17	per cum	per cum
	7	Welded wire mesh	USD	11	per MT	per MT
B	<u>Fuel rate</u>					
	1	Diesel	USD	1.18125	per litre	1.1 per litre
	<u>Electricity rate</u>					
	1	Electricity Rate	USD	0.18	per Unit	
C	<u>Other Items</u>					
	1	Drill used for jack hammer	USD	1.2	per m	
	2	Drill steel for crawler drill	USD	5.0	per m	
	3	Gelatin	USD	2.0	Per kg	
	4	Detonator	USD	0.5	Per kg	

13.4 Rates for equipment use

Rates for activities (hourly use of equipments) are based on the capital cost of the machines, their useful life, annual depreciation, rate for maintenance, fuel or power consumption & the associated labour rates required for operating those machines. After looking at all these costs, the hourly cost or rate of usage of all equipments required in construction are derived as follows:

Table 13.2 ABSTRACT OF HOURLY USE RATE OF EQUIPMENT

			USD/ hr
S No	Description	Size/ capacity	Rate
1	Excavator	1 cum	49
2	Excavator	2 cum	61
3	Wheel Loader	2.5 cum	52
4	Crawler Dozer	320 HP	102
5	Crawler Dozer	180 HP	83
6	Dumper	10 T	48
7	Dumper	18 T/20 T	60
8	Flat Bed Truck	10 T	27
9	Crushing and processing plant	200 TPH	132
10	Concrete pump	38 cum	54
11	Transit mixture	6 cum	44
12	Batching and mixing plant	90 cum	132
13	Front end loader	3 cum	64
14	Crawler Drill	400 cfm	61
15	Tower Crane	5 T	59
16	Tower Crane	10 T	82
17	Concrete Machine	6 cum	65
18	Jack Hammer	200 cfm	23
19	Ventilation Blower	1000 cfm	8
20	Grouting Machine	100 Kg/m ²	45

13.5 Rates for material use

Based on inputs of labour rates, material rates & equipment rates, the rates or costs for various activities involved in civil works are calculated. The summary rates are given below:

S no	Description of works	Direct Rate, USD	Unit
1	Excavation		
	Open excavation		
	In Soil	6	cum
	In Rock	10	cum
	Under Ground Excavation		
	In Rock	76	cum
2	Concrete		
	Surface Works		
	M10	96	cum
	M20	113	cum
	C.C. Blocks	115	cum
3	Steel		
	Reinforcement, Grade Fe415	2,127	ton
	Structural	3,098	ton
	Steel liner for Penstock	3,574	ton
4	Water stop		
	P.V.C.	12	m
5	Stone Masonry	96	cum
6	Boulder filling in Wire Crate	102	cum
7	Backfilling	4	cum
8	Stone Pitching	25	cum
9	Dewatering during construction	1,100	lumpsum
10	M-10 Back fill	132	cum
11	M-20 concrete lining in H.R.C	128	cum
12	Plain shotcrete (50 mm)	13	m ²
13	R.C.C Precast Legging	180	cum
14	Rock Bolts (25mm)	26	m
15	Consolidation Grouting	26	Bags
16	Drainage Holes	55	m
17	Contact Grouting	20	Bags

Detailed calculations for derivation of material rates, equipment rates & rates for civil work activities are provided as Annexure 3.

Chapter 14 – Bill of Quantities

14.1 Introduction

In order to arrive at an estimate for the Project Cost, the bill of quantities (BOQ) is to be determined for all the components of the project. The major cost heads for civil works are the excavation volumes, concreting volumes, quantity of steel required & other miscellaneous items.

The quantities for major items for the components are derived as follows:

14.2 Weir & Intake

Sl.No.	Item Work	Unit	Quantity
1	Excavation		
	a) in Soil	cum	605
	b) in Rock	cum	259
2	Fill work		
	Backfill	cum	124
3	Concrete		
	a) M:10	cum	36
	b) M:20	cum	258
	c)Concrete Blocks	cum	63
4	Steel		
	Reinforcement, Grade Fe415	MT	28
5	Wire Crates		
	Boulder Filling in wire crates	cum	126
6	Inverse Filter (Direct Cost)	cum	20
7	Rock anchors	m	29
8	Dewatering during construction	kwh	LS

14.3 Conveyance Channel

SNo.	Item Work	Unit	Quantity
1	Excavation		
	a) in Soil	cum	396
	b) in Rock	cum	170
2	Fill work		
	Backfill	cum	22
3	Concrete		
	a) M:10	cum	8
	b) M:20	cum	35.35
4	Steel		
	Reinforcement, Grade Fe415	MT	4
5	M-10 Backfill	cum	26

14.4 Desilting Tank

Sl.No.	Item Work	Unit	Quantity
1	Excavation		
	a) in Soil	cum	815
	b) in Rock	cum	349
2	Fill work		
	Backfill	cum	62
3	Concrete		
	a) M:10	cum	27
	b) M:20	cum	147
4	Steel		
	Reinforcement, Grade Fe415	MT	16
5	Masonry work		
	Stone masonry	cum	28

14.5 Head Race Channel (HRC)

SNo.	Item Work	Unit	Quantity
1	Open Excavation		
	a) in Soil	cum	54
	b) in Rock	cum	54
2	Channel Excavation	cum	1427
3	Concrete at Portals		
	a) M:20	cum	24
4	Steel at Portals		
	Reinforcement, Grade Fe415	MT	3
5	Rock Anchors	m	10
6	Masonry wall for Portal Bench	cum	48
7	M-20 Concrete Lining in H.R.T	cum	985
8	Drainage Holes (75 mm)	m	528
9	Rock bolts	m	643
10	Steel Supports	MT	21
12	R.C.C Precast Legging	cum	178
13	M-10 Backfill	cum	357
14	Consolidation Grouting	Bags	236
15	Contact Grouting	Bags	792

