Hydropower Investment Promotion Project (HIPP)

TSAGERI HPP

PRE-FEASIBILITY STUDY REPORT

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Hydroelectric Project Development
Pre-Feasibility Study

Tsageri Hydropower Project
Tskhenistskali River

Sponsored by USAID

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Definition of Technical Abbreviations

m^3/s-hrs	Cubic Meters per Second x Hours
CAPEX	Capital Expenditure
EIA	Environmental Impact Assessment
FDC	Flow Duration Curve
GEL	Georgian Lari
GIS	Geographic Information System
GoG	Government of Georgia
GW	Gigawatt
GWh	Gigawatt-hours
HIPP	Hydropower Investment Promotion Project (USAID-funded)
ha	Hectare
HP	Hydropower
HPP	Hydropower Plant/Hydropower Project
IFI	International Financial Institutions
kg/sec	Kilograms per Second
kV	Kilovolt
kW	Kilowatt (a measure of power)
kWh	Kilowatt-hour (a measure of energy)
masl	Meters above sea level
m^3/s	Cubic meters per second
MW	Megawatts
MWh	Megawatt-hours
SS	Substation
T	Metric Tonnes
TBM	Tunnel Boring Machine
US ¢	United States Cent (also USc)
US$	United States Dollar (also USD)
USAID	United States Agency for International Development

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

EXECUTIVE SUMMARY

TSAGERI HYDROPOWER PROJECT OVERVIEW

Project Description

The site of the proposed Tsageri HPP is north of the city of Tsageri in North Central Georgia. The site is located on the Tskhenistskali River. The plant capacity will be 110 MW with annual generation production of approximately 500 GWh.

The proposed Tsageri Hydropower Project involves the construction of an approximately 110 Megawatt (MW) run-of-river Hydropower Plant (HPP) on the Tskhenistskali River, in the Tsageri and Lentekhi Districts of western Georgia's Racha-Lechkhumi and Kvemo Svaneti Region.

The Tsageri HPP will be the downstream plant in a possible two-HPP cascade (Lentekhi and Tsageri HPPs) on the Tskhenistskali River. There would be significant operations advantages to a single developer if the decision were made to undertake the study, design, construction and operation of both the Tsageri HPP and Lentekhi HPP.

The Tsageri HPP site offers seasonally variable mean annual generation of approximately 500 GWh. The intake structure will provided for daily regulation of water to ensure maximum energy production during the peak demand periods of each day. The development of potential upstream seasonal storage reservoirs would improve annual energy production and reduce the seasonal variability of output.

Access to the site is excellent. The locations of both the powerhouse and diversion dam sites are adjacent to public roads that are being improved and paved during the summer of 2011. About 15 km of 220 kV transmission line would be constructed to connect the plant to the Lajanuri substation near Alpana, 15 km southeast of the Tsageri HPP site. The Tsageri-Lajanuri transmission line would generally be through agricultural areas with access roads in the vicinity (see Appendix 3, Location Map).

The Tsageri HPP development is expected to include a relatively low (27 m), concrete diversion dam, a 11,800-m-long, 6.0-m-diameter pressure tunnel, an excavated surge shaft, a steel lined penstock, and an underground (cavern) powerhouse.

Project cost and construction schedule

The currently estimated costs of the Tsageri HPP is USD 233.5 million or USD2,123/kW capacity installed. The project is expected to have a 1 year pre-construction period and 3 year construction period. The critical path of the project will be the construction of the 11.6 km tunnel.

Financial analysis

The project is expected to sell power during the 3 months of the year within Georgia (for the first ten years of the plant's operating life) and the remaining time into the Turkish competitive power market. Based on preliminary assessment, the TSAGERI HPP Project provides a good opportunity for investment and should be further investigated by potential investors. The expected IRR for the plant is approximately 17% based on parameters as shown in Appendix 12.

Conclusions/recommendations

According to preliminary assessments the plant offers a good potential opportunity to sell energy during three winter months inside Georgia, replacing (displacing) expensive thermal power, and export energy during the remainder of each year to take advantage of the seasonal differentials in power prices between Georgia and its neighboring countries.

Table 1: Project Significant Data

General	
Project name	**Tsageri Hydropower Project**
Project location (political)	**Tsageri and Lentekhi Districts of western Georgia's Racha-Lechkhumi and Kvemo Svaneti Region**
Nearest town or city	**Tsageri Town**
River name	**Tskhenistskali**
Watershed name	**Upper Tskheniskali**
Drainage area	**1,208 km^2**
Financial Estimates	
Estimated Construction Cost	**$233.5 Million**
Estimated Cost per kW capacity	**$2,123 /kWh**
Simple Pay Back Period	**10 years**
Pre-tax Internal Rate of Return-Assets	**6.7%**
Pre-tax Internal Rate of Return-Equity	**17.6%**
Hydrological Data	
Annual mean river flow at intake	**55 m^3/s**
Facility design discharge (m^3/s)	**90 m^3/s**
Annual average discharge through powerhouse	**47.7 m^3/s**
Preliminary design flood (100 yr return period)	**833 m^3/s**
Max. recorded flow (intra-day)	**650 m^3/s**
Intake Pond	
Highest regulated water level (HRL)	**670 m.a.s.l. with hinged crest gate up**
Minimum operating level (MOL)	**660 m.a.s.l.**
Highest flood water level (FWL)	**670.86 m.a.s.l. with hinged crest gates down**
Land needed for reservoir pond	**40 ha**
Empty pond elevation (upstream river bed)	**647 m.a.s.l**
Sanitary or environmental flow (assumed)	**1-10% of mean monthly flow for each month**
Total volume	**32 X 10^6 m^3**
Regulated volume	**22 X 10^6 m^3**
Headrace Tunnel Intake	
Sill level	**648 m.a.s.l.**
Bulkhead	**6.0 m x 6.0 m**
Trashrack	**7.0 m x 12.0 m**

Main Dam	
Crest elevation	**672 m.a.s.l.**
Length	**215 m**
Max height	**37 m above assumed bedrock foundation**
Bridge	**3 X 5.0 m X 25 m bridge at crest elevation**
Piers	**4 piers 6 m wide with sluice openings and to support access bridge over spillways.**
Sluice gates	**4 x 5.0 m wide x 7.0 m tall wheel gate with hydraulic operators**
Sluice openings	**4 x 2.0-m-wide x 3.0-m-high with 4 m x 6 m bell mouth inlet**
Volume of Dam	**83,800 m^3**
Spillway	
Crest elevation with hinged crest gate down	**666 m.a.s.l.**
Crest elevation with hinged crest gate up	**670 m.a.s.l.**
Hinged crest gates	**3 X 5.0 m X 25.0 m hydraulically operated**
Capacity at design flood level	**2,000 m^3/s**
Headrace Tunnel	
Headrace tunnel length	**11.5 km**
Diameter (circular or horseshoe)	**6.0 m minimum**
Slope	**0.2% minimum**
Water velocity, at design flow	**3.0 m/s**
Surge Shaft	
Diameter of Shaft	**6.0 m minimum**
Tunnel soffit elevation at surge shaft junction	**631.0 m.a.s.l.**
Assumed elevation of top of surge shaft	**710 m.a.s.l.**
Total shaft height (and basin if needed)	**79.0 m**
Pressure Tunnel	
Invert elevation at pressure tunnel junction	**625.0 m.a.s.l.**
Turbine center-line elevation	**500 m.a.s.l. for Francis unit**
Steel lined length	**180 m**
Steel lining diameter	**6.0 m**

Powerhouse	
Installed capacity	**110 MW**
Units and net capacity at high-voltage transformer terminals	**3 X 36.7 MW for Francis Turbines or 4 X 27.5 MW for Pelton Turbines**
Rated speed	**300 RPM for Francis Turbines or 150 RPM for Pelton Turbines**
Preliminary generator voltage	**15 KV or manufacturer's recommendation**
Rated generator capacity	**122 MVA at 0.90 Power Factor**
Size of powerhouse cavern	**20 m x70 m x 35 m for Francis Turbines or 25 m x 85 m x 35 m for Pelton Turbines**
Size of Transformer cavern	**20 m x18 m x 12 m**
Tailrace	
Tunnel length	**220 m**
Tunnel diameter (horseshoe)	**6.0 m**
Length of box culvert & discharge	**15 m**
Size of box culvert & discharge	**6.0 m X 6.0 m**
Estimated average tailwater elevation	**505 m.a.s.l.**
Transmission line	
Interconnection location	**Lajanuri HPP Substation near Alpana**
Distance to interconnection (km)	**15 km**
Voltage	**220 kV**
Power & Energy	
Gross head	**163.0 m**
Total head loss at rated discharge (5%)	**8.2 m**
Net head at rated discharge	**154.8 m**
Estimated average annual generation	**500 GWh**
Nominal installed capacity	**110 MW**
Preliminary annual plant factor (also called CF)	**53%**
Construction Period	
Conceptual design, feasibility studies & EIA	**1 year**
Engineering, procurement and construction	**3 years**
Ongoing environmental monitoring	**Some studies and data collection will extend throughout construction.**
Environmental	
Critical environmental receptors	**Racha-Lechkhumi and Kvemo Svaneti Planned Protected Area**

Figure 1: Georgian Project Location Map

1.0 GENERAL INTRODUCTION TO THE PROJECT

1.1 DESCRIPTION OF THE DEVELOPMENT AREA

The proposed Tsageri Hydropower Project involves the construction of an approximately 110 Megawatt (MW) run-of-river HPP on the Tskhenistskali River, in the Tsageri and Lentekhi Districts of western Georgia's Racha-Lechkhumi and Kvemo Svaneti Region. The approximate location is shown on the Georgian Project Location Map above. The Tsageri powerhouse will be approximately 1 km north of the town of Tsageri, with the diversion weir (dam) approximately 11.8 km upriver from the powerhouse.

The Town of Tsageri is the administrative center of the Tsageri District. The district population is about 16,515 people. The distance from Tbilisi to administrative center of Tsageri District is about 273 km.

The total area of district land equals 756 km^2. The largest part of Tsageri District is a mountainous area and the economy heavily relies on agriculture. The main economic activities of the region are potato growing and animal husbandry. Vineyards are also cultivated in some areas, especially in the lowlands near the town of Tsageri.

Infrastructure of the region is developed: there are highways and high voltage transmission lines at 35 and 110 kV. The towns of Tsageri and Lentekhi are connected by a rehabilitated road, which is scheduled for completion in mid-2011. These communities will also have stable water supply following completion of an ongoing project. The ongoing rehabilitation of water and sewage systems is being implemented by Georgia's Ministry of Regional Development and Infrastructure and Municipal Development Fund.

The landscape of the region is dominated by mountains that are separated by deep gorges. The average inclination of slopes is about 35^0-45^0. Forests occupy considerable areas of the territory. Mountain slopes are covered by mixed hardwoods and coniferous forests, with mountain meadows, rocky peaks, and glaciers above the tree line.

The region is culturally rich represented by many old churches, monasteries and other cultural relics. The region is also rich in minerals (arsenic, lead, zinc, granite etc) and mineral waters, but these minerals are generally not currently being exploited (mined and processed) to their potential.

Table 2: Natural Resources in Tsageri District

Name	Location	Amount in tones
Copper & Zinc	Village Zuluri	Is not estimated
Construction gravel	Tsageri, Lashitchala	10, 238
Limestone	Villages: Alpana, Robeli	9, 089
Agate	Village Zubi	1, 001

Source: Diagnostic Report of Tsageri Municipality; CARE Georgia; 2010

Racha-Lechkhumi and Kvemo Svaneti Planned Protected Areas are located on the southern slope of main watershed of the Caucasus range, in Lentekhi, Tsageri, Ambrolauri and Oni Districts at 500-4600 m above sea level. Refer to Cultural and Recreational Resources in Baseline Environmental Data in Section 6.1 for more information.

Table 3: Development Area Significant Data

Project Location (Political)	**Tsageri District of north-western Georgia's Racha-Lechkhumi and Kvemo Svaneti Region.**
Political Subdivisions	**Tsageri and Lentekhi Districts ***
Area Population	**16,515**
Nearest Town or City	**Tsageri**
River Name	**Tskhenistskali**
Watershed Name	**Upper Tskhenistskali**
Economic Activity in the Area	**primarily agriculture**
Special Natural Resources	**Water (commercial Bottled), timber, minerals (arsenic, lead, zinc, granite etc) and mineral waters**
Special Cultural Resources	**Churches, monasteries and historic defense towers**
Critical Environmental Receptors	**Racha-Lechkhumi and Kvemo Svaneti Planned Protected Areas**

* Although the project is located in both Districts, this report addresses the Tsageri District impacts. Lentekhi District impacts are addressed in detail in the Pre-Feasibility Study for the Lentekhi HPP.

1.2 DESCRIPTION OF THE LOCAL ELECTRIC POWER SYSTEM

The current transmission and HV distribution system in the Tsageri project area is 35 kV and 110 kV. The 220 kV network interconnection for the Tsageri HPP would be at Lajanuri HPP Substation near the town of Alpana, 15 km southeast of the Tsageri HPP powerhouse location.

The distribution lines and all of the 35 kV lines in the area are owned and operated by Energo-Pro, the licensed distribution utility serving most of Georgia outside Tbilisi. Energo-Pro also owns the Lajanuri HPP and a 110 kV line from the Lajanuri Substation to the Jakhunderi SS, along the Tskhenistskali River east of Lentekhi.

A single-circuit 220-kV line, property of the government-owned Georgian State Electrosystem (GSE), connects the Lajanuri HPP Substation to the Tskaltubo Substation west of Kutaisi (See Appendix 3, Location Map).

2.0 CLIMATE AND HYDROLOGY

In order to establish a comparison for environmental evaluation of the Tsageri HPP a set of baseline environmental conditions have to be identified. International practice today uses the baseline data to address changes that would occur during project construction and operations. In this manner the project can be viewed and assessed in an acceptable manner. Section 2 provides general baseline conditions for a range of environmental and site criteria (receptors). Section 6.2 addresses the Affected Environment, and Appendix 10 presents a series of tables that address the expected range of impacts to these receptors and recommendations for mitigation procedures and plans that are considered standard practice today.

2.1 CLIMATE: GENERAL DESCRIPTION

Much of western Georgia lies within the northern periphery of the humid subtropical zone with annual precipitation ranging from 1,000–4,000 mm (39.4–157.5 in). The precipitation tends to be seasonal, with winter snowfall and spring rains followed by drier months with sporadic rain. This rainfall can be particularly heavy during the autumn months. The climate of the region varies significantly with elevation and while much of the lowland areas of western Georgia are relatively warm throughout the year, the foothills and mountainous areas (including both the Greater and Lesser Caucasus Mountains) experience cool, wet summers and snowy winters (snow cover often exceeds 2 meters in many regions). Appendix 6 displays Annual Precipitation Map for the Tsageri HPP watershed region.

<u>Air Quality:</u> The monitoring of the air pollution is not carried out in Racha-Lechkhumi and Kvemo Svaneti Region. Only available data are those of stationary sources provided by the industry sector to the Ministry of Environment Protection of Georgia. According to the data emissions from the stationary sources are insignificant. (***<u>Source:</u>*** Caucasus Regional Environmental Center (REC)). During construction air quality is a receptor of importance and is included in the baseline section for this reason.

2.2 HYDROLOGY:

Table 4: Hydrology Significant Data

Records available	**Daily flow measurements for 39 years from the Department of Hydrometeorology.**
Method of analysis	**Monthly and annual flow-duration curves**
Drainage area at gauge	**1,450 km^2**
Drainage area at intake	**1,208 km^2**
Adjustment factor	**0.8331**
Maximum plant discharge	**90 m^3/s**
Minimum plant discharge	**10-12 m^3/s**
Stream flow for power generation	**Based on combined Flow Duration analysis and average daily discharge energy analysis. Expected range of Discharge 10 – 90 m^3/s. Reasonable Potential of approximately 500 GWh/year**
Flood flows	**Average Annual Flood (2.33 yr return period) = 300 m^3/s**
Highest recorded flow	**650 m^3/s (1939)**
Calculated 100 year flood	**833 m^3/s**
Recommended additional data collection and study recommendations for feasibility and design	**Stream flow gauging at various critical locations in the basin as well as at the Tsageri HPP intake; meteorology stations for air temperature, precipitation, Barometric Pressure, Relative Humidity, Wind speed and direction, Solar insulation, and snow depth.** **These stream locations would also be used for other monitoring of suspended and bedload sediments, water quality parameters, water temperature, fish, etc.**

2.2.1 Catchment Description

The Tskhenistskali River is 176 km long and drains an area of 2,120 km^2. Most of the drainage area is dominated by mountains that are separated by deep gorges. The average inclination of slopes is about 35^0-45^0. Mountain slopes are covered by mixed hardwoods and coniferous forests, with mountain meadows, rocky peaks, and glaciers above the tree line. A small percentage of the drainage area is occupied with agriculture where mild slopes or level topography allow. Elevations in the Tsageri HPP watershed catchment vary from approximately 4500 Meters to 500 Meters. At the Tsageri HPP diversion site the watershed area is 1208 km^2. Appendix 4 is the Watershed Map that displays the watershed that contributes to the Tsageri HPP proposed operations.

2.2.2 Surface Water Resource:

The rivers in Georgia drain into two main drainage basins: the western rivers drain into the Black Sea, and the eastern rivers drain into the Caspian Sea. Georgia is abundantly rich in water resources. The amount of water discharged is approximately 820,000 metric tons per km which is 2.5 times the world average. About 78 per cent of water resources are concentrated on the western area and only 22 per cent in the eastern area. The Tsageri HPP area is in the Western Black Sea Drainage Basin, Tskhenistskali River Upper portion. The country's water stock is about 56.5 km^3 per year. In Georgia, approximately 67 per cent of water resources are surface waters (Ref: Ubilava M., "Water Management in South Caucasus", Water Resources in the South Europe and Central Asia Region (2003)). The Rioni River is the largest tributary to the Black Sea in Georgia, draining approximately 20% of the country. Additional contributions to the Black Sea come from smaller rivers such as (moving southerly) the Enguri, Kodori, Supsa and Cholokhi. There are approximately 26,000 rivers in the country with total length of 59,000 km and about 860 lakes and reservoirs with total area of 170 km2. Approximately 93% of all rivers are less than 10 km long. The longest rivers of the country are: Alazani – 390 km (basin area – 12,000 km^2), Kura – 351 km (21,100 km^2), Rioni – 333 km (13,400 km^2) where Tsageri HPP is located, and Enguri – 206 km (basin area – 4,100 km^2). See Appendix 4, which is the Watershed Map. The Tsageri HPP is in the Western Black Sea Drainage Basin, Tskhenistskali River Upper portion, within the Rioni River watershed.

2.2.3 Upper Tskhenistskali River:

The river's upper course flows through a deep canyon with many rapids and waterfalls; the lower course crosses the Colchis lowlands. The river is fed by mixed sources; rain, snowmelt, rain on snow, glacial and groundwater contributions with rain predominating. Table 4 displays Tsageri HPP intake area discharge characteristics. The flow regime is characterized by high flows in spring and summer seasons; autumn experiences rising discharge levels as rain begins (until it turns to snow)' and relatively stable low flow during the winter. About 70% of the annual discharge occurs in spring and summer, 20% in autumn and 10% in winter. This pattern would change somewhat if seasonal storage was constructed upstream of the project to reserve excess flows during spring and summer to be discharged during the low flow periods.

The nearest stream flow gauging station is the Rtskhmeluri Gauge approximately 10 km downstream from the HPP intake location. The gauge has a drainage area of 1450 km^2. The gauge data used for this pre-feasibility analysis included the calendar year periods: 1935-1937, 1939-1941, and 1959-1990. Interim missing data for shorter than a year were supplemented by average monthly daily discharge calculated from the actual period of record. A drainage basin adjustment of 0.883 (1208 km^2/1450 km^2) was used to adjust flow record to the Tsageri HPP intake location. Appendix 2 includes monthly and annual flow duration curves.