14.6 Forebay

Sl.No.	Item Work	Unit	Quantity
1	Excavation		
	a) in Soil	cum	1291
	b) in Rock	cum	553
2	Fill work		
	Backfill	cum	40
3	Concrete		
	a) M:10	cum	12
	b) M:20	cum	168.2
4	Steel		
	Reinforcement, Grade Fe415	MT	19
5	M-10 Backfill	cum	63

14.7 Penstock

S.No.	Item Work	Unit	Quantity
1	Excavation		
	a) in Soil	cum	5396
	b) in Rock	cum	5396
2	Concrete		
	a) M:10	cum	91
	b) M:20	cum	1946.86
3	Steel		
	Reinforcement, Grade Fe415	MT	214
4	Steel Liner	MT	146
5	Stone Masonry	cum	611

14.8 Powerhouse

Sl.No.	Item Work	Unit	Quantity
1	Excavation		
	a) in Soil	cum	1056
	b) in Rock	cum	1056
2	Concrete		
	a) M:10	cum	34
	b) M:20	cum	628
3	Steel		
	Reinforcement, Grade Fe415	MT	94
4	M-10 Backfilling	cum	28
5	Structural steel for roof truss	MT	19
6	Protection work	L.S	
7	Slope stabilization	L.S	
8	Stone masonry	m ²	188
9	Dewatering	L.S	

14.9 Switchyard Civil Works

SNo.	Item Work	Unit	Quantity
1	Excavation		
	a) in Soil	cum	2055
	b) in Rock	cum	881
2	Concrete		
	a) M:10	cum	7
	b) M:20	cum	100.98
3	Steel		
	Reinforcement, Grade Fe415	MT	11
4	Gravel Packing (L.S)	cum	72

14.10 Tailrace

SNo.	Item Work	Unit	Quantity
1	Excavation		
	a) in Soil	cum	691
	b) in Rock	cum	296
2	Fill work		
	Backfill	cum	46
3	Concrete		
	a) M:10	cum	10
	b) M:20	cum	56.97
4	Steel		
	Reinforcement, Grade Fe415	MT	6
5	M-10 Backfill	cum	57

Detailed calculations for derivation of Bill of Quantities & costs are provided as Annexure 4. It is expected that final bill of quantities (BOQ) for the project works shall be obtainable after detailed engineering is done & designs are finalized.

Chapter 15 – Project Cost

15.1 Estimation of Project Cost

The project cost for Pinyinyi SHP has been estimated here based on a detailed analysis of quantities associated with the components involved & the rates/ prices of the activities or commodities used in construction. Other costs such as development cost, land cost, financing costs are also added to arrive at a complete & comprehensive project cost estimate.

A. Preliminary cost for studies, surveys & planning

This cost head includes the cost incurred by the developer in the initial stages of the project. This includes the cost incurred for preliminary project studies such as site identification, initial data collection, data measurement, report preparation, hydrology, topography & geological surveys, permits & clearances & other initial overheads for rent, utilities & travel/transport. This cost is summarized in the table below.

Sr No	Item	Amount, USD Million
1	Survey & Investigation work	0.04
2	Geological and soil testing studies	0.03
3	Consultant fees for -	
	DFSR preparation, tender document preparation	0.04
	Detailed engineering & Construction drawings	0.06
4	Vehicles for site visits	0.02
5	Miscellaneous & overheads	0.10
6	Ecology, seismology, CDM & other studies	0.04
	Total	0.33

B. Land cost

Land cost has been estimated based on the size of the components, the land rates prevalent for government and private land and other miscellaneous costs involved in land acquisition.

S No	Description	L (m)	W (m)	Hectares
1	Weir and Intake	20	25	0.05
2	Shingle flushing	171	2	0.03
4	Conveyance Channel	35	3	0.01
5	H.R.C	1550	3	0.33
6	Forebay	15	6	0.01
7	Spill Channel	30	3	0.01
8	Approach road to powerhouse	2000	8	1.60
9	powerhouse & switchyard	60	15	0.09
10	Penstock	1019	5	0.51
11	Tailrace	60	3	0.02
12	Dumping grounds	100	90	0.90
14	Colony/ temporary storage/ housing	50	40	0.20
15	Transmission line	78000	8	62.40
	Totals			66.16

The land cost has been worked out in the following table.

S No	Item	Unit	Quantity	Rate, USD	USD
1	Total Private Land	Hectares	12.83	10,000	128,341
2	Total Govt Land	Hectares	53.33	7,500	399,946
3	Compensation for crops @ 35% of private land	35%			44,919
4	Solatorium charges @ 30% of cost of private land	30%			38,502
5	Legal charges @ 2% of total land cost	2%			10,566
6	Establishment charges @ 6.25%	6.25%			35,825
7	Labor & material for demarcation 0.25%	0.25%			1,321
	Total				659,420

C. Civil Works

This head includes the civil works cost for the weir, intake structure, gates, conveyance channel, desilting tank and head race Channel.

S.No	Description	Amount (USD)	Amount USD Million
1	Trench Weir+Intake+Shingle Flushing Duct	147,330	0.15
2	Conveyance Channel and Desilting Tank	103,204	0.10
3	H.R.C	700,000	0.70
		950534	0.95

J. Power house civil works

This head includes the civil works cost for the penstock, forebay, spill channel, powerhouse, tailrace & switchyard.

J.	Works	Amount, USD	Amount, USD. Million
J-1	Forebay & spill channel	98,264	0.10
J-2	Penstock	900,000	0.90
J-3	Power House	473,968	0.47
J-4	Switchyard	79,008	0.08
J-5	Tailrace channel	42,830	0.04
	Total	1,594,070	1.59

K. Buildings

This cost includes the cost for permanent and temporary buildings for workers residence, storage, guest house etc.

Sr No	Work	Area (sq m)	Rate, USD	Amount, USD
Permanent Buildings				
1	Building Cost	600	220	132,000
2	Water supply and sanitation	6%		7,920
3	Electric installation	7%		9,240
4	Development of site	2%		2,640
5	Colony roads	2%		2,640
6	Beautification	1%		1,320
	Subtotal			155,760
Temporary buildings				
1	Building Cost	800	110	88,000
2	Water supply and sanitation	6%		5,280
3	Electric installation	7%		6,160
	Subtotal			99,440

Sr No	Work	Area (sq m)	Rate, USD	Amount, USD
	Contingency		5%	12,760
		Total Building cost		267,960

M. Plantation

This heading includes cost of planting and maintaining trees as per the regulatory requirement.

S No.	Work	Estimated Quantities	Unit	Unit rate	Amount USD
1	Cost of plant saplings	3000	# of plants	3	9,000
2	Pit making cost	3000	# of pits	3	9,000
3	Cost of labor of gardening (3 #)	108	months	100	10,800
4	Cost of protection (barbed wire)	3000		2	6,000
			Total plantation		34,800

O. Miscellaneous

This head includes capital cost for services, their running and maintenance, and other miscellaneous items.

Sr No	Items		USD Million
1	Capital costs		0.03
2	Running and maintenance of service		0.03
3	Other items		0.01
	Total		0.07

P. Maintenance

Maintenance cost is taken as 2.0% of the cost of the following works.

Sr. No.	Item		USD Million
1	C - Works		0.02
2	J - Power plant civil works		0.03
3	K - Buildings		0.01
4	R - Communication		0.01
	Total		0.07

Q. Special T&P

This includes the cost for special tools and plants required for construction. This cost has been assumed as USD 50,000 over the construction period. 15% of this cost is assumed to be recovered after construction as recoveries.

R. Communication

This includes the cost of road network in the project area. Also includes cost of bridges and repair work required to existing roads.

Sr No	Item			USD Million
1	Up gradation of road			0.20
2	Cost of building roads			0.22
3	Bridges			0.35
	Total			0.77

X. Environment & Ecology

Sr No	Item			USD Million
1	Construction staff & labor management plan			0.006
2	Land and environment management plan -			
	Rehabilitation and resettlement			0.005
	Muck management plan			0.003
3	Air environment management plan			0.002
4	Management of flora and fauna			0.004
5	disaster management plan			0.002
6	Environment & ecological monitoring during project const.			0.002
	Total			0.024

Y. Losses on Stock

This head includes losses due to pilferage, wastage etc. This is estimated as 1.5% of C-Works, J – Powerhouse Civil Works, K- Buildings & R-Communication and the amount is USD 30,000.

Other Items of cost are estimated as follows:

II	Establishment			
S. No.	Items			USD Million
1	Provision of 0.5% of I-Works less B-Land	5%		0.03
III	T&P			
S. No.	Items			USD Million
1	1% of I-Works	1%		0.07
IV	Receipts and recoveries			
S. No.	Items			USD Million
1	Receipts and recoveries from Q-Special T&P			0.01
2	Buildings (15% of 50% of K-Buildings as recoverable)			0.02
	Total			0.13
V	Audits & Accounts			
S. No.	Items			USD Million
1	Audits & accounts at 0.5% of works	0.5%		0.03
	Total			0.03
VI	Capitalization of abatement of Land revenue			
S. No.	Items			USD Million
1	0.5% of solatium cost of private land	0.5%		0.03
	Total			0.19

S. Electromechanical Works & T. Transmission

The detailed scope & price estimation for the electromechanical package is given below:

Sr No	Item			USD Million
1	Model Test			-
2	Generating plant and equipment		LS	1.05
3	Transport & Insurance			0.20
4	[Spare]			-
5	Miscellaneous, spares, contingencies, t&p			0.001
	<i>Subtotal</i>			<i>1.25</i>
6	Establishment cost @ 6% of above	6%		0.08
	<i>Subtotal</i>			<i>1.33</i>
7	Audit and account charges @ 0.5%	0.50%		0.01
8	Taxes & duties			0.10
	Total			1.43
		USD per MW		754,048
T - Transmission				
Sr No	Item	USD/km	KM	Total, USD Million
1	Cost of transmission line including receiving station and other items	40000	78	3.12

Hydro-mechanical cost (gates, trash racks) is estimated to be around USD 168,763. Putting all these cost items together, we can arrive at the completion cost of the project. The completion cost of the project also requires us to estimate the costs such as financing charges and interest during construction (IDC), working capital requirement, etc. These are calculated through a detailed financial model.

Costs of the 33 kV Transmission line for 78 Km has already been covered by Rural Energy Agency (REA), thus this cost will be removed from the total project cost.

Thus, we can arrive at an estimate of the completed capital cost of the project. This is provided in the following table.