Table 5: Tsageri HPP Intake Vicinity Characteristic Discharge Information (m^3/sec)

Annual average flow (m^3/sec)	**56.7**
Maximum average daily flow of record (m^3/sec)	**423**
Minimum average daily flow of record (m^3/sec)	**2.2**
Average monthly discharge during seasonal runoff period (April, May, June, July August, September) (m^3/sec)	**85.03**
Average monthly discharge during winter Season (Oct – March) (m^3/sec)	**27.54**
Average discharge during Georgian winter electric demand period (Dec-Feb) (m^3/sec)	**20.77**
Highest 30 day average discharge (m^3/sec)	**287.9**
Lowest 30 day average discharge (m^3/sec)	**3.61**
Assumed river discharge reserved for environmental/sanitary/ and other beneficial natural channel functions and values *	**1-10% of average monthly discharge, for each month**

* This percentage range is a conservative average. Examination of the immediate tributary flows into the Tskhenistskali River between the diversion dam and the powerhouse suggest that for several if not most of the months of the year reserved flows for in-stream environmental and sanitary requirements may not be required. It is recommended that this issue be included as part of detailed feasibility studies in so far as the amount of energy potential to gained if reserves are not required could be significant (on the order of 5% of average annual generation).

2.2.4 Sediments, Watershed Characteristics, and River Discharge

The upper reaches of the Tskhenistskali River upstream of the Tsageri HPP location carries a very high concentration of suspended sediment and moves a large volume of bed load sediment. The watershed is a steep-sloped generating a high-velocity surface runoff and river velocities.. During high flow periods large volumes of suspended sediment turn the river a grayish brown color. The erosion of river banks and valley slopes also contributes to very large bed load movement of coarse sediment, large rocks and debris. Table 6 presents monthly and annual sediment discharge in the Tskhenistskali River at Tsageri Gauge location. The table presents sediment loads that clearly support a significant and long term operations challenge for the Tsageri HPP and the requirements to address sediment management during detailed feasibility design.

Section 6.2 and Appendix 10 address possible mitigation measures for sediment management during construction and operations. It is important to note that the Tskhenistskali River watershed is a primary sediment delivery system to the Rioni River and hence to the Black Sea coast near Poti, Georgia. This sediment volume is critical to the Black Sea coastal environment in that is contributes to maintaining a quasi equilibrium sediment budget that helps minimize beach erosion down drift of the Rioni River mouth.

Table 6: Tskhenistskali River at Tsageri Gauge Location Sediment Load Data

Record Years	Average Monthly Discharge of Sediment kg/sec												Average Monthly Discharge	Annual Sediment Discharge 1000T
	01	02	03	04	05	06	07	08	09	10	11	12		
1976	0.90	0.46	4.0	50.0	360.0	210.0	110.0	33.0	12.0	8.8	2.9	2.0	66.0	2100.0
1977	0.83	1.1	4.8	36.0	150.0	200.0	50.0	1500.0	140.0	190.0	28.0	1.5	190.0	6000.0
1978	2.1	6.5	24.0	110.0	860.0	800.0	280.0	420.0	46.0	52.0	9.0	1.4	220.0	7000.0
1979	6.4	5.0	7.1	120.0	580.0	120.0	100.0	28.0	24.0	9.5	110.0	7.3	93.0	2900.0
1980	1.6	0.92	10.0	140.0	350.0	70.0	37.0	54.0	55.0	73.0	14.0	2.4	67.0	2100.0
Average	0.93	1.4	3.8	55.0	190.0	120.0	120.0	130.0	27.0	23.0	8.4	3.0	56.0	1800.0
Maximum	6.4	8.0	24.0	140.0	860.0	800.0	450.0	1500.0	140.0	190.0	110.0	32.0	220.0	7000.0
Minimum	0.05	0.077	0.11	2.1	16.0	15.0	11.0	3.9	1.5	0.51	0.018	0.047	11.0	350.0

Note: This data is unpublished and provided by a consultant to the project team. It is presumed that the data was collected and originally processed by the predecessor agency to Hydromet, (The National Environmental Agency, Dept of Hydrometeorology, Government of Georgia).

2.2.5 Meteorological Conditions (Air Temperature, Relative Humidity, and Wind Speed)

The Racha-Lechkhumi and Kvemo Svaneti Region is characterized by a subtropical climate. Precipitation and air temperature changes with the increase of elevation. In the lower elevation portion of the region (town of Tsageri, 474 meter above sea level) mean annual air temperature is 11.4^{0}C , in January the mean is 0^{0}C, in August the mean is 22^{0}C, recorded minimum temperature is minus 41^{0}C. Average annual precipitation rate for the town of Tsageri is 1,235 mm; maximum precipitation rate occurs in autumn, minimum in summer. At highest altitudes air temperature decreases, while precipitation increases and maximum annual precipitation can exceed 2,000 mm in the highest elevations of the Svaneti Region where the Tsageri HPP watershed is located.

For the analysis of the climatology of the project area, information from meteorological stations located in the town of Tsageri and village of Lailashi were used. See Appendix 6 for the Annual Precipitation Map, which shows the meteorological station locations.

Table 7 displays monthly values and annual mean values of climatology data.

Further data collection and analysis has identified a discrepancy in Ministry provided Meteorological Data. There is a significant difference in the magnitude of monthly average rainfall included in Table 7 that does not match well the distributed rainfall data that appears in Appendix 6. At this level of analysis we are identifying the discrepancy so that the Developer's Engineering Team can research this data further and decide which is more appropriate or how to adjust one set to match the other.

Table 7: Climate Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	
Data Type	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**mean**	**Annual Totals**
Average Monthly Air Temperature in °C	-1.4	-0.2	3.2	8.8	14	16.7	19	19.6	16	11.5	6	1.3	10	
Lowest Average monthly Air Temperature in °C	-4	-3.5	-0.6	4.9	9	12.3	15	15.4	12	7.2	2.3	-1.4	6	
Lowest Air Temperature in °C	-26	-22	-15	-5	0	5	8	7	1	-7	-20	-24	-26	-26
Highest Average Monthly Air Temperature in °C	2.6	4.5	8.2	14.4	19	22.4	25	25.2	22	16.9	11	5.4	15	15
Highest Monthly Air Temperature in °C	17	22	31	34	36	37	39	40	41	33	28	19	41	31
Average Relative Humidity in %	84	82	77	72	72	74	75	75	78	83	80	84	78	78
Average Monthly Precipitation in mm	99	103	101	105	109	110	93	84	106	116	101	108	103	1235
Average Monthly Wind Speed in meters/sec.	0.6	0.7	1.1	1.4	1.3	1.2	1.2	1.1	1	0.8	0.7	0.5	1	

Source: Lajanuri HPP Environmental Impact Assessment Report (approved by the Ministry of Environment) reportedly from Meteorological Station Located in Lailashi village and town of Tsageri

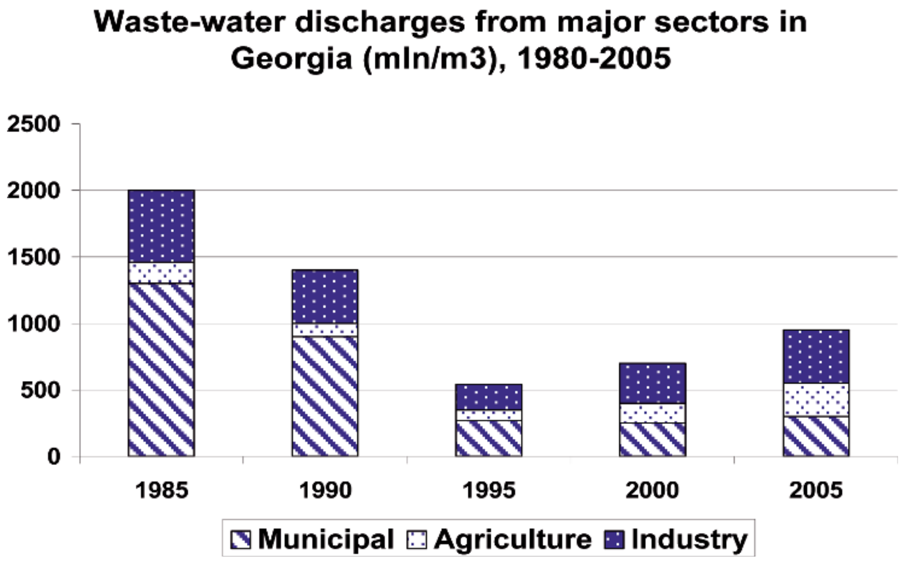
2.3 WATER QUALITY

Water Quality is a key environmental receptor and is a basic measure for assessing impacts from construction and operations. Water supply quality in the country is at a fair level, and a safe drinking water supply is the key component of the general objective to ensure the environmental safety and health of the people of Georgia. Poorly maintained and non-functional wastewater treatment facilities in urban areas and septic systems and non-treated municipal, agricultural and industrial discharges to rivers in most parts of the country present major challenges to overall water. (Ref: Betsiashvili M. and Ubilava, M. "Water Quality and Wastewater Treatment Systems in Georgia", 2009).

Water quality is seriously impaired by the dumping of untreated municipal, industrial, medical and agricultural wastes including along the Upper Tskhenistskali River Basin. The average amount of pollutants exceeds the established norms by 2 to 9 times and often represents a substantial threat to human health.

Figure 2 presents wastewater discharges from major sectors in Georgia in millions of cubic meters

Figure 2: Waste-water discharges



Ref: "Caucasus Environmental Outlook" Report of the Ministry of Environment and Natural Resources Protection of Georgia, 2005

After the break-up of the Soviet Union, contamination of surface waters in Georgia decreased, due to the major decrease of industrial production and subsequent wastewater discharges. This could have resulted in the temporary improvement of water quality. However, this is off-set by the fact that the majority of wastewater treatment facilities ceased to function or work at very low levels of efficiency. This lead to (and continues today) discharge of larger quantities of untreated wastewater directly into surface water bodies.

Field data for surface water quality in Georgia and the Tsageri HPP watershed is extremely limited. The water quality in Georgia is collected by the Environmental Baseline Monitoring Center of the State Department of Hydrometeorology (Hydromet). According to the Hydromet, 131 sampling points are chosen in Georgia for baseline water quality monitoring in the rivers and reservoirs. Due to the lack of funding, only 26 points are monitored at regular basis (i.e., samples are taken and analyzed each month), another 26 at irregular basis (i.e., samples are taken and analyzed 2 or 3 times per year), and the remaining 70 points are not monitored at this time. The infrequency of monitoring and questions about quality control during sample collection and analysis are of concern compared to international norms. Therefore, baseline water quality data should be included in any Lentekhi feasibility analysis to address water quality upstream of the HPP intake, in the bypass section of the river and in the river below where the tailrace merges with the river.

2.4 WATER WITHDRAWALS

Upstream of the planned HPP the Tskhenistskali River is used for timber transportation and watermill operation purposes.

Farther downstream the Tskhenistskali River is used for:

1) irrigation purposes (downstream from the planned powerhouse, where the river leaves the mountainous area, 8 irrigation canals are fed from the Tskhenistskali River, and irrigate approximately 16,500 ha).

2) part of the Tskhenistskali River is diverted to the Lajanuri River for operating the Lajanuri Hydro. The Lajanuri reservoir is located in Tsageri District. This reservoir feeds a hydropower plant that discharges to the Rioni River. The volume of the reservoir was 25.0 million m^3 overall, designed useful volume was 17.0 million m^3 and surface area is 1.6 km^2, although the reservoir is currently nearly filled with silt. The Lajanuri reservoir operates the Lajanuri HPP with installed capacity of 112 MW; the reservoir entered into operation in 1960.

While proposed run of river operations should have no impact on downstream water withdrawal users this water requirement needs to be verified as part of follow up feasibility analysis.

2.5 FLOODING AND FLOOD RISK

Flooding is characteristic in the Project watershed in the Project watershed and in the project vicinity. Steep slopes, deep gorges, significant areas of exposed rock and impervious surfaces, glacial runoff enhanced by warm temperatures and intense precipitation all contribute to major flooding risk for the project and the local environment. Topography, land cover, and intense precipitation periods contribute to rapid watershed runoff and river discharge response.

The Upper Tskhenistskali River Basin regularly sees heavy rains and snow melt, often resulting in flash floods and destruction of roads, bridges, houses, barns, crops and winter food storage. At times this creates a danger to the lives of people and livestock. The Government of Georgia (GoG) has rebuilt bridges and roads in the region several times after major floods. Frequent floods have a significant negative effect on the local villages through loss of agricultural lands, damage of infrastructure and homes. According to some studies, due to the intensification of landslides and floods the population of the Lentekhi District has decreased since 1986 by 40% (**Source:** Second National Communication of Georgia under UNFCCC). In conversations with local residents, they report that landslides have occurred at the upstream villages along the Tskhenistskali River and destroyed surrounding villages of Chikhareshi and Mele about 15-20 years ago. These villages are about 15-20 km above headwork site of the potential Lentekhi HPP site. The Kheledula River joins the Tskhenistskali River in Lentekhi and is prone to flash floods throughout the year.

During floods the movements of destructive mudflows and landslides have been observed. Mudflow caused by rains on May 11, 2005 damaged and destroyed four villages in the Martvili District (downstream of Tsageri town site). Overbank flooding in the Tsageri Town onto the river floodplain caused the destruction of the bridge which connected two villages on both sides of the river. The flash floods also increase the probability for landslides, which endanger people and often block roads, isolating people in the region. The steep nature of the slopes and erodible surface material along the river basin are the major factors for causing the landslides. Also, flood waters infiltrate the subsurface of the slopes creating soil instability and destroy the toe of the slopes, perpetuating the landslides.

Flood frequency analysis had been performed during the Soviet Era and was published in (Ref in Russian) "Surface Water Resources Transcaucasia and Dagestan, Volume 9 Edition 1, West Caucasia", by Administration of Hydrometeorologic Service of the Georgian SSR, 1969. Table 7 displays flood discharge as a function of frequency for the Naghomari (now Rtskhmeluri , and sometimes referred to as Tsageri) Gauging Station. A drainage basin adjustment of 0.8331 was used to adjust these values to the proposed location of the Tsageri HPP intake.

Table 8: Flood Frequency

Flood Frequency (Return Period in Years) *	Discharge in m^3/s
4	312
10	439
20	547
50	699
100	833
200	1368 *
500	2844 *
1000	5300 *

* These values are initial extrapolated values for peak flood discharge for these flood frequencies (expressed as return period). Further analysis is required during detailed feasibility design to refine these values of peak discharge for use in HPP design and to map floodplains, and assess impacts to the affected environment.

2.6 BIODIVERSITY

2.6.1 Flora

Flora is considered a primary receptor for environmental baseline comparison. The landscape of the HPP possible location area is dominated by mountains that are separated by deep gorges. The average inclination of slopes is about 35^0-45^0. Forests occupy considerable areas of the territory. Mountain slopes are covered by mixed hardwood and coniferous forests, with mountain meadows, rocky peaks, and glaciers above the tree line. Forests are characterized by dominance of Alder (*Alnus Barbata*), Oak (*Quercus iberica, Q. hartwissiana*), Chesnut (*Castanea sativa*), Hornbeam (*Carpinus caucasicus*), and Beech (*Fagus orientalis*), forest are rich with Colchic evergreen species. Within the deciduous forests there is interspersed Pine (*Pinus Kochiana*). The forest understory consists of Cherry-Laurel (*Laurocerasus officinalis*), Pontic Rhododendron (*Rhododendron ponticum*), Boxtree (*Buxus colchica*). Lianas include Green Brier (*Smilax excelsa*) and Ivy (*Hedera sp.*).

2.6.2 Fauna

Fauna is considered a primary receptor for environmental baseline comparison. Forests provide good feeding ground for various fauna species. Most common mammals in the Tsageri HPP area are: Common Otter (*Lutra lutra*), Lynx (*Lynx lynx*) and Wild Boar (*Sus scrofa*). According to local residents wolf and brown bear inhabit the area in autumn and winter; otter occurs in the region each year from July through October.

Avifauna of the region has previously been poorly studied. The following bird species have been observed in the vicinity of the HPP: Common Buzzard (*Buteo buteo*), Common Kestrel (*Falco tinnunculus*) and Golden Eagle (*Aquila chrysaetos*).

Among reptiles two rare species inhabit the area surrounding the HPP: the Transcaucasian Rat Snake (*Elphe longissima*) and Caucasian Viper (*Vipera kaznakovi*).

2.6.3 Fish Population

Local fishery is also considered a primary environmental receptor for baseline comparison. The following fish species are found in the Tskhenistskali River: Kolkhic Barbel (*Barbus tauricus escherichi*), Bream (*Abramis brama*), goby (*Gobius melanostomus*), trout (*Salmo fario*) and Khramulya (*Varicorhinus siedolbi*), are found in the Tskhenistskali River (Elanidze, R. 1988). The Red Book of Georgia classifies the Khramulya as National Statute Vulnerable, so it needs to be protected.

Spawning periods for major fish species found in the river are noted in table below.

Table 9: Tskhenistskali River Fish Spawning Periods

Fish	Spawning Period
Kolkhic Barbel	May-August
Bream	April-June
Goby	March-September
Trout	September-October
Khramulya	May-June

Literature on fish composition of Tskhenistskali River dates back several decades, which was before any hydropower dams were built downstream of the town of Tsageri. Therefore, it's hard to determine if all the above species still inhabit the study area. The sampling of fish species should be included in as part of environmental data collection during feasibility design (environmental assessment).

The construction area (dam, intake, tailrace) is not important from the point of view of fish industry. The HPP construction can not cause any additional damage to fish movement because there are already power plants located downstream to the Tskhenistskali River that prevent upstream migration and fish passage. Potential for a local fishery to develop as a benefit to the local community and recreation is possible and should be considered during feasibility studies.

3.0 GEOLOGY

3.1 GEOLOGICAL REPORT

The geologic data available at the time of the pre-feasibility study were Geologic maps at the scale of 1:500,000 and a field reconnaissance report "Geological-Engineering Survey in Lower Svaneti region in the middle portion of the Tskhenistskali River Prospect for arrangement of hydropower center (Pre-feasibility phase)" by subconsultant V.Sulkhanishvili. A copy of this report and associated table "Geological and Geological-Engineering Description of the Rock Types Within the Study Area" is included in Appendix 1.