Completed Capital Cost of Project

S No	Item	Civil USD MM	E&M USD MM	Total USD MM	As a % of total
A	Direct Cost				
I	I - Works				
	A - Preliminary	0.385		0.385	4.9%
	B - Land	0.66		0.66	8.4%
	C - Intake civil works	1.56		1.56	19.9%
	J - Power plant civil work	1.43		1.43	18.3%
	H - Hydro-mechanical	0.17		0.17	2.2%
	K - Buildings	0.27		0.27	3.5%
	M - Plantation	0.03		0.03	0.4%
	O - Miscellaneous	0.07		0.07	0.9%
	P - Maintenance during construction	0.07		0.07	0.9%
	Q - Special Tools and Plants	0.05		0.05	0.6%
	R – Communication Bridges, Roads	0.77		0.77	9.8%
	S - Power Plant		1.35	1.35	17.2%
	T – Transmission survey and Population		0.36	0.36	4.6%
	X - Environment, Ecology and Afforestation	0.02		0.02	0.3%
	Y - Losses on stock	0.08		0.19	2.4%
	Total: I - Works	5.5	1.71	7.385	94.3%
II	Establishment	0.21	0.02	0.30	3.4%
III	Tools and Plants (T&P)	0.07	-	0.07	0.8%
IV	Receipts & Recoveries	(0.03)		(0.03)	-0.3%
	Total Direct Cost	6.055	1.73	7.785	98.8%
B.	Indirect Cost				
	Capitalization of abatement of land revenue	0.01		0.01	0.05%
	Audit and account charges	0.03	0.01	0.04	0.32%
	Total Indirect Cost	0.04	0.01	0.05	0.38%
	Total direct & indirect cost	6.085	1.75	7.835	100.0%

S No	Item	Civil	E&M	Total	As a %
	Total hard cost, USD Million			7.835	
	Hard Cost, USD MM/MW	3.043	0.875	3.918	
	Project Cost before IDC, Working Capital, Financing Charges			7.835	
	IDC & Financial Charges from Financial Model			0.255	
	Contingency (from FM)			0.26	
	Initial working capital & spares (From FM)			0.225	
	REPDF cost			0.15	
	Total project cost, USD MM			8.725	
	Total project cost, USD MM/ MW			4.363	

Thus, the total project cost is estimated to be USD **8.725 Million**. The cost per MW is estimated to be USD **4.363 Million/ MW**. This is within the accepted and expected range of cost for such a project in Africa.