3.2 SEISMOLOGY

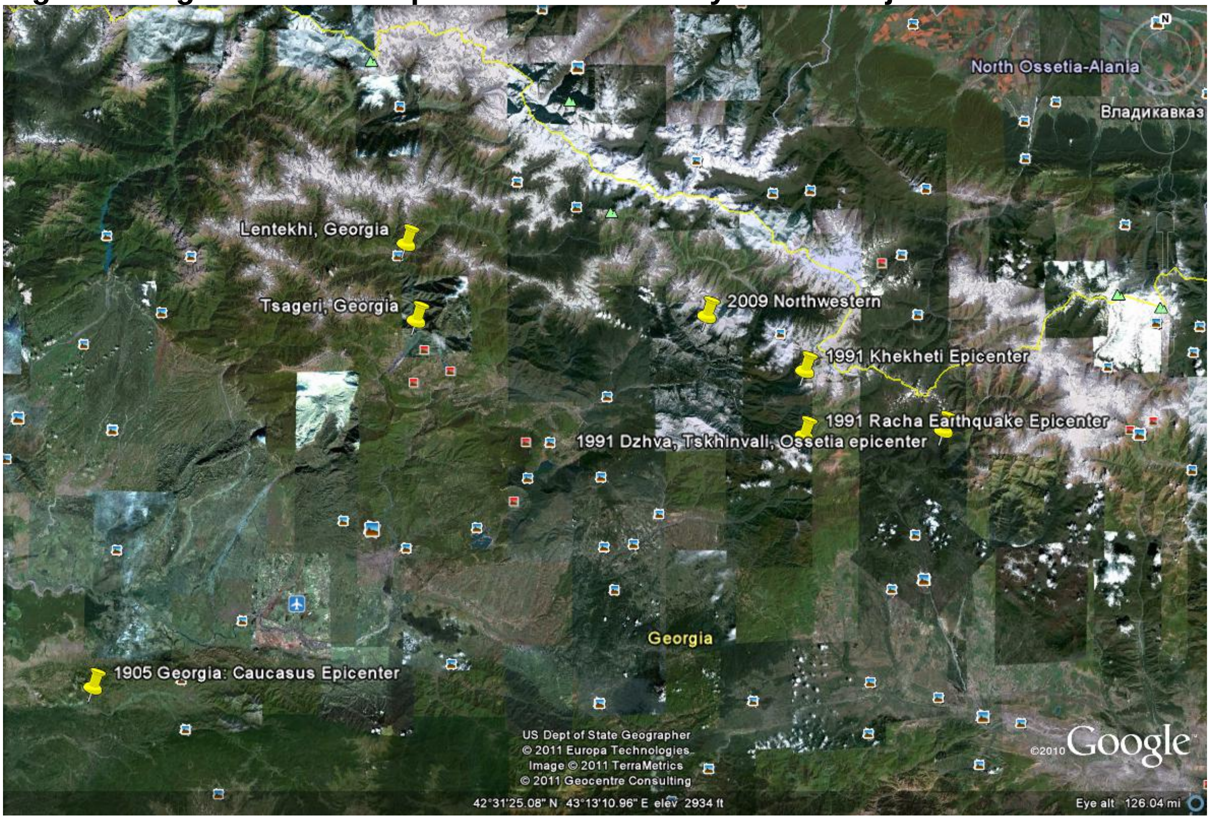
The geology of the project area is characterized by crossing the boundary between two tectonic zones: the Foldsystem of the greater Caucasus (Gagra-Djava Zone) and TransCaucasian Intermountain Area (Central Zone of Uplift). As a result of being on the boundary of these tectonic plates, according to the current Georgian seismic zoning classification the project is in hazardous zone 9. The design criteria for earthquake loads and resistance of structures must be defined in accordance with applicable standards and regulations.

Within the last century there have been 5 "significant" earthquakes in the vicinity of the project site. They are listed in the table below and located on the area map below. The two yellow stick pins to the northwest indicate the locations of the Tsageri HPP and Lentekhi HPP proposed project sites. Through proper design and construction, the risk from earthquake damage can be mitigated.

Table 10: Significant Earthquake Data

Date	Name	Mag.	MMI	Deaths	Damage	Distance From Tsageri HPP
Oct. 21, 1905	GEORGIA: CAUCASUS	7.5				95 km
April 29, 1991	RACHA: DZHAVA, CHIATURA, AMBROLAURI	7.0	9	270	Extreme	78 km
May 15, 1991	KHEKHETI	4.9	5	0	Moderate	75 km
June 15, 1991	DZHAVA, TSKHINVALI, OSSETIA	6.1	8	8	Severe	103 km
Sept. 22, 2009	NORTHWESTERN	6.0		0	Moderate	56 km

Figure 3 Significant Earthquakes in the Vicinity of the Project Site



3.3 CURRENT STATUS OF GEOLOGICAL INVESTIGATION

Because of the nature of a pre-feasibility study, surface mapping of outcrops has not been done and no borings have been conducted. Geological studies, including core borings must be part of the final feasibility study. It is critical that a site investigation program for the headworks area and the powerhouse area, test pits and some core drilling in both areas be done during the feasibility study.

Table 11: Geology Significant Data

Available data	**1:500,000 Scale Geological Map of Georgia (2003)**
Regional description	**Muri Canyon, Central Caucasus Mountains**
Seismicity, including earthquake loadings	**Richter Scale 7.0, Georgian Seismic Zone 9**
Field reconnaissance	**Done in 2011 by Lomiashvili and Sulkhanishvili with report available in Appendix 1.**
Subsurface borings	**To be done at Final Feasibility Study stage**
Investigation recommendations for Final Feasibility and Design	**Geotechnical borings at diversion weir, inlet, along tunnel and powerhouse locations.**

Based on the geological report, the assumptions relating to the construction of the tunnel are that the rock conditions will be extremely variable with the potential for a lot of faults and groundwater intrusion.

4.0 HYDROPOWER PROJECT DESCRIPTION

4.1 PROJECT DESCRIPTION

The proposed Tsageri Hydropower Project involves the construction of a 110 Megawatt (MW) run-of-river Hydropower Plant on the Tskhenistskali River, in the Tsageri District of western Georgia's Racha-Lechkhumi and Kvemo Svaneti Region.

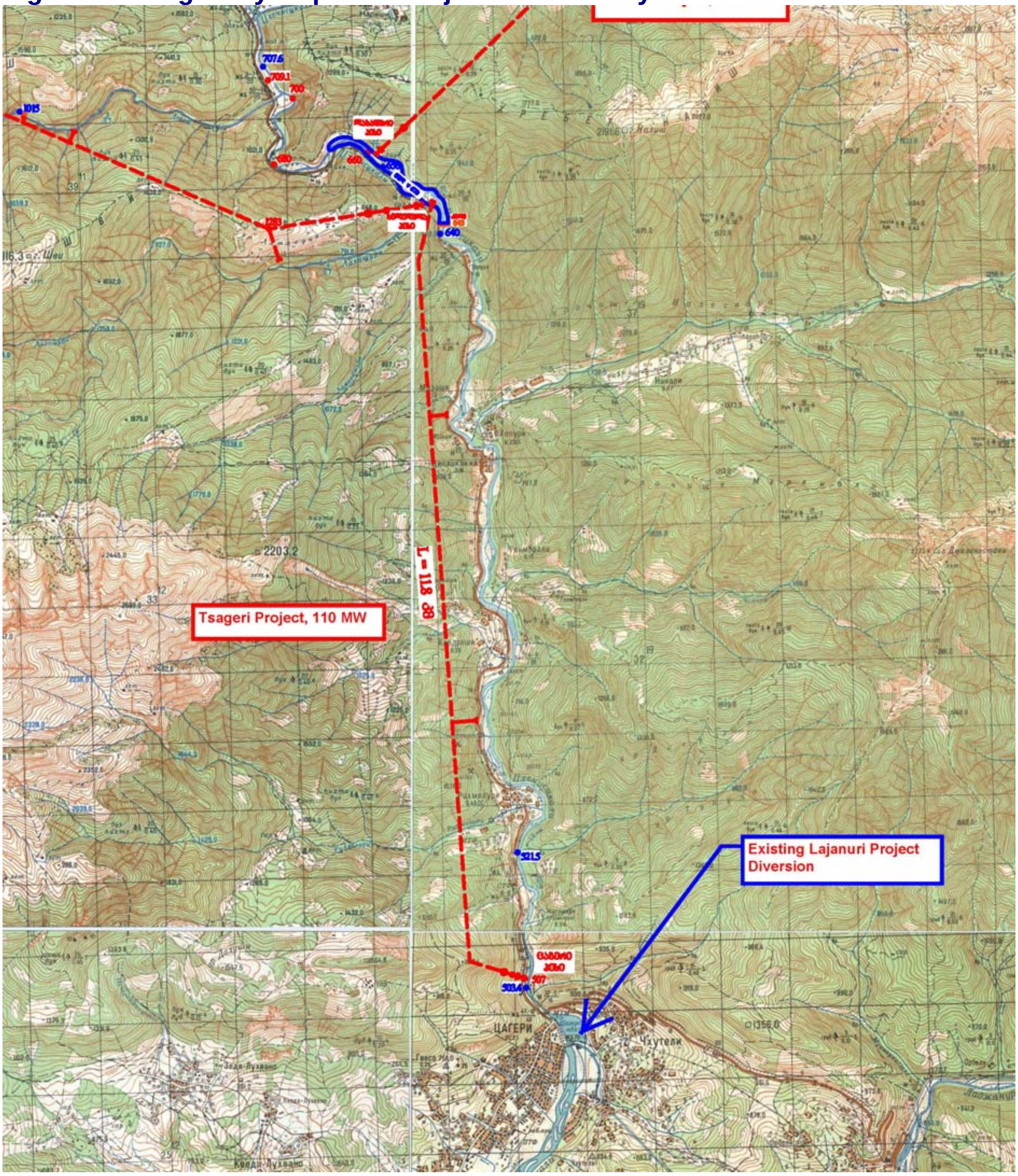
The Tsageri HPP development is expected to include a 27-m-high (above existing ground level) concrete diversion dam, a 11,800-m-long, 6.0-m-diameter pressure tunnel, an excavated surge shaft, a short penstock, and an underground powerhouse. Intermediate construction adits can be used to shorten the tunnel construction schedule. The hydroelectric units for this high-head development may consist of four Pelton or three Francis turbines with synchronous generators.

The power plant may work in island mode as well as in synchronization with the national power grid, allowing both direct and grid-connected supplies to consumers. To allow continuous operation of the Tsageri plant sufficient auxiliary backup power must be provided to allow black-starts when this plant is isolated from the national transmission network (island mode).

Access to the site is excellent. Both the powerhouse and diversion dam are adjacent to National Road 15, which was upgraded and paved during 2010 and 2011.

An overall view of the project arrangement is shown on Figure 4.

Figure 4: Tsageri Hydropower Project General Layout.



The dashed red line in the figure above shows the tunnel alignment, which also indicates the proposed locations of the dam upstream and powerhouse on the downstream ends of the tunnel. In addition, and not shown in the figure, is about 15 km of 220 kV transmission line that will need to be constructed to connect the plant to the Lajanuri Substation near Alpana.

4.1.1 Diversion Structure

The diversion structure will be a gravity dam, 35 meters high, from the assumed bedrock foundation to the operating water surface elevation.

Hydraulically operated, hinged crest gates ("flap gates") will be installed on top of the dam to pass floods without large increases in upstream water surface elevations.

Low-level reservoir sluicing gates will be included to flush sediment accumulations during high-flow periods. These will be controlled by slide or wheel gates installed over the water passage intake on the upstream face of the dam.

Special measures to accommodate log exclusion or passage should be considered as part of the project. At the present time, local timber men float logs downstream from their harvest areas. Logs from the upper reaches of the Tskhenistskali watershed might be intercepted at the proposed Lentekhi diversion pool, upstream, or at a future storage reservoir site. However, logs from the Kheledula, Laskadura, Devashi, and other intervening watersheds would be collected at the Tsageri diversion dam.

Log-handling measures may include booms or screens to guide logs to the shoreline, and takeout areas where loggers can collect timber and transfer it to trucks. These facilities will probably be located near the upstream limit of the reservoir.

Layouts of the proposed diversion dam, intake, and de-silting facility are included in Appendix 5.

4.1.2 Intake and De-Silting Facility

The intake for the project will be located on the west bank of the diversion reservoir, about 500 m upstream from the dam. It will include coarse bar racks to exclude large debris, a 6 m x 6 m bulkhead gate for maintenance, and a 6 m x 6 m wheel gate for normal operation. The intake will be submerged to allow operation of the facility at reduced reservoir elevation so that daily peaking or other operation modes may be possible.

There will be a de-silting facility downstream from the intake, following a short concrete transition. It will be designed to remove most of the suspended sediment in the flow that will be used for generation. This will serve to minimize abrasion damage to the facilities, especially the turbines. It will be segmented for flushing and maintenance purposes, so plant operation can continue while one segment of the de-silter is being flushed. Construction will be reinforced concrete with steel gates, railings, etc.. A second gated control structure will be located between the de-silting structure and the tunnel portal. It will be in an open channel section, and will include a trash rack, hydraulic boom rake, a 6 m x 6 m bulkhead gate, and a 6 m x 6 m hydraulically controlled wheel gate. There will be two smooth hydraulic transition sections: one will lead into the power tunnel and the second to a sluice that returns flushed sediment from the de-stilting facility to the Tskhenistskali River downstream of the dam.

4.1.3 Power Tunnel

The power tunnel will have a length of 11,800 meters, with a finished inside diameter 6.0 m. Rock quality is expected to be good, on average, but there are areas of weak rock along bedding planes, in contact areas, and in weak strata such as the karstic limestone that is found in the area.

The power tunnel will probably be excavated using a tunnel boring machine (TBM), since the length should justify the capital cost of purchasing the equipment. Two or more intermediate adits may be used for access during construction. Possible locations are shown on the Project Layout, Figure 2, above.

Most of the tunnel length will probably be supported using rock bolts and shotcrete. Sections through karstic limestone and other poor rock will require steel supports and reinforced concrete lining, and special measures may be needed to control groundwater inflow.

4.1.4 Surge Shaft

There will be significant pressure surge considerations at the Tsageri Project, due to the very long water conductor. To reduce the pressure increase in the tunnel when turbines are shut down, a surge shaft will be excavated vertically through sound rock from the end of the gradually sloping power tunnel, intersecting the natural slope above. The chamber will be open to the atmosphere (not pressurized), and will probably be concrete-lined. This will provide attenuation of pressure waves at a location just 200 m upstream from the powerhouse cavern. The exact location of the surge shaft will be selected for topographic and geological reasons during feasibility and design studies.

4.1.5 Pressure Shaft and Penstocks

A steel-lined pressure shaft and concrete-embedded penstock sections will lead from the power tunnel to the turbines in the powerhouse cavern. The pressure shaft will be excavated vertically, or on a steep slope that can be excavated using a raise climber. The pressure shaft length will be about 180 meters.

At the bottom of the pressure shaft, a trifurcation (for a 3-unit power plant) or double bifurcation (for a 4-unit power plant), positioned horizontally just upstream from the power cavern, will convey flow to the individual turbines.

4.1.6 Powerhouse Cavern

The underground powerhouse size and arrangement will be determined primarily by the site geological details and the turbine-generator units selected for installation. The main cavern will probably include the unit shutoff valves and most auxiliary systems, in addition to the units themselves.

The cavern dimensions will be about 20 to 25 meters wide, 70 to 90 meters long, and 30 to 35 meters tall and will include an overhead bridge crane with a capacity sufficient to lift the heaviest component in the turbine generator set (assumed an 80 tonne crane for preliminary cost estimating purposes).

Draft tube gates and operators may be included within the main cavern, or may be located in a small cavern downstream of the powerhouse opening.

4.1.7 Tailrace Tunnel

Three or four draft tube discharges will be combined into a single tailrace tunnel.

Free-surface tunnel operation is required for Pelton units. A pressure tunnel can be used for Francis units. Bulkheads will be included at the outlet to isolate the tunnel for maintenance.

4.1.8 Access Tunnels

Auxiliary tunnels are required to provide the powerhouse cavern with:

- Road access
- A transmission line route
- Ventilation

4.1.9 Substation Cavern

To minimize the length of medium-voltage cable from the units to the power transformers, the plant substation may be located underground, in a cavern close to the powerhouse cavern. That opening will be sized for power transformers; breakers; and control, monitoring, and relay installations.

4.1.10 Mechanical Equipment

There will be a turbine isolation valve for each unit, capable of closing against full flow. Butterfly valves will probably be used. Operators will use high-pressure hydraulic power.

Turbine selection for the Tsageri project must be evaluated in detail during feasibility studies. Preliminary turbine selections were made for Pelton and Francis options using the TURBNPRO evaluation software produced by Hydro Info Systems. Program output for the options is shown in Appendix 11

The Pelton turbine option includes four turbines producing a mechanical output of up to about 30 MW each. They are large vertical-shaft machines and have 6 jets each, a rotational speed of 150 rpm, and a runner pitch diameter of 3,365 mm.

The Francis option includes three turbines with a maximum mechanical output of about 42 MW each. They are vertical-shaft units, have a rotational speed of 300 rpm, and a runner discharge diameter of 2,049 mm.

Some of the advantages and disadvantages of each type, which must be considered during feasibility studies, are listed in the following table:

Table 12: Advantages and Disadvantages of Turbine Types

Advantages	Disadvantages
Pelton Turbines	
Very wide operating flow range at high efficiency (typically 85 to 90 percent, over 10% to 100% of flow, for a six-jet machine) Jet deflectors allow very fast machine shutdown without stopping the water flow, greatly reducing surge control problems.	Slower rotational speed, which results in physically large turbines and generators. Runner must be set higher than maximum tailwater elevation, and the head between the runner centerline and tailwater is lost.
Francis Turbines	
High rotational speed, resulting in smaller turbine and generator dimensions Higher peak efficiencies (typically up to 93%) The full head on the unit is available for generation.	Narrow range of operation as compared to Pelton turbines. Special measures are needed to control pressure rise during unit shutdown.

Unit governors will be electronically controlled, with high-pressure hydraulic components.

Other powerhouse mechanical systems will include:

- Potable water supply
- Wastewater disposal
- Ventilation
- Fire suppression
- Compressed air
- Drainage and dewatering pump systems
- Powerhouse bridge crane
- Draft tube gates and operators

4.1.11 Electrical Equipment

Generators will be vertical-shaft synchronous machines compatible with the selected turbines. Stator output voltage will probably be about 15 kV.

Static exciters will be used.

Medium-voltage breakers will probably be vacuum type.

Computerized monitoring relays, and controls will be used. Automatic generator control will be installed. The system will be in direct communication with the GSE dispatch center in Tbilisi over fiber-optic, microwave, or satellite communication links.

Power transformers will be 15/220 kV, oil insulated, and may be located in an underground cavern because of space limitations at the powerhouse site. High voltage breakers may be SF6. It may be worthwhile to include a substation transformer for connection to the local system at the town of Tsageri, at 35 kV or 110 kV

Other electrical systems will include:

- A diesel generator to provide backup power and black-start capability
- Station service, including lighting, motor-control centers, etc.
- DC power supply including station batteries and chargers
- Lightning protection

4.2 ALTERNATIVES EVALUATED

Various powerhouse and diversion locations were investigated and evaluated. The current diversion location was selected to locate the dam:

- A short distance below the Lentekhi power plant discharge tunnel portal
- Below the confluences with two right-bank tributaries—the Devashi River and the Lakhashuri River.
- At a site where the dam length is relatively short and good rock conditions are found on both abutments.
- Where the impoundment formed by the dam and the dam construction area would displace very few or no residents.

The intake was located where there are:

- Good tunnel portal conditions for the tunnel entrance.
- Adequate space for de-silting facilities.
- Sound foundations on competent rock.

Various combinations of water conductors were briefly evaluated, including canals, tunnels, pipelines and penstocks. The tunnel option was quickly selected because of space limitations in the narrow canyon, the large diameter of the required conduit, and the generally acceptable geologic conditions along a potential tunnel alignment.

Above- and below-ground power plant configurations were evaluated. The current concept of a below ground cavern type power plant was selected because of the lack of a suitably flat area large enough for the power plant and substation. Rather than moving the powerhouse to another location that would reduce the gross head, a below-ground powerhouse is proposed. The location selected for the powerhouse is based on topographic and geologic conditions. There is a deposit of karstic limestone a short distance downstream from the selected location which had to be avoided; and moving the powerhouse farther upstream would result in an unwanted loss of gross head.

4.3 PROPOSED PROJECT COMPONENTS:

- Minimal access roads from public paved roadway.
- 27-m-high X 200-m-long diversion dam
- De-silting structures
- Sluicing structures
- Intake
- Tunnel and penstock access structures
- Water conductors (canals, tunnels, penstocks)
- Surge tanks or shafts

- Underground (cavern type) power plant
- Underground discharge across public roadway to river
- Electrical and mechanical plant equipment, including incoming valves with governors, turbines, generators, switch gear, etc.
- Auxiliary backup power to allow black-starts when isolated from network (island mode)
- Power plant substation, including two power transformers
- Possibly interconnection transformers for 35 kV or 110 kV systems.
- 15 km of 220 kV Transmission line, including access roads as needed.
- Substation expansion and equipment for interconnection at Lajanuri Substation

Table 13: Hydropower Development Significant Data

Maximum gross head	**163 meters**
Maximum generation flow	**90 m³/s**
Number of units	**3 Francis units or 4 Pelton units**
Potential installed capacity	**110 MW**
Mean annual power output	**Approximately 500 GWh**
Construction time	**4 years including final feasibility, EIA and design.**
Anticipated Life-span	**50 years**

5.0 POWER AND ENERGY STUDIES

Tsageri HPP energy assessment was completed using available Tskhenistskali River discharge records and operating scenarios that fit the proposed site and watershed conditions. River discharge records are described in Section 2.2.2, Surface Water Resources. The energy assessment used two different approaches to estimate expected average annual and average monthly generation. Each approach will be summarized in the following paragraphs.

5.1 FLOW DURATION CURVE ANALYSIS (FDC ANALYSIS)

Flow duration curve analysis is a standard practice used by hydrologists, scientists, and engineers to examine discharge records and develop an understanding of discharge (in m^3/s) as a function of the percentage of time a flow value is equal to or exceeds a given value during a period of time. The time frame used in this analysis is both monthly and annual in hours. The area under a flow duration curve represents the available flow in a given time period (m^3/s-hrs). Available flow is defined as the flow or discharge magnitude available for hydropower generation in the time period selected. Flow duration curves for Tsageri HPP are presented in Appendix 2.

The Flow Duration Curve Analysis approach uses an EXCEL workbook that provides a range of user selected input values required for calculating expected HPP generation. This includes a percentage of time a river discharge value is equal to or exceeds (monthly or annual), average HPP efficiency, estimates of gross head loss, and reserves for in-stream requirements. The FDC approach does not require the analyst/engineer to preselect an installed turbine capacity. Rather it provides a range of discharge values as a function of selected exceedance percentages to calculate generation (MWh) expectations that becomes input in a turbine/generator selection.

Appendix 2 also contains a selected representative sample of an exceedance percentage and associated monthly discharge that would be expected to be available for HPP generation (in m^3/s-hrs). This analysis subtracts reserve flows for in-stream requirements to identify net m^3/s-hrs available for HPP generation. This value combined with average monthly HPP unit efficiency and gross head loss is used to calculate average monthly generation in MWh.

Operations scenarios represent a conceptual understanding of how Tsageri HPP would be operated under a variety of flow conditions. Several factors are important in calculating the net available discharge for HPP generation. Plant operations decisions must respond to environmental regulations, available river discharge for HPP generation, electricity demand, maintenance, etc. The FDC analysis can generally account for these operational variables by lumping them into overall HPP operations efficiency, changes to reserve percentages, and selection of appropriate equal to or exceeded percentage for river flow. The FDC analysis should be refined in significant detail during the detailed feasibility study stage of project development. The FDC analysis approach provides an initial expectation of generation by month and annually and is expected to bring the analysis for energy to be in the range of 5% - 10% of the Daily Discharge Generation analysis. It is also used to help select the appropriate turbine discharge for the HPP installation. Monthly and annual curves and estimated generation is presented in Appendix 2.

5.2 DAILY DISCHARGE GENERATION ANALYSIS

When a proposed project design flow had been selected, a separate MS EXCEL workbook was used to calculate the power and energy production during each day within the period of stream flow record. The analysis accounts for:

- Adjustment of stream gauge flows to the project intake location, using a drainage basin area ratio.
- The month and season during which the flow occurs.
- The assumed bypass flow during the month in which the flow occurs.
- Water conductor diameter, calculated based on a target velocity at the full design flow.

- Friction losses using Manning's equation, water conductor length and diameter, and hydraulic roughness ("n").
- Minor head losses.

Power and energy production figures were calculated using a range of plant design flows (i.e.: 60 – 90 m^3/s). Monthly results for a design flow of 90 m^3/s are summarized in the following tables. This flow is the maximum economical development for run-of-river operation. A somewhat smaller flow may be optimum, depending on the value of energy. If upstream storage may be developed in the future, selection of the turbine-generator type (Francis or Pelton) and HPP discharge during the feasibility design should consider the long-term operations with or without seasonal storage to maximize Tsageri HPP generation and operations flexibility.

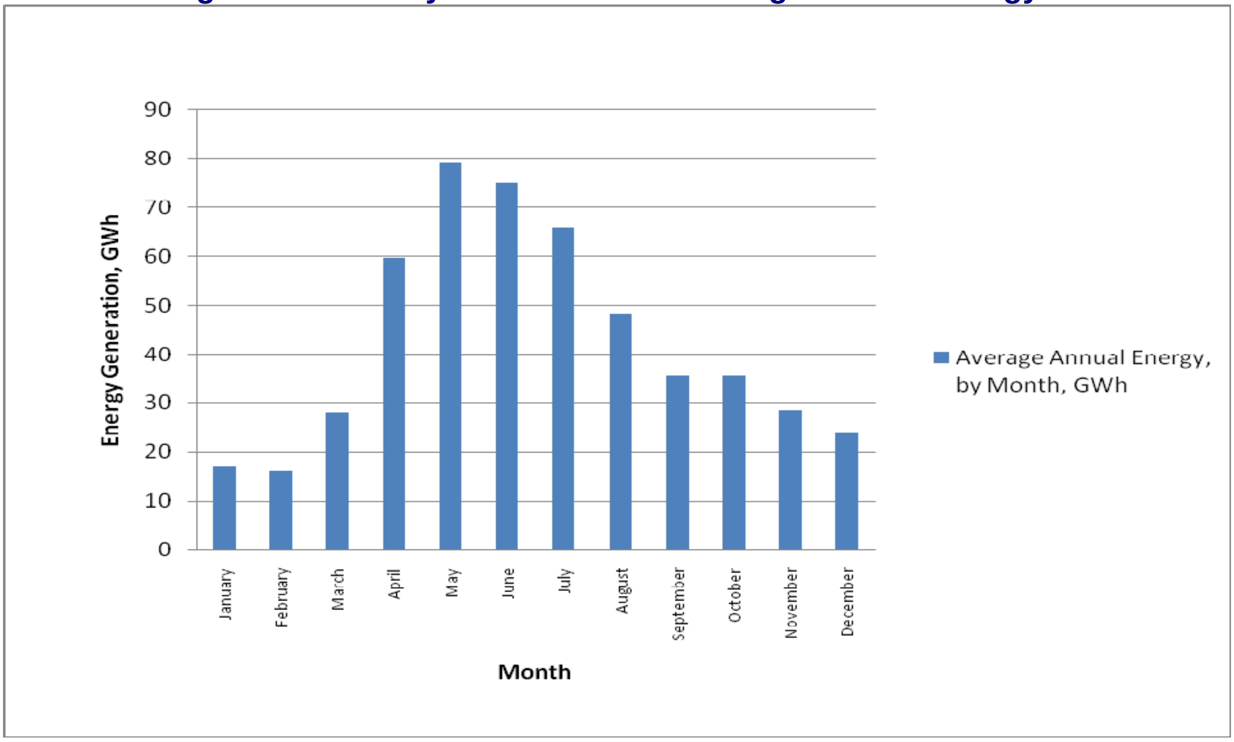
Table 14: Average Tsageri HPP Megawatt Production, 90 m^3/s Design Flow

Period	Mean Daily, MW	Minimum Daily, MW	Maximum Daily, MW
January	23.13	0.43	113.75
February	24.01	4.50	98.82
March	37.61	2.23	113.75
April	82.87	15.62	113.75
May	106.09	32.95	113.75
June	104.16	47.86	113.75
July	88.59	27.04	113.75
August	64.87	16.51	113.75
September	49.56	14.23	113.75
October	47.90	10.63	113.75
November	39.49	12.29	113.75
December	32.39	9.00	113.75
Annual	58.66	0.43	113.75

Table 15: Average Tsageri HPP Daily Energy Production, 90 m^3/s Design Flow

Period	Mean Daily, GWh	Minimum Daily, GWh	Maximum Daily, GWh	Mean Annual by Month, GWh
January	0.56	0.01	2.73	17.21
February	0.58	0.11	2.37	16.28
March	0.90	0.05	2.73	27.98
April	1.99	0.37	2.73	59.67
May	2.55	0.79	2.73	78.93
June	2.50	1.15	2.73	75.00
July	2.13	0.65	2.73	65.91
August	1.56	0.40	2.73	48.26
September	1.19	0.34	2.73	35.68
October	1.15	0.26	2.73	35.64
November	0.95	0.30	2.73	28.43
December	0.78	0.22	2.73	24.10
Annual	1.41	0.01	2.73	513.09

Figure 5: Monthly Distribution of Average Annual Energy



6.0 ENVIRONMENTAL AND SOCIAL STUDIES

6.1 COMMUNITY AND SOCIO-ECONOMIC BASELINE DATA

Racha-Lechkhumi and Kvemo Svaneti Region occupies 8% of Georgia's overall territory and it covers an area of 4,954 km². According to the official statistical data from 2002, the Racha-Lechkhumi and Kvemo Svaneti Region has a population of 50,969 people. Since 1990 the main demographic trends for the Racha-Lechkhumi and Kvemo Svaneti Region have been an increase in mortality, decrease in birth rate and migration to larger cities. This region is the most sparsely populated in the country. Administrative districts within the Racha-Lechkhumi and Kvemo Svaneti Region are: Ambrolauri, Oni, Tsageri and Lentekhi.

6.1.1 Infrastructure

Infrastructure of the Racha-Lechkhumi and Kvemo Svaneti Region is developed: there are highways and high voltage transmission lines at 35 and 110 kV. Tsageri and Lentekhi towns of the Racha-Lechkhumi and Kvemo Svaneti Region will soon be connected by a rehabilitated road. Local residents will also have stable water supply following completion of an ongoing project. Rehabilitation of water and sewage systems is ongoing. The project is being implemented by Georgia's Ministry of Regional Development and Infrastructure and Municipal Development Fund. There are 28 public schools, one museum, one theatre and one library in the Lentekhi community.

Proposed HPP will be located within the administrative borders of Tsageri District. Some socio-economic characteristics of these districts are described below:

The distance from Tbilisi to administrative center of Tsageri District is about 273 km.

The total area of Tsageri District land equals 756 km^2. The largest part of Tsageri District is a mountainous area and the economy heavily relies on agriculture. The main economic activities of the district are potato growing and animal husbandry. Vineyards are also cultivated in some areas, especially in the lowlands of Tsageri District.

Table 16: Tsageri District Statistics

Location:	Northern Georgia, Racha-Lechkhumi and Kvemo Svaneti Region
Administrative District:	Tsageri
Area:	756 km^2
Population:	16,275
Population density:	22 people/km^2
Administrative center:	Tsageri

6.1.2 Population and Settlements

According to the statistical data of 2009, the population of Tsageri District is about 16,275 people (about 7,434 household). About 730 household are registered in the town of Tsageri and 6,704 household are registered in villages. Comparing the statistical data from 2006 and 2009, the population has decreased by 240 people during this interval. The demographic decline is due to high migration rate, although there are no precise statistical records available on migration. Based on official information from the District, unemployment rate in Tsageri District is about 11%. (***Source:*** Tsageri Municipality Diagnostic Report, CARE Georgia, 2010)

6.1.3 Cultural Heritage and Recreational Resources

Archeological sites, churches, towers, and related cultural and heritage sites are important baseline environmental data. The Racha-Lechkhumi and Kvemo Svaneti Region is rich in old churches, monasteries and other cultural relics. The table in Appendix 9 shows some of existing cultural resources of Lentekhi and Tsageri Districts of Racha-Lechkhumi and Kvemo Svaneti Region. According to the literature review, no registered archeological and/or historical assets are located within the project development area.

6.2 ENVIRONMENTAL RECEPTOR IMPACTS & MITIGATION PRACTICES

An important component of feasibility studies is addressing impacts to the receptors in the affected environment. Further, minimizing environmental and social impacts through accepted international practices are very important criteria for the evaluation, construction and operation of the Tsageri HPP.

The proposed Tsageri HPP site **baseline conditions** have been described in sections 2, 3 and 5.1 above. Appendix 10 presents expected environmental receptor impacts and appropriate mitigation practices should be included in detailed feasibility studies. Effects to and mitigation approaches to protect Environmental Receptors are identified to provide a source of focus for environmental assessments studies that will help evaluate the overall impacts to the site and the local vicinity.

General Categories for Environmental Receptors:

- Surface Water Resources (Quantity, Water Quality, Flood Risk)
- Land Cover
- Air Quality
- Geology and Soils,
- Cultural Heritage and Recreational Resources
- Biodiversity (flora, fauna, etc.)
- Community and Socio-Economic

Affected Environment Assessment: The Tsageri HPP has two hydropower development activity periods that will impact environmental receptors, over different time horizons, and at different risk or impact levels. The following are the activity periods of interest:

- Construction: Compared to the lifecycle of the facility this is a short term impact period of approximately 3 years. It includes all phases of construction from initial land and water resource disturbance to startup of plant operations.
- Operations: Time horizon for full operational lifecycle before major component replacement is 30 to 40 years

Risk to an environmental receptor from the activities are evaluated as Low, Medium, or High and should be refined further during the detailed feasibility study. Risk evaluation also includes whether the impacts to receptors are (R) Reversible or (IR) Irreversible and (T) Temporary or (P) Permanent.

An important part of detailed project feasibility design is to incorporate a set of mitigation practices that address impacts during the expected activities periods. These mitigation practices should be detailed, focused on environmental receptors, and be the standard and acceptable practices at the time of each activity period.

Tables for each environmental receptor listed above have been prepared in order to provide general assessment with respect to the proposed construction and operation of the Tsageri HPP. These tables are presented in Appendix 10

From an affected natural environmental perspective the Tsageri HPP can be developed so that the project overall minimizes its construction and operations impacts on the local and watershed environment. Appropriate attention must be given to overall construction management planning and execution to assure inclusion of the necessary safety, health, and environmental mitigation practices to construct and operate Tsageri HPP in an acceptable legal, environmental and regulatory manner.

7.0 PROJECT COST ESTIMATE AND CONSTRUCTION SCHEDULE

7.1 CAPITAL EXPENDITURE

The capital expenditure is as important to the feasibility of a hydropower project as the energy that can be produced or the tariff that is expected for the energy produced. Based on this cost estimate, we have confidence that the completed Tsageri project will cost about $2,271 per kW, installed which is used in the financial analysis in Section 9.0

As mentioned in other sections, this project could be implemented with either Francis or Pelton turbines. This will be determined by the developer during the final feasibility stage based on various characteristics of the two turbine types. For the purpose of this cost estimate, it was assumed that three Francis turbines are housed in the underground cavern powerhouse.

Unit costs are based on a comparable hydropower project in Georgia started in 2009. All costs are in US dollars to avoid exchange rate issues and because a large part of the mechanical and electrical equipment will be imported.

7.2 ESTIMATE OF OPERATING COSTS

Operating costs generally can be estimated in two ways: as approximately 5-7% of revenues or 1% of capital expenditure. On the Tsageri project both numbers were consistent, so we used the slightly higher 1% of capital cost in our financial analysis in Section 8.

Table 17: Tsageri HPP Estimated Capital Expenditure

	Units	Amt	Unit Cost	Total US$	Year 1	Year 2	Year 3	Year 4	Year 5
Land purchase	ha	40	$10,000	$400,000	$400,000				
Preparatory & infrastructure works	LS			$5,400,000	$5,400,000				
Stream diversion and cofferdams	LS			$1,890,000	$945,000	$945,000			
Modification to Highway 15	m	4,000	$685	$2,740,000	$1,370,000	$1,370,000			
Dam & spillway	LS			$25,767,695		$12,883,848	$12,883,848		
De-silting structure	LS			$13,782,000		$6,891,000	$6,891,000		
Portal				$1,212,720		$606,360	$606,360		
Power tunnel including rockbolts & shotcrete	m	11,500	$2,446	$28,125,894		$8,437,768	$11,250,357	$8,437,768	
Pressure tunnel/penstock to powerhouse (steel lined) including grout, rockbolts, concrete, etc	m	180	$8,482	$1,526,814			$1,526,814		
Surge shaft including grout, rockbolts, concrete	m	79	$4,891	$386,425			$386,425		
Addits including grout, rockbolts, concrete, etc	m	600	$2,446	$1,467,438		$1,467,438			
Adit plug including grout, concrete, access door	Each	2	$318,086	$636,173				$636,173	
Power house (cavern) including grout, rockbolts, concrete, access tunnel, tailrace etc.	LS			$10,755,061		$5,377,530	$5,377,530		
Transformers and switchgear chamber	LS			$347,552		$173,776	$173,776		
Electric and mechanical parts (turn-key)	LS			$66,103,942		$19,831,183	$26,441,577	$19,831,183	
Grid connection transmission line	km	15	$385,000	$5,775,000		$1,732,500	$2,310,000	$1,732,500	
Subtotal of schedule items				**$166,316,713**					
Geology (investigation field, lab and office) @ 1%	LS			$1,663,167	$1,663,167				
Feasibility study @ 1%	LS			$1,663,167	$1,663,167				
EIA @ 1%	LS			$1,663,167	$1,663,167				
EPCM @ 14%	LS			$23,284,340	$20,955,906	$698,530	$698,530	$698,530	$232,843
Contingencies (Assumptions Variable) @ 20%	LS			$38,918,111	$6,812,081	$12,082,987	$13,709,244	$6,267,231	$46,569
Total				**$233,508,665**	**$40,872,489**	**$72,497,919**	**$82,255,461**	**$37,603,384**	**$279,412**
MW Capacity	110		CAPEX/kW	**$2,123**					

7.3 CONSTRUCTION SCHEDULE

The construction schedule is envisioned to be one year for Geotechnical investigation, Final Feasibility Study and Environmental Assessment followed by three years of construction. Geotechnical investigation will include borings along the route of the tunnel, at the dam site and at the powerhouse site. Field observations and laboratory testing on the rock cores will contribute invaluable insight into the character of the rock in the tunneling zone. The Final Feasibility Study must include a much more detailed design and cost estimate based on the ultimate configuration determined by the developer.

The extent of the construction appears to be a 3 year schedule, with the critical path through the headrace tunnel, surge shaft and pressure tunnel & penstock. It appears that work on the dam and portal and tail race will need to be done during the winter (November through March) when low flows can be diverted During the Summer (April through September) the water level in the narrow canyon is too high and the velocities to high for cofferdams to hold. All flow impediments, such as cofferdams, need to be removed during the spring runoff until the sluice openings are ready to pass this amount of water.

8.0 ECONOMIC AND FINANCIAL ANALYSIS

According to preliminary assessments the plant offers a good opportunity to sell energy during winter inside Georgia, replacing expensive thermal power, and export part of the energy during the remainder of the year to take advantage of the seasonal differentials in power prices between Georgia and its neighboring countries. It may be possible for the developer to offset some of his costs by trading “carbon credits” in an available market. This economic and financial analysis does not consider the complex issue of trading carbon credits but the potential developer should consider their applicability when reviewing the project’s financial returns.

Since Georgia only needs the power for winter demands, the developer of the Tsageri HPP must find viable buyers of power in the region for the remainder of the year. One potential market for sale of the power from the HPPs is western Turkey. The growth in electricity sales in Turkey is high and demand is quickly out-stripping supply. In addition, Turkey is joining the European transmission network in 2011 which provides the possibility to sell into the lucrative EU power market. The installation of the new 400 KV electricity transmission line between Georgia and Turkey is scheduled to be complete in 2012. Access to the Turkish and European market is dependent on the negotiation of the Georgia-Turkey Cross Border Energy Agreement.