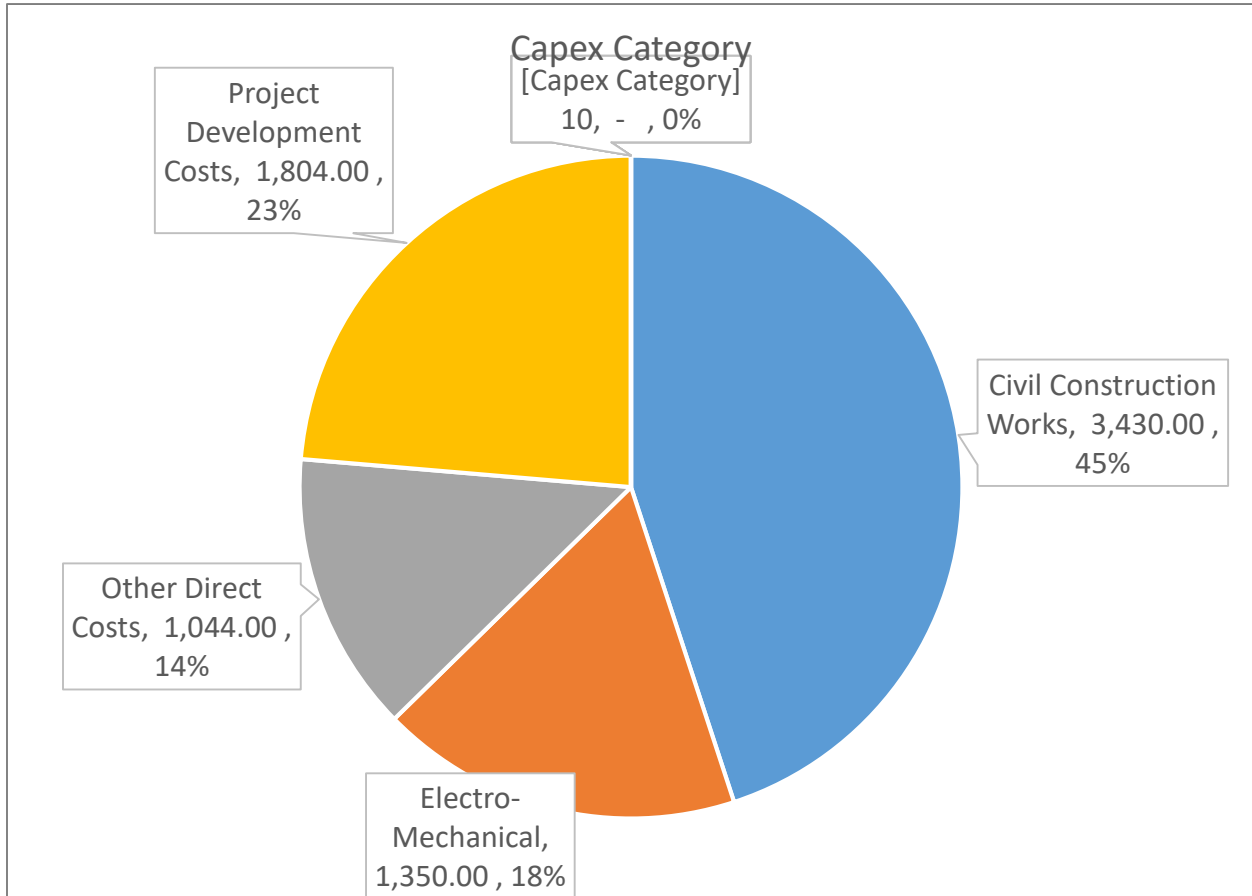
Chapter 16 – Financial Evaluation

16.1 Financial Model

The Excel spreadsheet named ‘*Pinyinyi SHP FM - Tanzania - Cresco 26032020*’ is a spreadsheet based Financial Model (the “Model” or “FM”) for the proposed Pinyinyi SHP Project in Tanzania (the “Project”). The FM provides financial projections for an assumed operation period of 20 years from the date of commissioning of the Project.

The Model replicates the financial implications of project finance, construction and operation under a BOO (‘Build-Own-Operate’) model. The FM contains projected financial statements and calculates the Internal Rate of Return (IRR) for the Developer & the financial parameters such as DSCR for the lender.

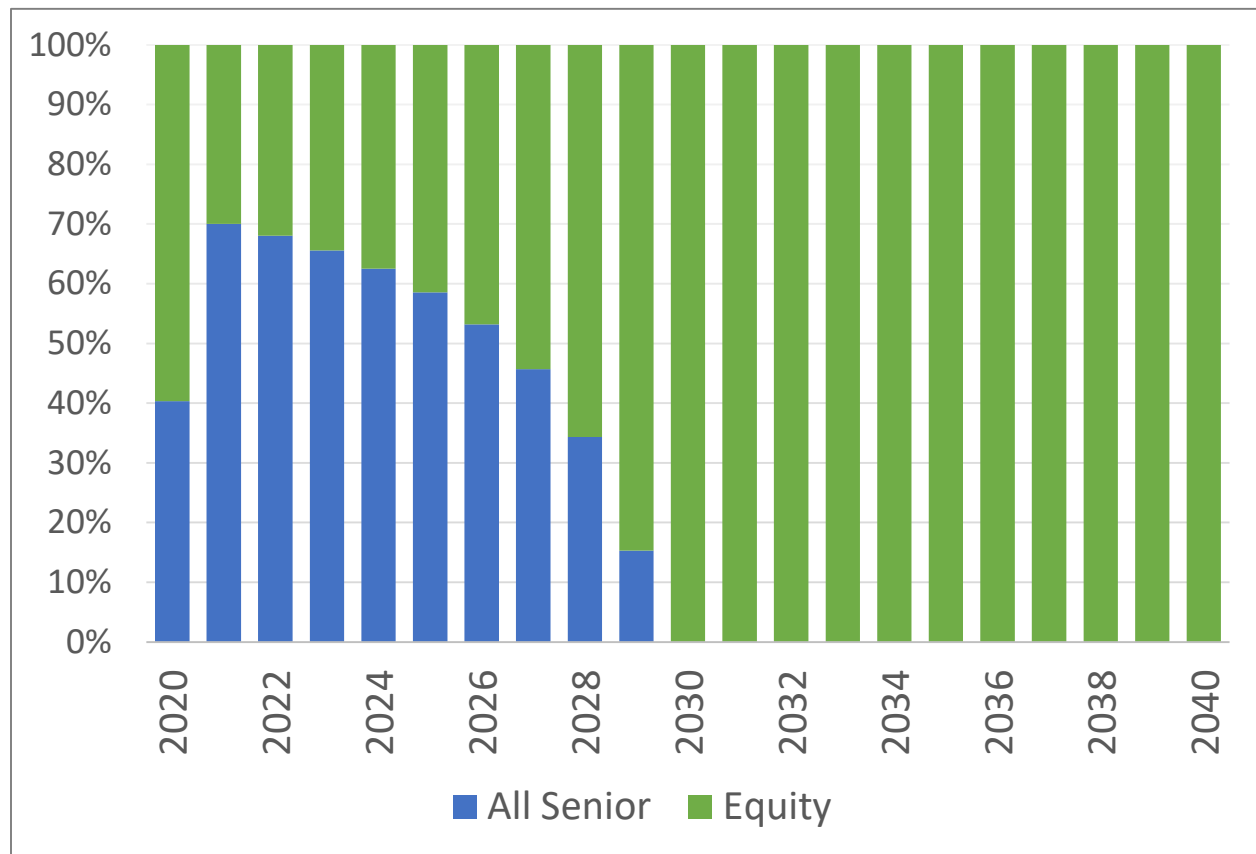
The model calculations are divided into two main parts: the construction period which is modeled on a monthly basis, and the operations period which is modeled on a quarterly basis. The model phases the construction expenditure over a period of 18 months.



The development expenditure as incurred is fully funded through equity, and is modelled as a single payment from the project to the shareholder at financial close.

Debt is included as a source of funds in the debt: equity ratio (70:30) and Debt drawdown is permitted during the construction period after financial closure.

Debt to Equity



The model covers an operational period of 20 years, calculating the electricity generation and revenue realization for the project. It accounts for the operations and maintenance (O&M) cost, interest and principal payment & tax payments to generate financial statements such as P&L Account, Cash Flow and Balance Sheets. Other calculations such as depreciation and amortization, working capital are also included for each quarter.

The financial returns to the developer are calculated in the financial model, together with the Debt Service Coverage Ratio, which can be found on the ‘Summary’ sheet.