To get Tsageri HPP power to those markets in other countries, there must be transmission access at affordable tariffs. Investigations by the Georgian and Turkish utilities are ongoing concerning the capacity of the transmission network as well as the structure of tariffs to ensure that the sale of power is not impeded. To get current information on tariffs and cross-border sales the developer of the Tsageri HPP will need to work closely with GSE, EnergoTrans and the Georgian National Energy and Water Supply Regulatory Commission.

Table 10 is a calculation of the monthly revenue and payback period for the investment. It starts with the m^3/s-hrs of water that can be captured at the Tsageri HPP based on the monthly flow-duration curves (see Appendix 2) and an assumed bypass of 1-10% of the average monthly flow as flow reserved for in-steam habitat and environmental functions and values. This leads to the saleable kWh that can be generated per month. The net price per kWh at the plant is determined by applying the assumed tariffs for Georgia and Turkey and subtracting dispatch and transmission fees. The net price for Georgia and Turkey are distributed according to the apparent demand pattern throughout the year. The monthly generation capacity of Tsageri HPP is multiplied by net price per kWh for that month to get monthly net revenue at the plant. From this the amount of electricity used at the plant and therefore could not have been sold and operating costs at 1% of the capital expenditure are deducted to get net operating revenue. Based on this, the expected payback period was calculated as about 10 years.

The price per kWh exported to the grid is based on the following current tariffs by starting with the gross tariff, deducting all dispatch and transmission costs to get the net tariff to the developer at the point the power is exported into the grid.

Table 18 Georgian Market Net Tariff Calculation

Georgian Market	US$	GEL
Gross Tariff $/kWh	0.041402	
Dispatch tariff ($/kWh)	0.000882	0.0015
Transmission tariff 1 ($/kWh)	0.002941	0.005
Transmission tariff 2 ($/kWh)	0.001059	0.0018
	0.03652	

Table 19 Turkish Market Net Tariff Calculation

Turkish Market Tariff Calculation	US$	YTL
Tariff $/kWh	0.07	
Transmission Tariff Georgia		
Dispatch tariff ($/kWh)	0.000882	
Transmission tariff 1 ($/kWh)	0.002941	
Transmission tariff 2 ($/kWh)	0.001059	
Total Transmission costs in Georgia	0.004882	

Transmission Tariff Turkey	US$	YTL
Dispatch tariff ($/kWh)	0.002632	0.005
Transmission tariff 1 ($/kWh)	0.002632	0.005
Transmission tariff 2 ($/kWh)	0.002632	0.005
Transmission tariff 3 ($/kWh)	0	0
Other	0	
Total Transmission costs in Turkey	0.007895	0.015

	0.05222

Table 20: Tsageri HPP Financial Analysis & Payback Period for 110 MW and 90 m^3/s Design

Month	Total CMS-HR Under Curve	Saleable CMS-HR per month	Saleable kWh	Price / kWh	Revenue
Jan	13,791	12,291	15,377,457	0.0375	576,655
Feb	12,913	11,658	14,585,190	0.0375	546,945
Mar	21,966	19,748	24,706,569	0.0375	926,496
Apr	83,786	61,479	76,916,156	0.0520	3,999,640
May	91,664	64,433	80,612,019	0.0520	4,191,825
Jun	83,786	61,226	76,599,959	0.0520	3,983,198
Jul	64,635	54,463	68,138,913	0.0520	3,543,223
Aug	43,598	38,107	47,675,143	0.0520	2,479,107
Sep	29,966	27,653	34,597,013	0.0520	1,799,045
Oct	31,108	27,665	34,611,506	0.0520	1,799,798
Nov	23,285	21,543	26,952,076	0.0375	1,010,703
Dec	19,412	17,432	21,809,175	0.0375	817,844
Totals	519,909	417,698	522,581,176	Total Revenue / Yr	25,674,479
				(Electricity for site)	($256,745)
				(operating costs)@ 1%	($2,335,087)
CF =	53%			Net Operating Revenue	$23,082,648
				Estimated Capital Exp.	$233,508,665
				Pay Back Period	10.12

		Constant	Net Head	Efficiency	
kWh	=	9.806	150.1	85%	CMS-HR
kWh	=	1251.09851			CMS-HR

This simple payback period represents only the engineering, construction and operating costs.

Financial considerations such as borrowing, interest, internal rate of return etc. are addressed in the financial analysis in Appendix 12.

Future Storage Developments by Georgian Government: This Pre-Feasibility Study for the Tsageri HPP is based on a run of river operations plan with daily regulation. Other studies and analyses of the Upper Tskhenistskali River have identified full development to include seasonal reservoirs in the upper reaches of the basin. These two reservoirs, if built by the Government of Georgia, would be multipurpose facilities that would include for example, flood control, sediment management, recreation, low flow augmentation, water quality improvement, and potential increases in Tsageri HPP annual energy value. A developer should recognize the future potential and could include this long term potential in detailed feasibility studies.

Appendix 1

Geology Report

Company DELOITTE

USAID Hydropower Investment Promotion Project (HIPP)

Geological-Engineering Survey in Lower Svaneti region in the middle portion of the Tskhenistskali River

Prospect for arrangement of hydropower center

(Pre-feasibility phase)

Tbilisi 2011

CONTENTS

Geological - Engineering Survey

1. Introduction

The purpose of this geotechnical investigations is to evaluate the proposed water-catchment area, dam site, power tunnel and underground hydropower plant construction within Lentekhi district and “Muri Canyon” interval in the Tskhenistskali River at the pre-feasibility phase.

For completing the present task, summarization and systemization of the existing data about the region was performed. The next phase included reconnaissance routes and surveys on 1:50,000 scale within the above mentioned section of the gorge conducted by Project Chief Engineer (A. Lomiashvili) and Geological-Engineer (v. Sulkhanishvili).

General geological-engineering survey was designed based on pre-feasibility level data gathering to identify issues to be addressed in detail during the feasibility study. The 1:50,000 scale geological- engineering map indicating sections and locations of hydropower plants is attached to graphic survey. It is understood that if the project is implementation, it will include building an underground hydropower plant of 110 thousand kilo-watt capacity and driving an 11.8 km long, 6.0 m diameter power tunnel.

2. Region Physical-Geological Description

Study area is located in Lentekhi administration region at a distance of 307-325 km from Tbilisi and covers the interval in the middle portion of the course of the Tskhenistskali River from Lentekhi through Muri Canyon. Sub-latitudinal ridges, particularly Egrisi and Lechkhumi are general orographic elements on this area. The mentioned ridges and their branchs are characterized with steep slopes (35-45°) and narrow rocky crests. The high mountain area of the region is completely cut with the network of deep gorges. Differences of elevation between the gorge bottom and watershed crests range between 300 m and 1000 m. The study area is also characterized by a dense hydrographic network. The Tskhenistskali River is a major river which runs in a north to south direction in this interval. The following rivers are its largest tributaries: Devashi, Lakhashuri, Lamanasheri, Rtskhmeluri and Khopuri.

Heavily fractured mountain relief contributes to climate vertical zoning and micro-climate process development. The study area climate is moderately humid and is characterized by cold winters and warm long summers. The regional climate is damp, subtropical according to atmospheric circulation, humidity and rainfall amount.

A great part of the study area is covered with dense forest. Coniferous forest (pine and fir-tree) is widely spread below the alpine pasture, and mixed hardwood forest is prevalent in gorges where beech, oak and hornbeam are dominant. Timber production plays an important role in the region's economic policy.

The study area and its vicinity are rich with mineral resources. Among metallic minerals, there exists one copper and polymetal deposit (Rtskhmeluri) and several prospective ore-occurrences. The region is especially rich with industrial minerals deposits such as diabase (Kvedreshi), limestone (Meriskhili); brick clay (Tsageri, Khoperi, Tsiplakakia), gravel (Tskhenistskali, Lasuriashi); building sand (Tsiplakakia, Rtskhmeluri) and sandstone (Devashi, Lakhashuri) deposits. Reserves at most of these deposits are not practically depleted.

The Kutaisi-Lentekhi asphalt road running along the river Tskhenistskali is the main highway of the region, which is kept open during the whole year. Gravel roads connect the villages to one another. Generally, the populated areas are located along the banks of the Tskhenistskali River and in the downstream portions of its larger tributaries - on alluvial cones and terraces. The inhabitants engage in arable farming, gardening and cattle-breeding.

The study area is located in seismic hazardous zone of magnitude 9 according to present seismic zoning scheme of Georgia.

3. Geological - Tectonic Structure

Study area is located in the sub-zones of Khaishi and Racha-Lechkhumi syncline of Gagra-Java Zone of Caucasus South Slope Folded System and is built with formations of lower Mid-Jurassic clay shale and sandstones, volcanogenic-sedimentary formations of Bajocian porphyrite suite and cretaceous system epicontinental sediments. Lower and Mid-Jurassic terrigene sediments are spread over the north and central parts of the study area and are known as Sori suite (J^3_{1-2} S). In geological section it is in conformity continued with Mid-Lias Muashi (J^2_1 ms) suite aspid slates. Sori suite itself is divided into two sub-suites: Lower (J^3_1 S_1) and Upper (J_2 S_2). The first one is composed of interlayers of dark gray clay shales and coarse-grained micaceous sandstones. The thickness of separate sandstone layers sometimes reach 1-1.5m. Sub-suite thickness varies between 400 m and 500m. The Upper Lias layer is determined according to fauna interpretation.

The Sori suite upper sub-suite (J_2 S_2) sediments continue the section in conformity and are Composed of alternation of dark clay shales, micaceous-quartzy fine-grained sandstones and aleurolites. The quantity and thickness of sandstone layers in the upper part of the sub-suite is increasing. The thickness of those sediments is 400-450m and their Aalenian (Mid-Jurassic) stage is also determined according to fauna interpretation.

The Bajocian porphyrite suite in the study area is known as Khojali suite (J_2 ***h***d). The suite volcanogenic-sedimentary formations are spread over the lower part of the study area and are Composed of tuff-breccias, tuff-conglomerates, various porphyrite heavy coverings and their tuffs. Tuffogenic sandstones and sandy clay shales are alternating in the lower and upper part of the suite. The rocks' listed varieties don't belong to any determined stratigraphic horizon, they alternate one another very quickly in lateral as well as in vertical section and create a complicated pyroclastic, lava and sedimentary complex with thickness varying within a wide range of 850 m to 2000m.

The Lower Cretaceous epicontinental sediments transgressively proceed Bajocian porphyrite suite. These sediments participate in construction of the north flank of a large structural unit, the Racha-Lechkhumu syncline, and are spread throughout the Muri Canyon area.

The geological section of the Lower cretaceous sediments starts with the Berriasian - Hauterivian (K_1br-***h***) micro-conglomerates and sandstones low thickness (up to 10m) basalt patch that proceeds the same age thick-layered, dolomitized limestones (thickness 50m) and Barremian age (K_2 b) light gray, fine-grained massive limestones, dolomitized limestones, clayey limestone and marl suite with thickness reaching 250m. Aptian stage (K_2 ap) epicontinental sediments in Muri Canyon vicinities are composed of layered polymorphic marl limestones and marls (20-50m). Albian stage layered blue clays and clayey marls with thickness of 30-40m continue participation in the upward section of the mentioned sediments.

The Upper cretaceous begins with Cenomanian (K_2 cm) sediments. Due to lithological peculiarities they strictly differ from the sediments located above and below them in the section and are composed of coarse grained glauconitic sandstones, sandy marls and clays. Their thicknesses vary within the range of 10-180 m.

Turonian and Coniacian stages (K_2t + cn) are composed of alternation of dense layered limestones and greenish marls. These rocks are exposed in the vicinities of Tsageri town and Muri Bridge. Their thicknesses vary within a range of 20-120m. Santonian and Campanian stages (K_2st + cp) are composed of light gray and yellowish polymorphic or cryptocrystalline lithographic limestones (50-150 m). In upward section they are continued with Maastrichtian (K_2 m) dense fine-layered limestones (50-150m).

The Cretaceous system is finished with Danian (K_2 d) massive or medium and thick-layered crystal limestones which vary in thickness in the range of 60-150m. The mentioned sediments in geological section are proceeded by Paleogene system carbonate rocks which are exposed outside the study area and there is no point in discussing them now.

The quaternary system in the study area is composed of the upper (Q III) and recent quaternary (Q IV) formations. The upper quaternary alluvial sediments (a Q III) are limited in area and are located in some terraces remained on the river Tskhenistskali. They are composed of different proportions of cobbles, gravels and sands. Also, upper quaternary deluvial and deluvial-proluvial sediments are not widely spread. Rather hard proluvial formations are spread in the vicinities of Rtskhmeluri and Kvedreshi villages. These villages are actually populated on alluvial fans, their thicknesses are 15-20m. Deluvial-proluvial sediments are also met in both banks of the river Khopuri (the left affluent of the riv. Tskhenistskali), from the middle portion of the flow until the river mouth.

Recent alluvial formations (a Q IV) in the study area are composed of boulder-cobble bed, cobble-sands and rarely clays that work as river-bed fillers. Their more-or-less high accumulations are observed in those places in the gorge where accumulation zones are developed.

Proluvial sediments generally create alluvial fans of side tributaries. Genetically, these sediments are generally related to mudflows which periodically occur during the heavy rain. Their composition is directly dependent on the base rocks which are spread in tributaries and are composed of crushed stone-clayey materials.

Deluvial sediments (d Q IV) are spread over the mountain slopes underneath which they create more-or-less heavy plumes. Their composition is also determined by the base rocks lithology and is represented by angular debris and the clay soil which consolidates them. Intrusive rocks on the study area are composed of Mid-Jurassic diabase (β J_2) and quartzy porphyrite (q б J_2) sub-volcanic bodies. These rocks create dykes and sands of various thicknesses and spreading ability. Generally, they are concentrated in Rtskhmeluri ore field contour and play significant role in localization of polymetal mineralization. Above mentioned Low and Mid-Jurassic terrigene and volcanogenic sedimentary formations of Khaishi sub-zone are intensively folded and create several thicker, asymmetrical folds linearly stretched to sub-latitudinal direction which flanks are complicated with secondary folds and disjunctives. Among the folded structures developed in this part we should mention the followings (from north to south): Lamanashuri, Khopuri, Tsiplakakia, Tarigoni, Rtskhmeluri and Lajanuri anticlines and synclinal folds that are arranged among them.

Geological construction of the study area is greatly complicated with faulting structures of various directions and amplitudes. Among them we should distinguish Idliani-Rtskhmeluri uplift type deep fault observed in the south part of the region. The fault has a NW-SE direction and is inclined at 70-75° angles. The Sori suite terrigene rocks located in the upper part along the fault is over-thrusted on Bajocian porphyrite suite formations. Vertical amplitude is up to 300m. The fault to the east when approaching the Rtskhmeluri River is gradually ending. The mentioned fault belongs to the pre-Middle-Jurassic stage and intrusions of porphyrite suite magma components along it probably occurred while it was in progress. This opinion is supported by the arrangement of porphyrite and diabase dykes along the fault, which must be the magma outcrop canal. The Idliani-Rtskhmeluri fault is paralleled by a number of low amplitude scaly faults – satellite faults of a heavy deep fault.

To the south of the Idliani-Rtskhmeluri faults there is located the Racha-Lechkhumi syncline sub zone. The mentioned sub-zone is a distinctly expressed syncline structure, which is traced along the general Caucasus direction 60 km from the village of Kulbaki in the west to the village of Skhvavi in the east. Mid-Jurassic, Cretaceous, Paleogene and Neogene sediments participate in its construction. The structure originated during the Bathonian orogenic phase as a united composite syncline that got distinct shapes during later phases. The fold is evidently of asymmetric construction. The rock layers are mostly vertical (80-90^0) in its north flank. The south flank is less slopping (30-40°) and is complicated by multiple folds from secondary folding stages.

4. Geomorphology

The study area is located in the south part of the Caucasus Alpine System where the general morphologic units are the followings: sub-latitudinal Egrisi ridge (mount Tsikori – 3173m), Lechkhumi Ridge (mount Tekali – 3043m) and meridionally located gorge of the river Tskhenistskali. According to a wide range of geological peculiarities, relief dissecting quality and base rocks sustainability against denudative processes the following three types of relief are distinguished:

1. Alpine erosive – denudative relief with old marks of glaciations, developed on the substrates constructed with Lower and Mid-Jurassic intensively folded Sori suite terrigene rocks;

2. High and Medium mountainous erosive relief, developed on dislocated substrate constructed by Bajocian volcanogenic-sedimentary formations; and

3. Medium and Low mountainous erosive relief developed on Cretaceous carbonate sediments.

The first type relief is spread over the central and north part of the region where are spread Lower and Mid-Jurassic Sori suite intensively folded sandstones and clay-shales that are not well sustainable against the denudative processes and complicated with fractured and rupture dislocations. Due to the dense hydrographic network, relief is here highly dissected. Dissection depth varies within a 300-1000 m range. Relief positive shapes – watersheds and their branchings are characterized with narrow rocky and sharp crests; and gorges are characterized with narrow and deep V-shaped transversal profiles and steep inclining slopes (35-45°).

The second type of relief is developed in the south part of the region where the Bajocian volcanogenic-sedimentary formations are spread. The rocks here are composed of massive porphyrite dykes sustainable against denudative processes and lava coverings, tuff-breccias, tuff-conglomerates and poorly sustainable layered rocks – tuffogenic sandstones and tuffs. Variegation of these rocks is observed while forming of alpine petromorphic relief which stipulates distinctiveness of relief shapes and intense dissection of the surface. Porphyrites, tuffo-breccias and tuff-conglomerates in the crest parts of the ridges originate rocky, tent-style or tower-like forms, on the slopes – inclined, dissected relief or hanging walls. In contrast, rather soft rocks – tuff-sandstones and tuffs create saddles on the watershed crests and smoother relief on the slopes. Narrow and deep gorges, steeply inclined stepped slopes are typical for the multiple affluents. Numerous waterfalls are observed in the gorges of a few affluents which heights sometimes reach 30-40m.

The third type of relief is developed in the south part of the study area where Cretaceous sediments are composed of limestones, marls, glauconitic sandstones, clays, sandy clays, dolomitized limestones and others. This type of relief is spread along the narrow line among Jurassic sediments in the north –and among Paleogene sediments in the south and is connected to the north flank of Racha-Lechkhumi syncline. Thus, rocks lithology as well as tectonic structure of their spreading zone stipulate relief morphological feature. Relief various shapes, distinct shapes, walls of 30-35m heights are typical for this type of relief that are developed in the gorge of the river Tskhenistskali to the north from Tsageri in the Upper cretaceous limestones. Much higher walls we can meet in Muri Bridge vicinities where the river Tskhenistskali creates a deep antecedent gorge in Cretaceous carbonate rocks which is known as “Muri Canyon”. Here, the slopes of the gorge are almost vertical and the river-bed width doesn’t exceed 15m. As for the river Tskhenistskali, it creates meridional lateral erosive gorge in the study area (crosses the folded structure at a more-or-less right angle) with V-shaped transversal profile which has unequal width. In the wider sections of the gorge, in some places, accumulation zones are observed with well-developed embankment and the terrace arranged above the embankment.

5. Hydrology

The water-bearing nature of the rock in the study area is determined by lithological-structural as well as morphological and climate conditions. Considering all these factors, here are distinguished several water-bearing complexes and one impermeable horizon spreading zones. The first water-bearing complex is connected to clay shales and sandstones of Lower and Mid-Jurassic Sori suite. Underground water circulation in these rocks is going in the fractures resulting from the weathering and along the layer surface as well and in fractures and fault structures that originated in tectonic dislocation zones. Most of the springs are connected to upper, more weathered zones of sandstones and shales with thickness reaching to some dozen meters. Recharge of water-bearing complex mainly occurs by means of atmospheric precipitations and at the expenses of water obtained after melting of snow but discharges into the hydrographic network. Spring discharges vary between 0.5-5.0 l/sec. The springs related to diluvions are characterized with less discharge – 0.02-1.0 l/sec. Shallow (or depthless) circulation waters are hydrocarbonate-calcium-magnesium or hydrocarbonate-calcium-sodium compositions. These waters total mineralization is low - about 0.07-0.7 g/l; total hardness varies within 0.7-5.0 mgr/eq.; carbonate hardness – within 0.8-3.4 mgr/eq. PH – 5.0-7.0; water temperature of 5-14°C. Chemistry of springs of deluvial cover is also similar.

Deep circulation underground waters are generally hydrocarbonate-calcium-sodium compositions. Such a mineral spring with significant flow (several thousand liters during twenty-four hours) is located on the right bank of the river Tskhenistskali near the village Tsiplakakia. At a distance of 11 km, to the south from Lentekhi, the spring is related to a fault zone and directly springs out from the base rock. Water temperature is 14 ° C, mineralization – 3.3 g/l. Carbon dioxide is emitted. Low-flow springs of the same composition are found in the gorges of the river Lamanasheri and near the village of Chkheteli.

The second water-bearing complex of underground water circulation connected to the Khojali suite volcanogenic-sedimentary formations originates in fractures as well as in rock pores. Generally, poor water encroachment is typical for the Khojali suite but its flow significantly surpasses flow of Liasian terrigene sediments. Recharge of shallow circulation underground waters is at the expense of atmospheric precipitations and consequently is characterized by seasonal variability. They get additional recharge from melting of snow, flow of which is between 0.9-2.0 l/s, and mineralization - 0.09gr/l. The discharge of deep circulation underground water varies between 2.5-4.0 l/s, with mineralization between 0.28-0.3 gr/l. The discharge of waters flowing out from deluvial-colluvial cover reaches 1.0 l/s.

Shallow circulation waters generally have hydrocarbonate-calcium-magnesium-sodium chemical composition. In some springs related to tectonic dislocations we can observe increase of sulphate -ion and chlorine-ion content (up to 30 mgr/eq %). Dry residues vary within 0.06-0.3 gr/l. Total hardness doesn't exceed 5 mgr/eq. PH – 5.7. Underground water temperature varies between 5 - 14° C. Deep circulation underground waters are mainly composed of mineral waters containing sulphur, hydrogen, chlorine, sulphate, -calcium, -sodium, and bicarbonate.

The third water-bearing complex is related to Cretaceous carbonate sediments which participate in construction of the north flank of Racha-Lechkhumi syncline in our study area and is composed of sandstones, limestones, dolomitic limestones, marly limestones, marls, and clays. Limestones in this complex are dolomitic that are more fractured than sandstones and marls that contributes to circulation of atmospheric precipitations and origination of underground waters. Consequently, the springs of this complex mainly belong to fractured genesis. In some places, karstic phenomena are observed that is found in all types of limestones with various intensity especially, in Turonian - Cenomanian limestones. According to circulation terms, there are distinguished two zones in underground waters. The first covers hypsometrically elevated area and total exposure part of carbonate sediments over erosion basis. The second zone is located under it and is composed of deep circulation waters. Debit of shallow circulation springs varies within 0.3-2.0 l/sec. Chemically, they are bicarbonate-calcium-sodium composition. Chlorine and sulphate ion content doesn't exceed 7 mgr/eq.%, but sodium and magnesium ions rarely reach 20 mgr/eq%; mineralization is low – about 0.08-0.4 gr/l, total hardness – 0.4-4.0 mgr/eq. PH – 5.6-60, temperature – 12-15°C. Chemistry of waters related to deluvial cover is also analogue. The waters of this complex are widely used for potable water supply. One of the impermeable horizons in the study area is connected to Aptian-Albian (K_1 ap-al) sediments. These rocks participate in the construction of Racha-Lechkhumi syncline north flank in form of low thickness patch and are composed of marl limestones, marls and clays. The rocks are characterized with weak fracturing and related water debit doesn't surpass 0.05 l/sec; they are bicarbonite-calcium composition; total mineralization – 0.2 gr/; total hardness of waters – 2.0 mgr/eq; temperature 10-12 °C.

Besides the water-bearing complex related to above discussed base rocks, water-bearing horizon of underground waters of alluvial-proluvial genesis plays an important role in the study area which are spread over alluvial-proluvial sediments of the Tskhenistskali River embankment and terrace existing above the embankment. Water-bearing horizon is also developed in alluvion of big tributaries and in quite heavy alluvial cones. These sediments are composed of boulders, cobbles, gravels, crushed stones, and sands. High filtration character and consequently abounding in water are typical for them. Underground water debit related to recent alluvial sediments varies within 1.0-8 l/sec. Total mineralization is low – 0.1-0.5 g/l. To the chemical standpoint they have bicarbonate-calcium- magnesium or bicarbonate-calcium-sodium composition. Total hardness is 0.4-0.7 mgr/eq. pH 6-7, temperature 4-15 °C. Depth of arrangements of water-bearing horizon surface varies within 0.2-0.4 m. Recharge is generally going with river-waters and partly with infiltration of atmospheric precipitation; regime is changeable and depends on changes in river-water level. The waters of this horizon are characterized with good drinking qualities and their prospective value is low due to limit in spreading.

6. Geological-Engineering (Geotechnical) Conditions

According to geological-engineering zoning of Georgia, the study area belongs to an area of alpine and medium-altitude mountains of the Caucasus South Slope Folded System. Among geotechnical groups of rock: hard-rock, soft-rock and friable-unconsolidated rock zones. Bajocian porphyrite waters (J_2 *h*d) tuff-breccias, tuff-conglomerates, porphyrites lava coverings, cretaceous limestones and dolomitized limestones constitute the hard-rock group. The same geotechnical group includes Mid-Jurassic sub-volcanic formations: diabase-porphyrites (J_2) and quartzy porphyrites (J_2).

Clay shales of Low and Mid-Jurassic Sori suite with sandstone interlayers that are mostly dominant in the study area constitute the soft-rock group.

Friable-unconsolidated rock group includes fragmented and processed materials of river beds, embankments, above-embankment terraces and alluvial fans of Upper-Quaternary Q_{III} and recent Q_{IV} alluvial-proluvial origin, such as: cobbles gravel, crushed stone, and sand, with inclusions of various sized boulders. The same group includes diluvial, alluvial-diluvial and colluvial sediments spread over the slopes and plumes developed in some places in the bottom of the slope. Their spreading is too limited and is mainly related to the local areas relief specific shapes. Their thicknesses vary, generally in the range of 0.3-1.5 m and rarely greater than 2.0-3.0 m. Consequently, their value in forming of region geotechnical conditions is insignificant. The study area geotechnical conditions are directly related to physical-mechanical property of above-mentioned rocks. The main part of the project hydropower construction is a dam, power tunnel, pressure tunnel, hydropower plant and tailrace, which will be developed underground and around the hard and soft rock zones. Rock Quality Designations (uniaxial compression strength Rc) vary within a wide range (see tab. #1). The quality designations for the same rock are also variable in the upper weathered zones of the vertical section and in unaltered zones below it. For instance, the quality designation of weathered clay shale is 50 kg/cm^2, and un-weathered clay shale is 800 kg/ cm^2. Also, rocks physical-mechanical properties are different in tectonic dislocated and alternated zones. All above-mentioned factors cause complications in evaluating geotectonic conditions and require detailed investigations at the exact locations of potential construction work during the feasibility study phase.

Exogenic processes are important for determination of geotechnical conditions on the study area. Characteristics and peculiarities of these processes are determined by region complex geological-geomorphologic structure, hydrometeorological and climate conditions, neotectonics, seismic-technical activations, rocks geotechnical properties and sometimes population domestic activities. The most common among developed exogenic processes are: rocks physical-chemical weathering, denudation, landslides, mudflows and snow avalanches.

Weathering processes on the study are is quite intensive; high mountain climate conditions, rocks high level exposure, intense fracturing and consequently high water-permeability play key roles in weathering processes. These rocks cause disintegration and origination of friable-fragmented materials. The significant accumulation of the latter in the slopes of the gorges and in river beds creates mudflow feeding area. Erosion is the most active process among denudation processes on the study area which is composed of spatial as well as linear forms. Spatial erosion processes are developed in heads of tributaries and slopes of the gorge. There is no information about process speeding value. We should think that it is significantly increased during rains and snow melting period.

Linear erosion processes are observed in every river and gorge of the region and represent both lateral and vertical forms. Lateral erosion mainly is developed in the river Tskhenistskali and its abundant tributaries where broadening of the bottom of the gorge is produced by the meandering of the river. Lateral erosions average speed is 0.5-5.0 m per year, based on monitoring on some sections of the river Tskhenistskali. However, sometimes this value can reach 5.0-8.0 m in 24 hours during particularly high runoff events. Deep or regressive erosion is developed from the mouth of tributary or temporary streams going towards the head and forms longitudinal profile balance, that is, where the slope is steepest and water is flowing fastest, vertical scour happens fastest. There is no data about its speed value.

Among denudation processes one of the most important is the karstic effect. Based on technical opinion the proposed underground hydropower plant is supposed to be placed in the complex of Upper Cretaceous carbonate rocks. As we already mentioned, the limestones in this complex are characterized with heavy fracturing that contributes to precipitation infiltration, circulation and origination of underground water, which in turn creates convenient circumstances for development of karstic processes. It is true that the karst cavities are not specifically known in the vicinity of the proposed powerhouse, but a great number of high discharge karstic springs in the mentioned limestone layered zone show their probable existence. In regard to this, one of the main tasks at the feasibility phase of the geotechnical survey should be a study of speed of karst forming conditions, to help avoid major complications during construction of the hydropower plant or its operational period.

Landslides and mudflows are considered as the most widespread and hazardous geodynamic processes which historically did harm to local inhabitants and continue to cause significant problems even today. The landslides that develop in the region are plastic and floatingly-plastic. According to accessible depth, they are mainly surface form (up to 5.0 m deep), rarely there are deep forms (15-20 m). In some cases we have landslides of complex morphology when base rock is moving together with cover. Such types of landslides are generally connected to the rocks of Lower and Mid-Jurassic Sori suite.

Besides the landslides, other types of gravity displacements such as slope collapses and screes which create obstructions to roads during long-lasting rains and snow melting period.

Mudflows (or debris flows) deserve a great deal of attention due to their destructive forces. Coincidence of several natural conditions are necessary for their origination. Among them the most important are:

1. Alpine relief with steep exposed slopes and significant slope of the rivers or temporary stream beds;
2. Significant accumulations of friable-fragmented materials originated from weathering in beds and on the slopes of a gorge;
3. Climate properties that are expressed by periodically fast melting of high snow cover that is typical for this region, and by long-lasting heavy rains.

Generally, observations show that mudflows originate after long-term rains that last for several hours and gradually change into short-term heavy rains (lasting for several minutes) with intensities equal or exceeding 0.8 mm/s. Heavy mudflows are periodically experienced in the gorges of the following rivers: Devashi, Lakashuri, Khopuri, Kvedreshi, Rtskhmeluri, and others. Mudflow does harm to public utilities in the region, destroys buildings and plot of lands that are the core reasons why people are forced to change their residencies.

Snow avalanches are also quite frequent within the study area. They are similar natural phenomena to slope collapses which also have great destructive force. Avalanche prone areas are located on the slopes of the gorge, in funnel-shaped or circ-shaped depressions. Snow avalanche debris is deposited in avalanche cones; and after melting different sized fragments remain. The main destructive force is an air blast wave that immediately proceeds the impact of a snow avalanche.

Flooding is also frequent in the study area. During long-lasting rains and melting of snow not only the basic rivers but small brooks or gullies are characterized with rapid increase of water flow rates, which greatly exceed the average value (flash floods). Flooding generally occurs in the spring time when snow is melting. Minimum water levels in the rivers usually occur in the late autumn and winter periods.

General description and physical-mechanical indicators of the rocks spread over the study are given in the attached table.

7. Conclusions and Recommendations

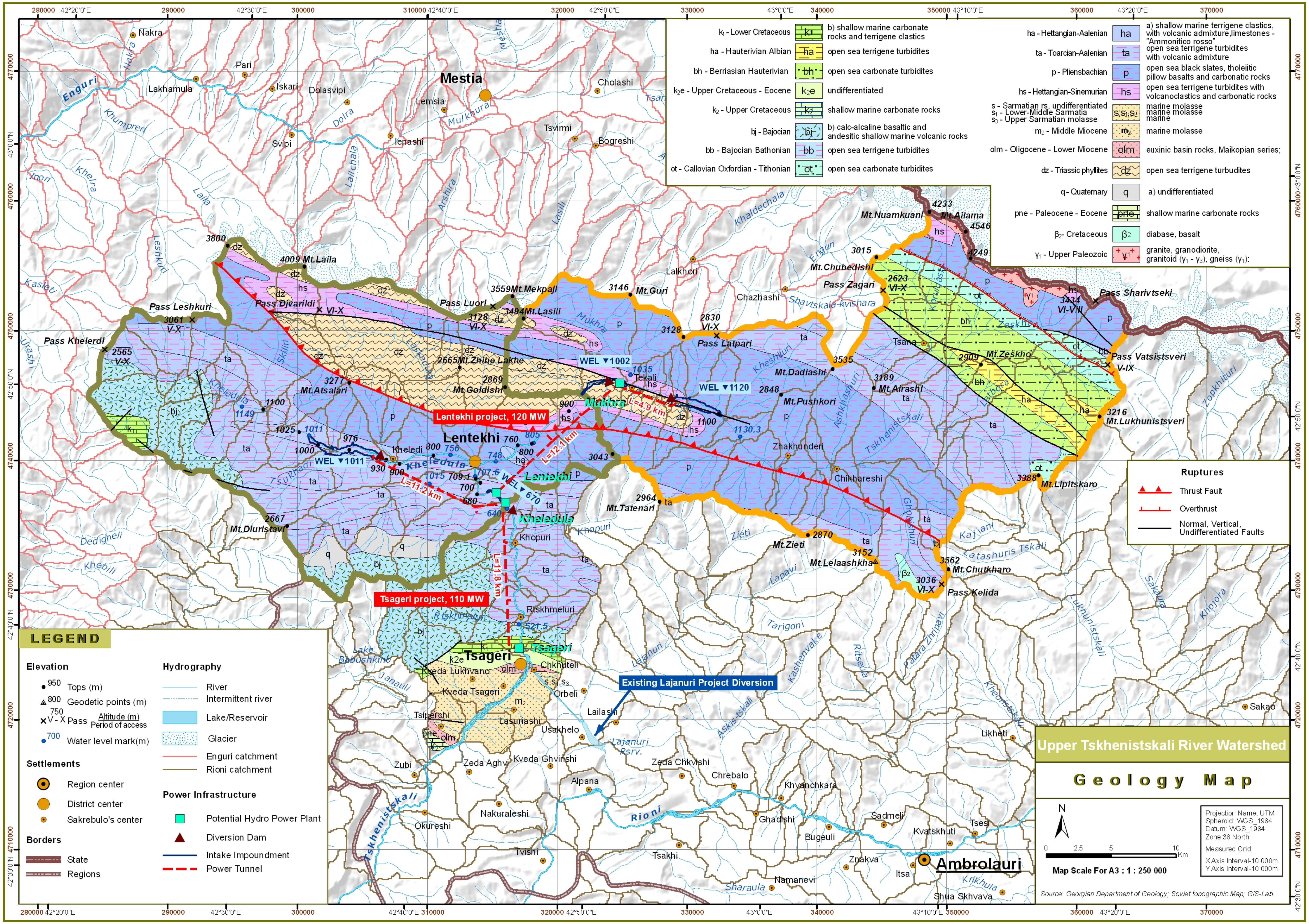
- According to complication of geotechnical conditions, the study area due to complex tectonic structure and high seismic activivity is classified as “quite complicated III category”;
- Alluvial-proluvial, sedimentary, volcanogenic-sedimentary and magmatic rocks are spread throughout the study area; they belong to geotechnical engineering groups of friable-unconsolidated, soft- The mentioned rocks according to their physical-mechanical properties create more-or-less convenient conditions for building of hydrotechnical construction and for long-term operations;
- The study area is rich in industrial minerals. Here are found: diabase, limestone, sandstone, gravel, and building sand deposits which reserves surpass quantity of materials needed for construction of this hydropower project and their utilization helps its minerals’ supply problem. At the next phase of survey, separation of these deposits reserves into A and B category is essential and complete evaluation of quality of industrial minerals to accomplish the relevant demands is necessary;
- Intense recent geodynamic processes are deemed to be the main obstacles for building and operating of the proposed hydropower plant and may present serious obstacles for implementation of the project in particular areas. Building of protection structures should be considered during detailed design to mitigate risk from geodynamic processes.

Geologist-Engineer - V. Sulkhanishvili

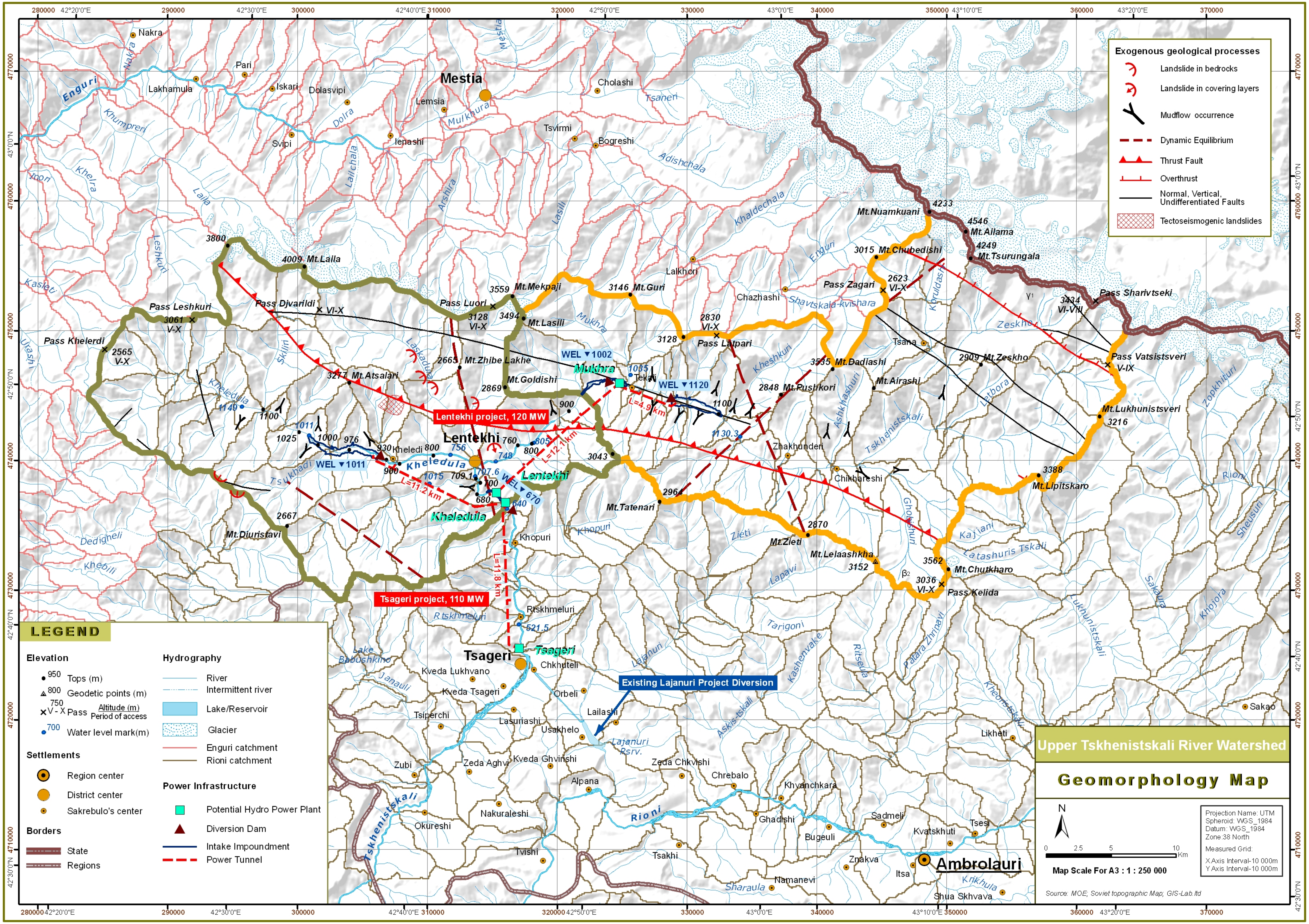
Geological and Geological-Engineering Description of the Rocks Spread Over the Study Area