The model identifies the critical variables that have a significant impact on the results of the model. The model conducts Sensitivity Analysis for these variables for a range of values and calculates their impact on financial indicators such as investor returns. The summary of results of the sensitivity analysis is shared in the “Summary.” Sheet.

The model operating procedure, the assumptions and the results of the financial model have been discussed below:

16.2 Financial Model: General

The Model is a Microsoft Excel Version 2010-compatible file consisting of 22 worksheets. The Model contains various macros. Please see ‘*Macros*’ section in this document for more details.

The model is based on the standard distinction between hard-coded inputs (in **blue ink** and grey background) and calculated values (in **black ink** and white background). Although the Assumptions worksheets contains a small number of calculations, most of the hard coded inputs are contained in this Input worksheet. The only hard coded values that are not project inputs used in the model are ‘constants’ (such as the number of months in a year), which are applied in the form of named ranges.

16.3 Financial Model: Set up

The model covers two distinct periods: a construction period modeled on a monthly basis (with inputs in the ‘*Capex*’ sheet), and an operating period, modeled on a quarterly basis. The construction period covers the period from February 2020 through July 2021, while the operating period covers 20 years from July 2021 through July 2041.

The Financial Model is not fully compatible with versions of Excel earlier than 2010, and it will automatically enable specific Excel functionality required for the model.

16.4 Financial model: Structure

The financial model is comprised of 22 worksheets, briefly described below.

Worksheet	Description
Cover	Cover page for ease of identification of a printed version of the model
Contents	Introduces the sheets and states the color conventions used in the model

Worksheet	Description
Model Logic	High level overview of the model workings
Change Log	Record of changes to the Model
Issues	Optional list of items to address within the Model
Welcome Page	Main Navigation tab for ease of use
Summary	Presents the key results, including summary of the Power Generation, Commercial and financial calculations. Calculates the Levelized cost of generation
AFS	Forecast financial statements, on an annualized basis
IFS	Forecast financial statements, on the timeline of the Model (monthly during construction and quarterly during operations)
Sensitivities	Sensitivity inputs and results
Integrity	Displays any Model errors
Timing + Macro	Project timing, macroeconomic and tax assumptions
Capex	Capital expenditure inputs
Funding	Funding inputs
Revenue+OPex	Generation, revenue and operating expense inputs
Scenarios	Scenario set-up and full results
Timing Calcs	Timing and macroeconomic calculations
Cons Calcs	Construction phase calculations
Funding Calcs	Funding & Returns calculations

Worksheet	Description
Rev+Ops Calcs	Operations, Revenues and Operating cost calculations
Tax + Dep Calcs	Calculates the Depreciation and Tax payments

Note – The above may not be in the same sequence as in the model.

16.5 Financial model: Macros

The Model contains various Macros. Macros need to be enabled for the model to open and run correctly, and Model users are directed to the User Manual in this regard.

16.6 Financial model: Checks

A number of checks have been incorporated in the financial model, which are collated in the Integrity sheet, and summarized at the top of each sheet.

16.7 Financial model: Assumptions

The assumptions used in the model have been summarized in this section. Assumptions are contained in the five “assumptions” sheets in the model.

I. Capacity Assumptions:

The capacity assumptions govern the project capacity and the plant availability. They are entered in cells G6 to G11. The capacity has been entered as 2.0 MW in cell G6. The other capacity assumptions are:

Installed Capacity	MW	2.0
Generation adjustment for hydrological variation	%	5%
Annual availability of plant	%	90.00%
Auxiliary consumption	%	0.50%
Transformation Losses	%	0.00%
Transmission losses to Interconnection point	%	0.00%

II. Capital Structure

It has been assumed that 30% of the project will be funded through equity and the remaining will be funded using debt.

Equity	30%
Senior Debt	70%

III. Senior Debt Assumptions

The Senior Debt / project finance will fund 70% of the project cost and is assumed to have a repayment tenor of 8.5 years. The assumptions for senior debt have been tabulated below:

Type		Local
Currency		US\$
Facility Amount	MM US\$	5.91
All-in fixed interest rate	% per annum	7.5%
Commitment fee	% per annum	0.00%
Upfront fee	%	0.67%
Tenor (post construction)	Years	8.5
Moratorium (post construction)	Years	-
Target minimum DSCR		1.30
DSRA funded upfront	MM US\$	0.5

The working capital loan is denominated in USD. The assumptions pertaining to the working capital loan are as follows:

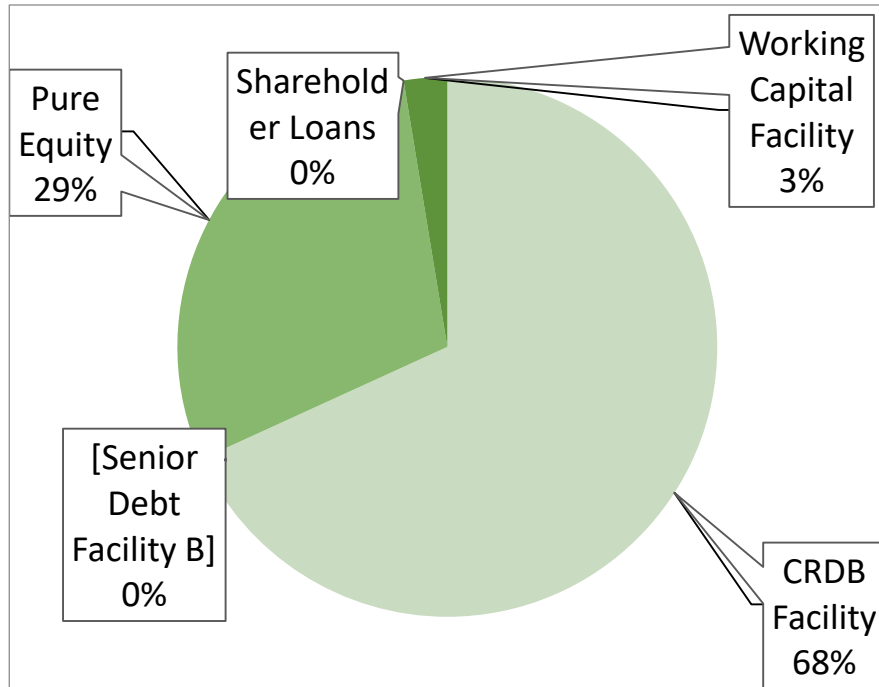
Facility Amount	MM TSH	1000
Interest rate (p.a.)	%	7.5%
Upfront fee	%	1.5%
Commitment fee	%	0%
Working capital Revenue side	Days	30
Working capital cost side	Days	60