Structural Stage	Geotectonic Unit	Formation	Rock geological genetic complex	Rock Complexes Geological Index		Rock Complexes Geological-Engineering Group: Friable-unconsolidated	Semi-rocky	Rocky	Rock Physical-Mechanical Properties: Density in Natural Condition P g/cm^3	Hardness Ratio according to M. Protodiakonov	Flotation Ratio K m/per day	Ground Calculation Resistance Ro 0.1 mPa	Resistance on One-axis Compression Ro 0.1 mPa
Quaternary	Caucasus South Slope Folded System I Transcaucasian intermountain area II	Continental sediment	Alluvial-Proluvial formations, river beds, embankment, alluvial fans, fragmented and processed materials. Cobbles boulders, gravel, crusted stone and sand.	ap Q_{IV}		■				0.5-1.5	4.0-10.0 Broad interval	1.0-3.0	-
Alpine	Transcaucasian intermountain area II Central Zone of uplift II_2	Epicontinental-Carbonate Sediment	Clay, Marls, Sandstone, as interlayers and packs	Oligocene Miocene	E_3+N_1		■		1.70-2.00 2.64-2.70 2.20-2.60	1.0-1.5 8.0 2.0	-	-	Clay 5-30 Sandstone 80-600 Marl 5-100
			Marly limestone, marl, glauconitic sandstone, Limestone, dolomitized-limestone.	Chalk	K			■	2.61-2.63 1.70-2.00 1.80-2.22	8.0 1.5 4.0-5.0	-	-	Limestone 500-900 Clay 5-30 Dolomitized.limestone 150-2000
	Caucasus South Slope Folded System I Chkhalta-Laila Zone I_4 and Gagra-Djava Zone I_5 Khaishi sub-zone	Magmatic intrusion	Quartzy porphyrite, Diabase, diabase-porphyrite	Middle Jurassic	uJ_2			■	2.77-2.90	1.0	-	-	Porphyr.covers 1170-2140
		Volcanogenic-Sediment	Tuff-breccia, tuff-conglomerate, Tuffogenic sandstone, tuff, porphyrite lava covering. (porphyrite Series)		J_2 b			■	2.57-2.82	6.0-8.0	-	-	Tuffogenic sandstones 950-2700 Tuff-breccia. 500-2000
		Metamorphic Marine-Sediment	Clay shale, scaly shale, dark gray and occasionally black micaceous quartzy sandstone inter-strata (Sori and Muashi Series)	Lower Jurassic	J_1		■		2.45-2.55 2.52-2.60	5.0-6.0 4.0-5.0	-	-	Scaly shale 600-1100 Clay shale 50-600
			Metamorphic clay shale and phyllite shale, sandstone and gray marble lenses (Dizi Series)	Paleozoic and Triassic	Pz+T			■	2.70-2.72 2.69-2.70 2.80-2.81	6.0 8.0 8.0	-	-	Clay-shales 600-1350 Marble 600-1400 Metamorphic Sandstone 1200-2190

Geodynamic events and processes	**Other marks**	**Project hydro tectonic tract**
Landslip and snow slip of rocks	Bounder between geologic genetic complexes	Mark of source building and flood m.
Splitting line	Tectonic destructions and chinks	Derivation diameter and length m.
Side erosion	III — III' Incision line	Hydro power building and tail water mark m.
Silt		Number of hydro power
Split blocks		



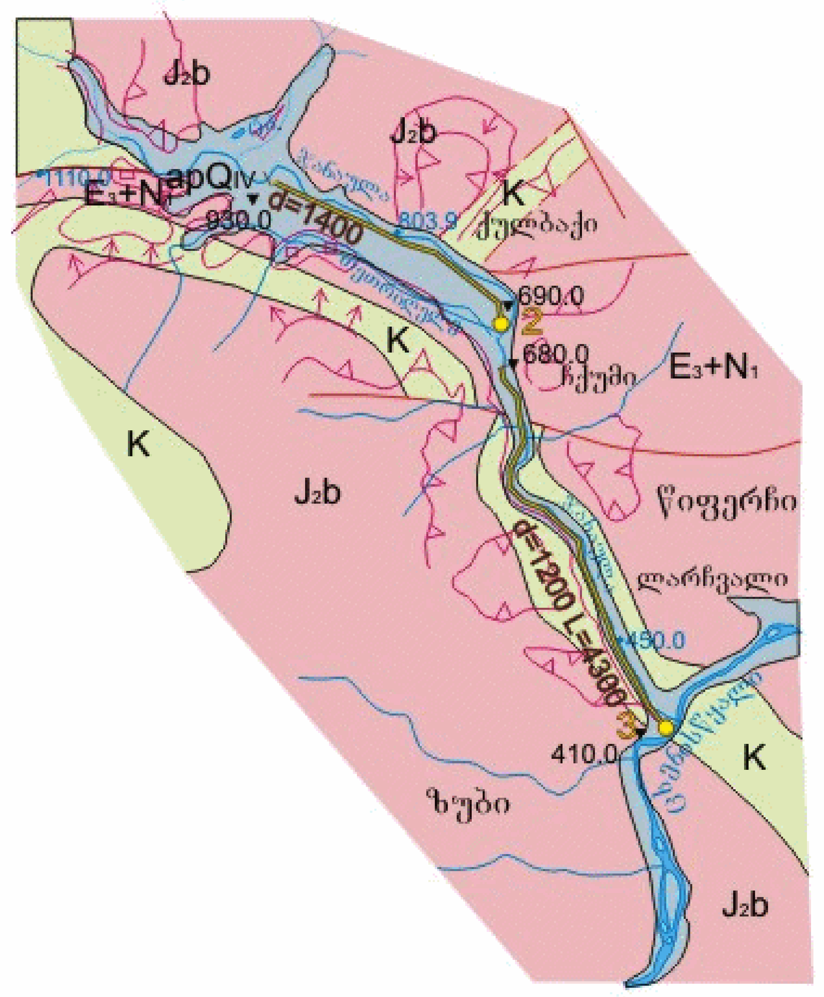
Upper Tskhenistskali River Watershed
Geology Map
LEGEND
Elevation
Tops (m)
Geodetic points (m)
V - X Pass Altitude (m) Period of access
Water level mark(m)
Settlements
Region center
District center
Sakrebulo's center
Borders
State
Regions
Hydrography
River
Intermittent river
Lake/Reservoir
Glacier
Enguri catchment
Rioni catchment
Power Infrastructure
Potential Hydro Power Plant
Diversion Dam
Intake Impoundment
Power Tunnel
k1 - Lower Cretaceous — b) shallow marine carbonate rocks and terrigene clastics
ha - Hauterivian Albian — open sea terrigene turbidites
bh - Berriasian Hauterivian — open sea carbonate turbidites
k2e - Upper Cretaceous - Eocene — undifferentiated
k2 - Upper Cretaceous — shallow marine carbonate rocks
bj - Bajocian — b) calc-alcaline basaltic and andesitic shallow marine volcanic rocks
bb - Bajocian Bathonian — open sea terrigene turbidites
ot - Callovian Oxfordian - Tithonian — open sea carbonate turbidites
ha - Hettangian-Aalenian — a) shallow marine terrigene clastics, with volcanic admixture,limestones - "Ammonitico rosso"
ta - Toarcian-Aalenian — open sea terrigene turbidites with volcanic admixture
p - Pliensbachian — open sea black slates, tholeiitic pillow basalts and carbonatic rocks
hs - Hettangian-Sinemurian — open sea terrigene turbidites with volcanoclastics and carbonatic rocks
s - Sarmatian rs, undifferentiated; s1 - Lower-Middle Sarmatia; s3 - Upper Sarmatian molasse — marine molasse; marine molasse; marine
m2 - Middle Miocene — marine molasse
olm - Oligocene - Lower Miocene — euxinic basin rocks, Maikopian series;
dz - Triassic phyllites — open sea terrigene turbudites
q - Quaternary — a) undifferentiated
pne - Paleocene - Eocene — shallow marine carbonate rocks
β2 - Cretaceous — diabase, basalt
γ1 - Upper Paleozoic — granite, granodiorite, granitoid (γ1 - γ3), gneiss (γ1):
Ruptures
Thrust Fault
Overthrust
Normal, Vertical, Undifferentiated Faults
Lentekhi project, 120 MW
Tsageri project, 110 MW
Existing Lajanuri Project Diversion
L=4.9 km
L=12.1 km
L=11.2 km
L=11.8 km
WEL ▼1002
WEL ▼1120
WEL ▼1011
WEL ▼670
Mukhra
Lentekhi
Kheledula
Tsageri
Mestia
Ambrolauri
Lentekhi
Tsageri
Nakra
Pari
Lakhamula
Iskari
Dolasvipi
Lemsia
Cholashi
Tsvirmi
Bogreshi
Ienashi
Svipi
Lalkhori
Chazhashi
Tsana
Tekali
Kheledi
Zhakhunderi
Chikhareshi
Khopuri
Rtskhmeluri
Chkhuteli
Orbeli
Kveda Lukhvano
Kveda Tsageri
Tsipershi
Lasuriashi
Usakhelo
Lailashi
Zubi
Zeda Aghvi
Kveda Ghvinishi
Zeda Chkvishi
Chrebalo
Alpana
Khvanchkara
Ghadishi
Sadmeli
Tsesi
Kvatskhuti
Bugeuli
Nakuraleshi
Okureshi
Tvishi
Tsakhi
Znakva
Itsa
Namanevi
Shua Skhvava
Likheti
Sakao
Mt.Laila
Mt.Mekpaji
Mt.Lasili
Mt.Guri
Mt.Zhibe Lakhe
Mt.Goldishi
Mt.Atsalari
Mt.Diuristavi
Mt.Tatenari
Mt.Zieti
Mt.Lelaashkha
Mt.Chutkharo
Mt.Lipitskaro
Mt.Lukhunistsveri
Mt.Airashi
Mt.Pushkori
Mt.Dadiashi
Mt.Zeskho
Mt.Chubedishi
Mt.Nuamkuani
Mt.Ailama
Pass Leshkuri
Pass Khelerdi
Pass Djvarildi
Pass Luori
Pass Latpari
Pass Zagari
Pass Sharivtseki
Pass Vatsistsveri
Pass Kelida
Enguri
Khumpreri
Dolra
Mulkhura
Mestia
Lailchala
Arshira
Laila
Khelra
Leshkuri
Kaslet
Skilri
Mukhra
Kheledula
Tsukhadi
Dedigheli
Khebili
Khopuri
Zieti
Lapavi
Tarigoni
Kashenvake
Ritseula
Lajanuri
Lajanuri Rsrv.
Janauli
Askis-tskali
Rioni
Tskhenistskali
Sharaula
Krikhula
Lukhunistskali
Sakaura
Khojora
Kajiani
Latashuris Tskali
Ghobishuri
Ashkhashuri
Kheshkuri
Zeskho
Shavtskala-kvishara
Kaldechala
Lasili
Koruldashi
Lake Babushkino
Projection Name: UTM
Spheroid: WGS_1984
Datum: WGS_1984
Zone:38 North
Measured Grid:
X Axis Interval-10 000m
Y Axis Interval-10 000m
Map Scale For A3 : 1 : 250 000
Source: Georgian Department of Geology; Soviet topographic Map; GIS-Lab.


Upper Tskhenistskali River Watershed
Geomorphology Map
Exogenous geological processes
Landslide in bedrocks
Landslide in covering layers
Mudflow occurrence
Dynamic Equilibrium
Thrust Fault
Overthrust
Normal, Vertical, Undifferentiated Faults
Tectoseismogenic landslides
LEGEND
Elevation
950 Tops (m)
800 Geodetic points (m)
750 V - X Pass Altitude (m) Period of access
700 Water level mark(m)
Settlements
Region center
District center
Sakrebulo's center
Borders
State
Regions
Hydrography
River
Intermittent river
Lake/Reservoir
Glacier
Enguri catchment
Rioni catchment
Power Infrastructure
Potential Hydro Power Plant
Diversion Dam
Intake Impoundment
Power Tunnel
Lentekhi project, 120 MW
Tsageri project, 110 MW
Existing Lajanuri Project Diversion
Mestia
Lentekhi
Tsageri
Ambrolauri
Mukhra
Kheledula
Lentekhi
Tsageri
L=4.9 km
L=12.1 km
L=11.2 km
L=11.8 km
WEL ▼1002
WEL ▼1120
WEL ▼1011
WEL ▼670
Mt.Nuamkuani 4233
Mt.Ailama 4546
Mt.Tsurungala 4249
Mt.Chubedishi 3015
Mt.Laila 4009
Mt.Mekpaji 3559
Mt.Guri 3146
Mt.Lasili 3494
Mt.Dadiashi 3535
Mt.Zeskho 2909
Mt.Lukhunistsveri 3216
Mt.Lipitskaro 3388
Mt.Chutkharo 3562
Mt.Zieti 2870
Mt.Lelaashkha 3152
Mt.Tatenari 2964
Mt.Diuristavi 2667
Mt.Atsalari 3277
Mt.Zhibe Lakhe 2665
Mt.Goldishi 2869
Mt.Pushkori 2848
Mt.Airashi
Pass Leshkuri 3061 V-X
Pass Khelerdi 2565 V-X
Pass Djvarildi VI-X
Pass Luori 3128 VI-X
Pass Latpari 2830 VI-X
Pass Zagari 2623 VI-X
Pass Sharivtseki 3434 VI-VIII
Pass Vatsistsveri V-IX
Pass Kelida 3036 VI-X
Enguri
Rioni
Tskhenistskali
Kheledula
Lajanuri Rsrv.
N
0 2.5 5 10 Km
Map Scale For A3 : 1 : 250 000
Projection Name: UTM
Spheroid: WGS_1984
Datum: WGS_1984
Zone:38 North
Measured Grid:
X Axis Interval-10 000m
Y Axis Interval-10 000m
Source: MOE; Soviet topographic Map; GIS-Lab.ltd

მდ. ცხენისწყალზე და მის შენაკადებზე მცირე სიმძლავრის ჰესების მოწყობის პერსპექტივა საინჟინრო-გეოლოგიური რუკა (წინასაპროექტო სტადია)

მ-ბი 1 : 100 000

მდ. ჯანაულას უბანი



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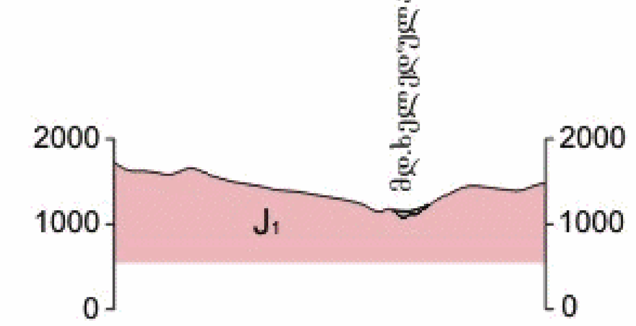
მ-ბი 1:100000



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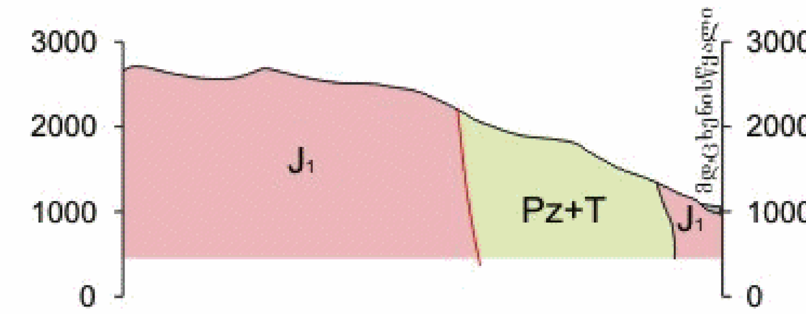
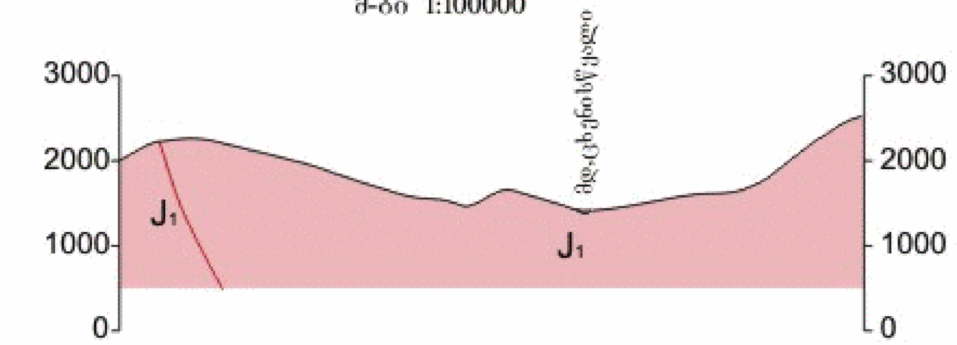


ჭრილი III-III'
მ-ბი 1:100000



სტრუქტურული სართული	ტექტონიკური ერთეული	ფორმაცია და მისი ტიპი	ქანების გეოლოგიურ-გენეტიკური კომპლექსი	ქანების კომპლექსების გეოლოგიური ინდექსი		ქანების კომპლექსების საინჟინრო-გეოლოგიური ჯგუფი: ფხვიერ-შეუკავშირებელი	ნახევრად კლდოვანი	კლდოვანი	ქანების ფიზიკურ-მექანიკური თვისებები: სიმკვრივე ბუნებრივ მდგომარეობაში ρ გ/სმ³	სიმტკიცის კოეფიციენტი მ. პროტოდიაკონოვის მიხედვით	ფილტრაციის კოეფიციენტი K მ/დღ	გრუნტის საანგარიშო წინააღმდეგობა R_0 0.1 მპა	წინააღმდეგობა ერთღერძა კუმშვაზე R_0 0.1 მპა
ალპური	კავკასიონის ნაოჭა სისტემა I ამიერკავკასიის მთათაშუა არე II	კონტინენტური დანალექი	ალუვიურ-პროლუვიური წარმოშობის მდინარეთა კალაპოტების და გამოზიდვის კონუსების ნატეხოვანი და დამუშავებული მასალა, კაჭარ-კენჭნარი, ხრეში, ღორღი, ხვინჭა და ქვიშა, ლოდების ჩანართებით	apQ_{IV}		■				0.5-1.5	4.0-10.0 ფართო დია-პაზონი	1.0-3.0	-
	ამიერკავკასიის მთათაშუა არე II (ცენტრალური აზევების ზონა II_2)	დანალექი	თიხები, მერგელები, ქვიშაქვები შუა-შრეებისა და დასტების სახით	ოლიგოცენ-მიოცენი	E_3+N_1		■		1.70-2.00 2.64-2.70 2.20-2.60	1.0-1.5 8.0 2.0	-	-	თიხა 5-30 ქვიშაქვა 80-600 მერგელი 5-100
			კირქვები მერგელოვანი, მერგელები, ზოგან თიხებისა და გლაუკონიტიანი ქვიშაქვების შრეები, დოლომიტიზირებული კირქვები	ცარცი	K			■	2.61-2.63 1.70-2.00 1.80-2.00	8.0 1.5 4.0-5.0	-	-	კირქვა 500-900 თიხა 5-30 დოლომ. კირქვა 150-2000
	კავკასიონის ნაოჭა სისტემა I ჩხალთა-ლაილის I_4 და გაგრა-ჯავის I_5 ზონები	მაგმური ინტრუზია	დიაბაზები	შუა იურა	uJ_2			■	2.77-2.90	1.0	-	-	2850-2900
		ვულკანოგენურ-დანალექი	ტუფოკონგლომერატები, ტუფოქვიშაქვები, ტუფოალევროლიტები (პორფირიტული სერია)	შუა იურა	J_2b			■	2.57-2.82 -	6.0-8.0	-	-	ტუფოქვიშაქვა 950-2700 ტუფოკონგლომერატი 500-2000
		მეტამორფიზირებულ-დანალექი	თიხა ფიქლები და ასპიდური ფიქლები, მუქი ნაცრისფერი, იშვიათად შავი, კვარციანი ქვიშაქვების შუაშრეები (სორის და მესტიის წყება)	ქვედა იურა	J_1		■		2.45-2.55 2.52-2.60	5.0-6.0 4.0-5.0	-	-	ასპიდური ფიქლები 600-1100 თიხა ფიქლები 50-600
			მეტამორფიზირებული თიხა ფიქლები და ფილიტიზირებული ფიქლები, ქვიშაქვები, მარმარილოვანი ნაცრისფერი კირქვების ლინზები (დიზის წყება)	პალეოზოური და ტრიასული	Pz+T			■	2.70-2.72 2.69-2.70 2.80-2.81	6.0 8.0 8.0	-	-	თიხა ფიქლები 660-1350 მარმ. 600-1400 მეტამორფ. ქვიშაქვა 1200-2190