IV. Source of Funds

The sources of funds for the project will be Equity and Senior Debt. The amount of debt, equity and the capital structure of the project are shown below:

Capital Structure (Source of Funds)	Amt. (US\$ MM)	Percentage
Total Senior Debt	6.275	70%
Equity investment by Developer	2.550	30%
Cost overrun funded by Private participant (Equity)	-	0%
Total Source of Funds	8.725	100%

Sources of Funds



V. Uses of funds

The usage of funds can broadly be classified into to two categories, as tabulated below:

Use of Funds	Amt. (US\$ MM)
Capital expenditure	7.685
Financing Costs	<u>1.040</u>
Total Use of funds	8.725

VI. Timelines (Dates)

The financial model has been set up as a monthly calculation during development and construction period and quarterly calculation during operation period. The financial results are also displayed

in annual format in the financial returns and the summary sheet. The basic inputs for calculating the dates are given below:

VII. Construction timeline Dates

Start of construction	29-Feb-21
End of construction	31-Jul-22
Commercial operations start date (COD)	01-Aug-22
End of operation	31-Jul-42

VIII. Timelines (Periods)

The timelines assumed in the model for the development, construction and development period are given below:

Timelines (Periods)			Total
Construction Period	months	18	18
Operation Period	years	20	

IX. Construction Cost Escalation

Costs have been assumed at end-2020 rates. Escalation of construction cost has already been included in the estimation of cost. The construction has been assumed to be completed in 18 months.

X. Capitalized Financial costs Amortization Assumptions

Tax amortization rate	5%
Book Amortization Rate	5%

XI. Depreciation Assumptions

The depreciation rates assumed are as follows:

Asset Class	% of Total Hard cost	Annual Tax Depreciation rate	Annual Book Depreciation Rate
Civil works	68.6%	4.00%	2.50%
Electro-mechanical	17.7%	6.67%	5.00%
Power lines & Other	13.7%	10.00%	6.67%
Total	100.00%		

XII. Power potential at 100% availability

Power potential at 100% availability	MU at 100% availability	Base PLF	PLF with overloading *
75% Dependable Year	14.77	90%	91%

*PLF = Plant load factor, has been taken from the Power Potential Chapter of the Detailed Feasibility Study Report (DFSR)

XIII. Other Miscellaneous assumptions

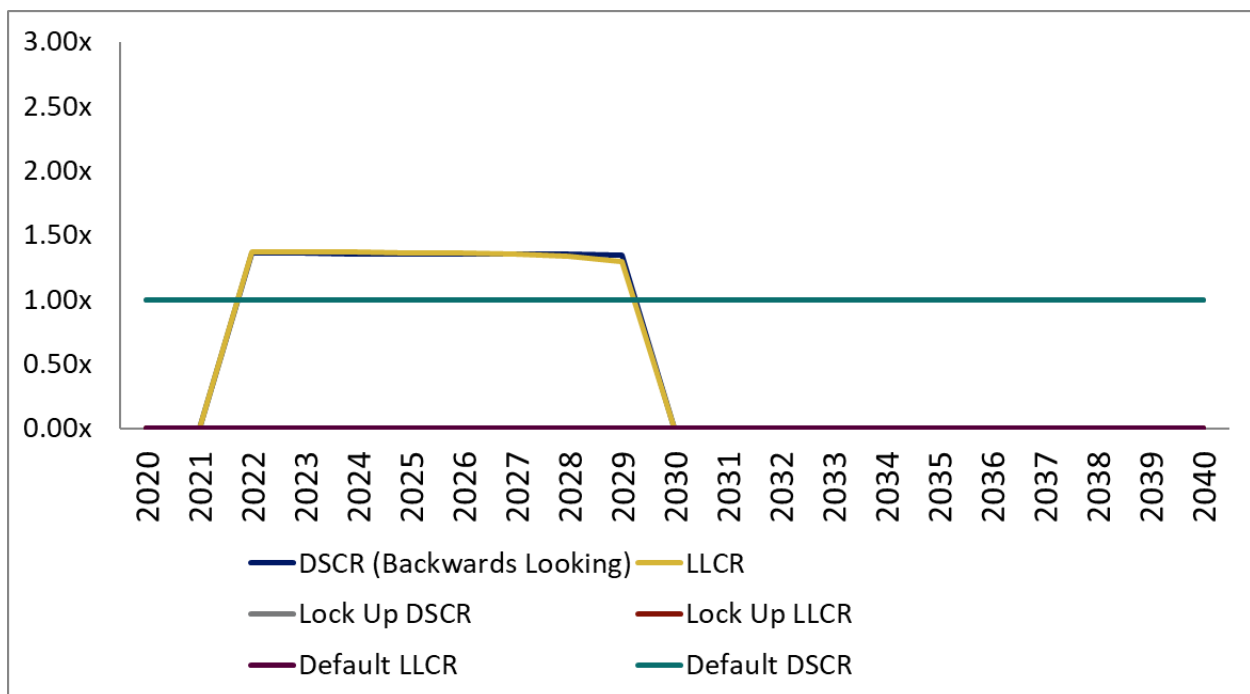
Rebate on prompt payment of bills	%	0%
Corporate Income tax rate	%	30%
Minimum Alternate Tax (MAT)	%	0%
Income tax holiday	years	0
Withholding Tax Rate	%	0%

16.8 Financial Model: Base case results

It is estimated that the project will export about 14.9 GWh of electricity per annum at a levelized generation cost of USD 8.95 cents/kWh.

The net revenue from electricity sales has been calculated to be around US\$ 1.33 MM in the first operational year. The project is expected to have an EBITDA of US\$ 1.26 MM and a PAT of US\$ 0.56 MM in the first operational year.

Coverage Vs Breach ratios



The revenues from the project will support an average DSCR of 1.35x and a minimum backward-looking DSCR of 1.35xx which is in the acceptable range. The project IRR is expected to be around 10.66% (nominal), whereas the private participant equity IRR would be around 15.77% (nominal) in the base case.

The real-terms payback time for the equity investment is expected to be ten (10) years from the start of project development activities. The Net Present Value (NPV) of the developer equity investment over the period is calculated to be US\$ 1.7 Million, based on a 4% discount rate. Thus, in the base case, the project shows promising returns to the equity investors.

16.9 Financial model: Sensitivity Analysis

The result of various sensitivity assessments are shown below:

Scenarios

Case	Equity Nominal IRR	Peak Funding	DSCR (12 month B/w)
1: Base Case	15.77%	8 666	1.35x
2: Capex up 5%	14.51%	9 062	1.29x
3: Capex up 10%	13.32%	9 474	1.23x
4: Capex up 15%	12.25%	9 893	1.18x
5: Generation down 5%	14.31%	8 654	1.27x
6: Generation down 10%	12.85%	8 643	1.20x
7: Capex down 5%	17.15%	8 269	1.41x
8: Capex down 10%	18.68%	7 873	1.48x
9: 3 Month Construction Delay	13.27%	9 367	1.24x
	0	0.00%	-
11: Maintenance Costs down 20%	16.11%	8 666	1.36x
12: Maintenance Costs up 10%	15.59%	8 666	1.34x
13: 6 month construction delay, 10% cost overrun	12.12%	9 692	1.20x
14: Capex up 10%, generation down 5%, opex up 5%	11.92%	9 463	1.16x
15: Generation reduces to DSCR of 1x	9.09%	8 613	1.02x

16.10 Financial model: Inferences from sensitivity analysis

The sensitivity analysis shows that the deviations in the cost of the project and the returns to investors are within an expected range. The project has the cushion to absorb the tested changes in cost, construction period, changes in hydrology, etc. It is observed that even when the cost of the project increases by 10%, the minimum backward-looking DSCR is at 1.23x. The Internal rate of return to the private participant falls to 13.32%.

A decrease in hydrology by 10% results in a minimum DSCR of 1.20x. The Internal rate of return to the private participant falls to 12.85%.

The sensitivity analysis checks for three cases of variation in capital cost: the base case, an increase of 10% in capital cost and an increase of 15% in capital cost. The results are satisfactory in all three cases, given the type of project.

The sensitivity analysis also checks for a case of a combination of 10% increased capex, a 5% reduction in generation and a 5% increase in opex. In this case, the minimum backward-looking DSCR is 1.16x and the nominal equity IRR 11.92%.

16.11 Financial model: Conclusion from the sensitivity analysis results

It can be seen from the financial model base case and the sensitivity analysis, that the project is economically viable, and able to achieve reasonable DSCRs and IRRs for this type of project, which support the investment case for both equity and debt.

Case	Equity Nominal IRR	Peak Funding	DSCR (12 month B/w)	Energy Demand (Op Year 1)	Energy Sales (Op Yr 1)
1: Base Case	15.77%	8,666	1.35x -		14,905
2: Capex up 5%	14.51%	9,062	1.29x -		14,905
3: Capex up 10%	13.32%	9,474	1.23x -		14,905
4: Capex up 15%	12.25%	9,893	1.18x -		14,905
5: Generation down 5%	14.31%	8,654	1.27x -		14,159
6: Generation down 10%	12.85%	8,643	1.20x -		13,414
7: Capex down 5%	17.15%	8,269	1.41x -		14,905
8: Capex down 10%	18.68%	7,873	1.48x -		14,905
9: 3 Month Construction Delay	13.27%	9,367	1.24x -		14,905
0	0.00%	-	0.00x -		-
11: Maintenance Costs down 20%	16.11%	8,666	1.36x -		14,905
12: Maintenance Costs up 10%	15.59%	8,666	1.34x -		14,905
13: 6 month construction delay, 10% cost overrun	12.12%	9,692	1.20x -		14,905
14: Capex up 10%, generation down 5%, opex up 5%	11.92%	9,463	1.16x -		14,159
15: Generation reduces to DSCR of 1x	9.09%	8,613	1.02x -		11,477