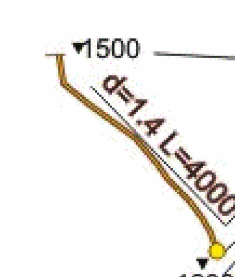
გეოდინამიკური მოვლენები და პროცესები

- მეწყრები და კლდეზვავები
- მოწყვეტის ხაზი
- გვერდითი ეროზია
- ხევი
- მოწყვეტილი ბლოკები

სხვა აღნიშვნები

- საზღვარი გეოლოგიურ გენეტიკურ კომპლექსებს შორის
- ტექტონიკური რღვევები და ნაპრალები
- III — III' ჭრილის ხაზი

საპროექტო ჰიდროტექნიკური ტრაქტი



- სათავე ნაგებობის და შეტბორვის ნიშნული მ.
- სადაწნევო დერივაციის დიამეტრი და სიგრძე მ.
- ჰესის შენობა და ქვედა ბიეფის ნიშნული მ.
- ჰიდროელექტროსადგურის ნომერი

Appendix 2

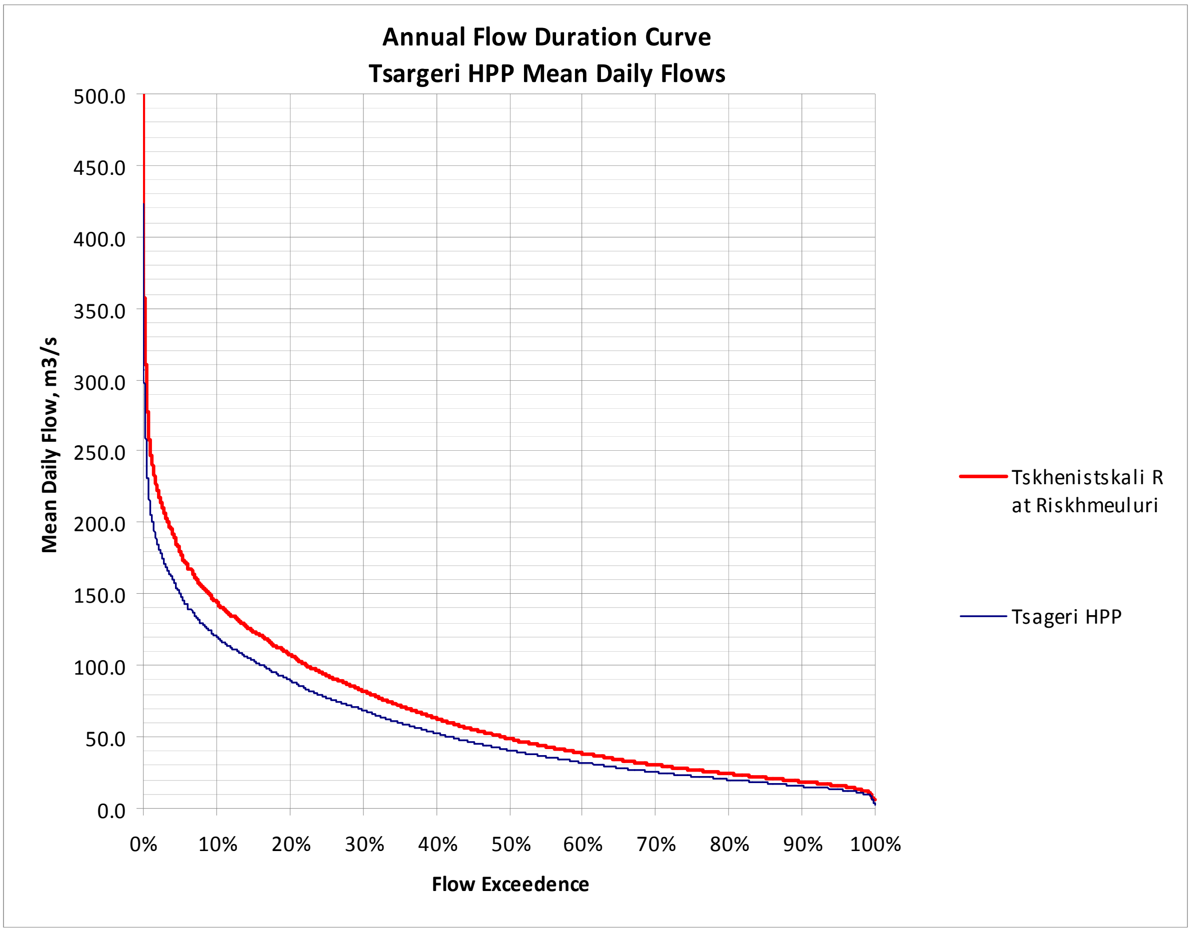
Monthly and Annual Flow Duration Curves

Note related to this Appendix:

The generation tables following each Flow Duration Curve represent a conservative selection of input data and, therefore, a conservative analysis for monthly and annual Tsageri HPP generation using this methodology.

Tsageri HPP Flow Duration Curves and Energy Analysis

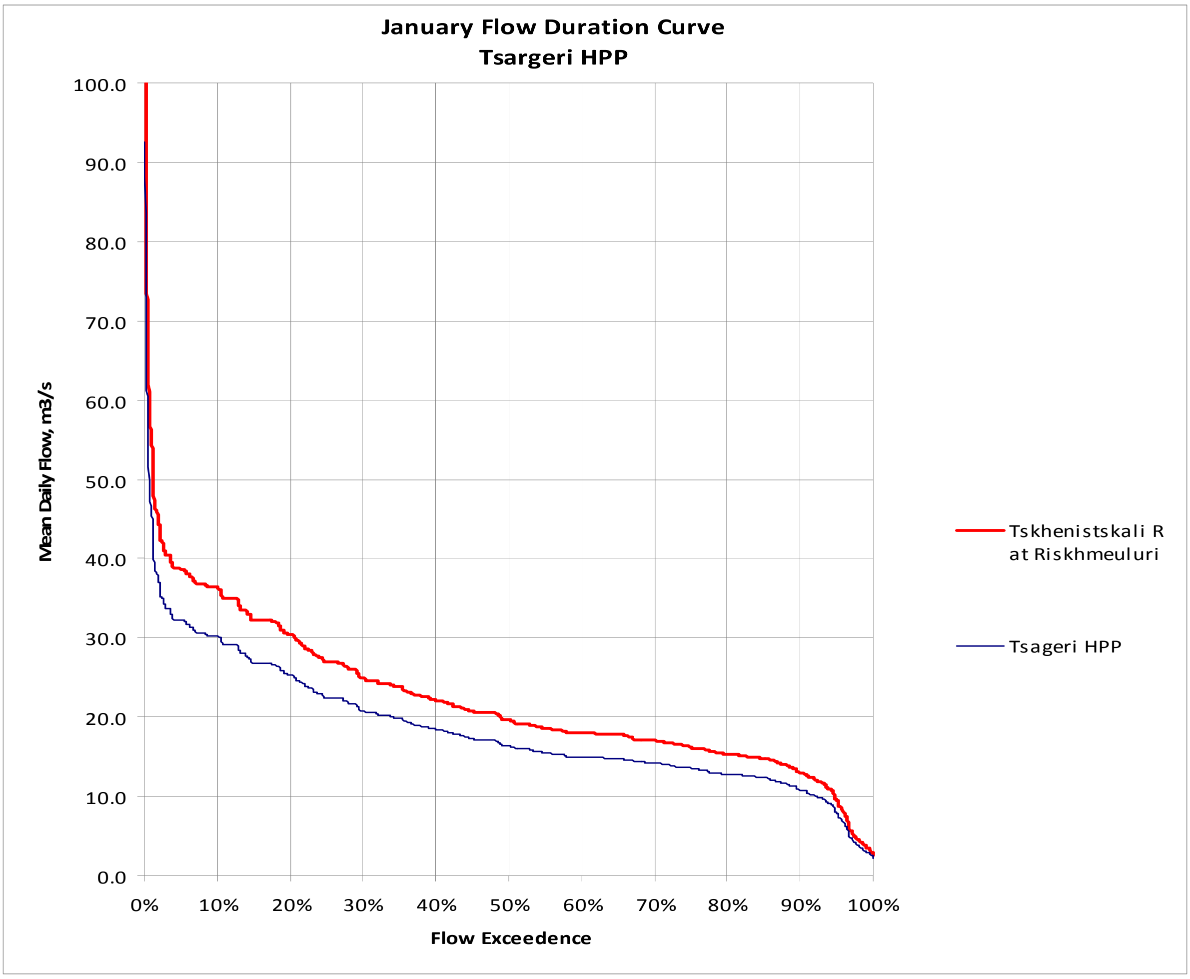
Appendix 2 Table of Contents



Annual

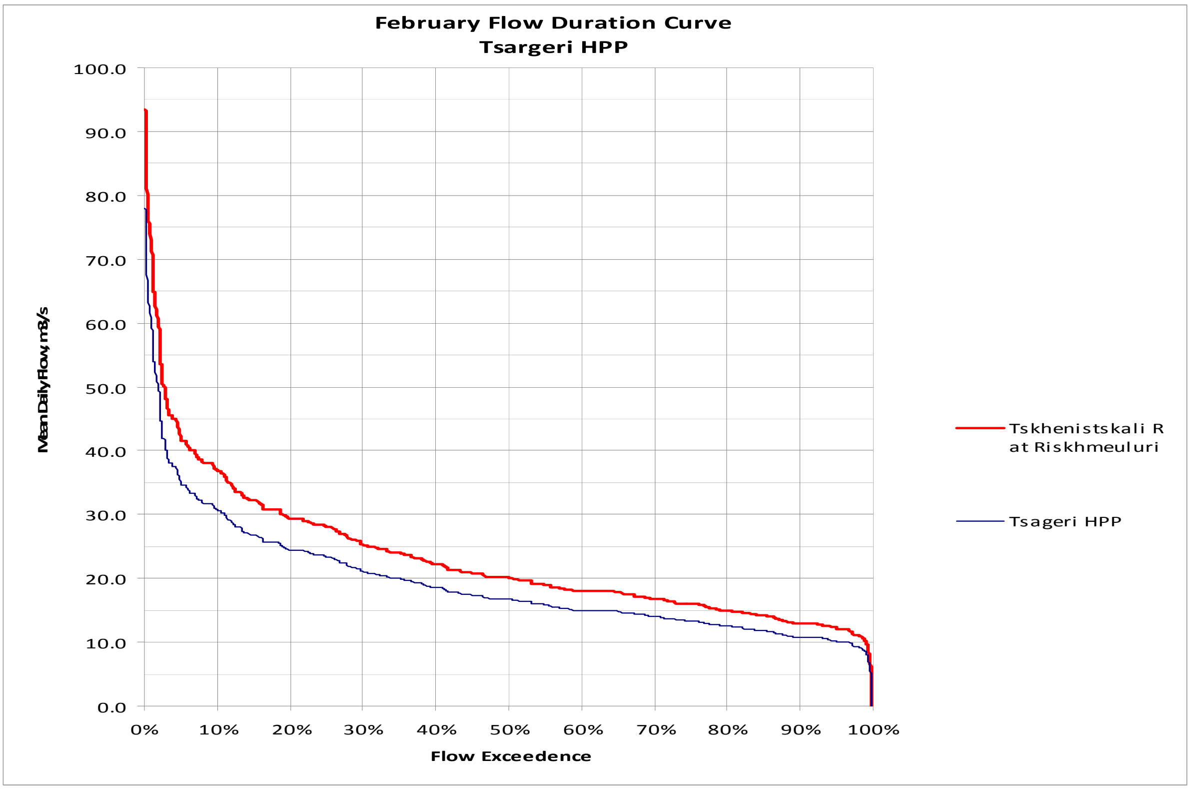
Area under Adjusted Flow Duration Curve	496,930
Select Discharge equal to or exceeded % For HPP	20%
Equivalent Total Turbine Discharge at Selected CF	89.98
Non usable portion of FDC at selected CF	74121
Gross Available CMS-HRS for Generation at selected CF	422,809
Annual Average Daily Discharge	56.74
Select Env/Sanitary Flow as a % of Monthly Avg Dalily Discharge	10%
Environmental/Sanitary Flow in CMS	5.33
Non-usable Environmental/Sanitary CMS-HRS	46687
Net CMS-HRS Available for Generation	376122
Estimated Intake Elevation in Meters	665
Estimated Discharge Elevation in Meters	507
Gross Head for Generation in Meters	158
Length of Penstock/Pipeline/tunnel in Km	11.4
Head Loss (assume 5% of gross head) in Meters	7.9
Net Head for Generation in Meters	150.1
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Annual Generation in MWH	470,566

Monthly Summary of FDC Generation based on % Exceedence and Average HPP Unit Efficiency					
	Month	Exceedance %	Equivalent Discharge in CMS	Estimated Av Monthly Efficiency	Average Monthly Energy in MWH
	Jan	2%	37.41	85%	14,248
	Feb	2%	50.03	85%	13,514
	Mar	2%	70.81	85%	22,893
	Apr	70%	90.39	85%	71,269
	May	77%	89.98	85%	74,693
	Jun	70%	90.39	85%	70,976
	Jul	34%	91.64	85%	63,136
	Aug	10%	89.98	85%	44,175
	Sep	3%	92.47	85%	32,057
	Oct	5%	90.39	85%	32,070
	Nov	2%	82.73	85%	24,973
	Dec	2%	58.48	85%	20,208
Annual Average Values		23%	77.89	85%	
FDC Summed Annual Average Generation					484,211



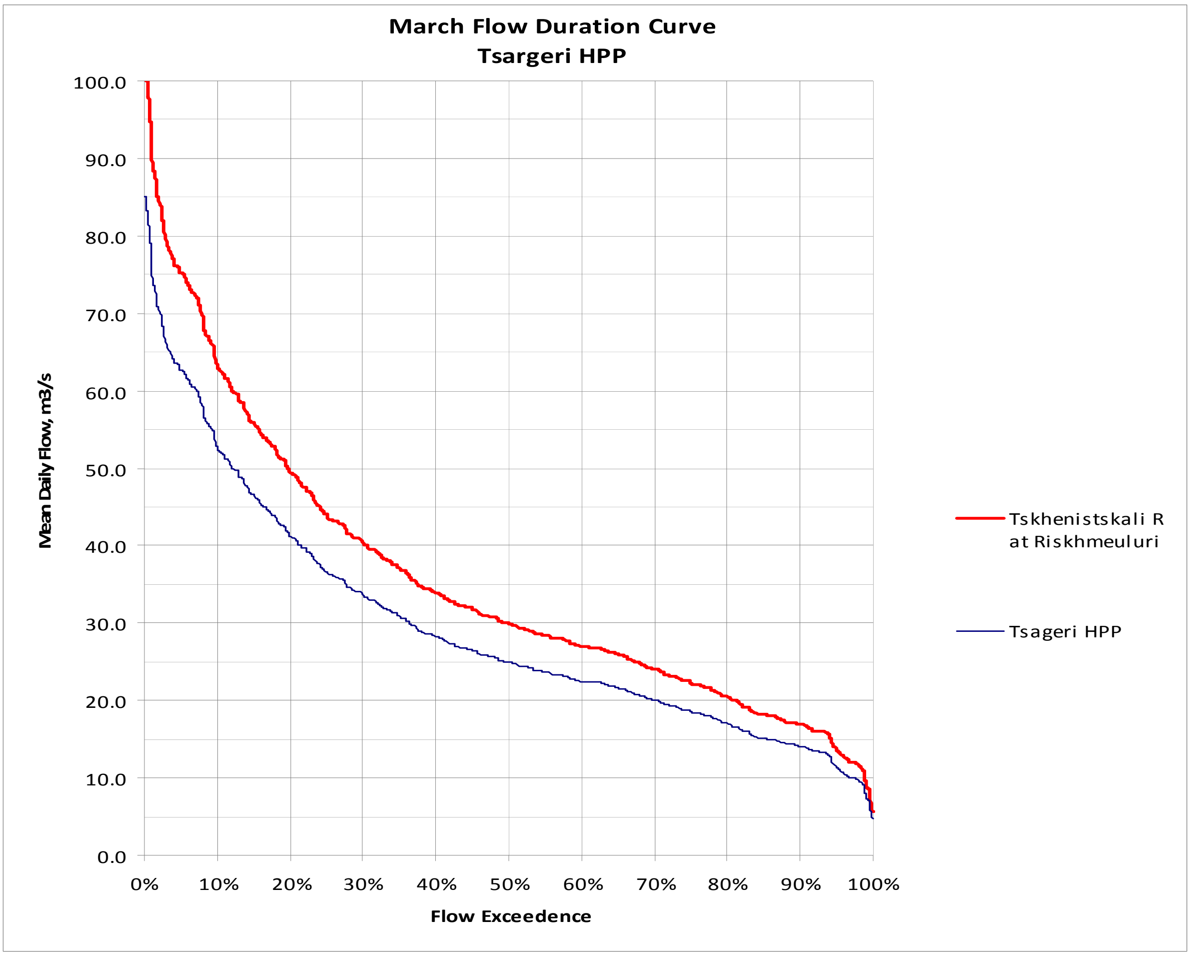
January

Area under Adjusted Flow Duration Curve	13,791
Select Discharge equal to or exceeded % For HPP	2%
Equivalent Total Turbine Discharge at Selected exceedance %	37.41
Non usable portion of FDC at selected Exceedance %	118
Gross Available CMS-HRS for Generation at selected Exceedance %	13,673
Monthly Average Daily Discharge	18.58
Select Env/Sanitary Flow as a % of Monthly Avg Dalily Discharge	10%
Environmental/Sanitary Flow in CMS	1.86
Non-usable Environmental/Sanitary CMS-HRS	1382
Net CMS-HRS Available for Generation	12291
Estimated Intake Elevation in Meters	665
Estimated Discharge Elevation in Meters	507
Gross Head for Generation in Meters	158
Length of Penstock/Pipeline/tunnel	11.4
Head Loss (assume 5% of gross head)	7.9
Net Head for Generation	150.1
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in KWh	14,248,376
Estimated Average Monthly Generation in MWh	14,248



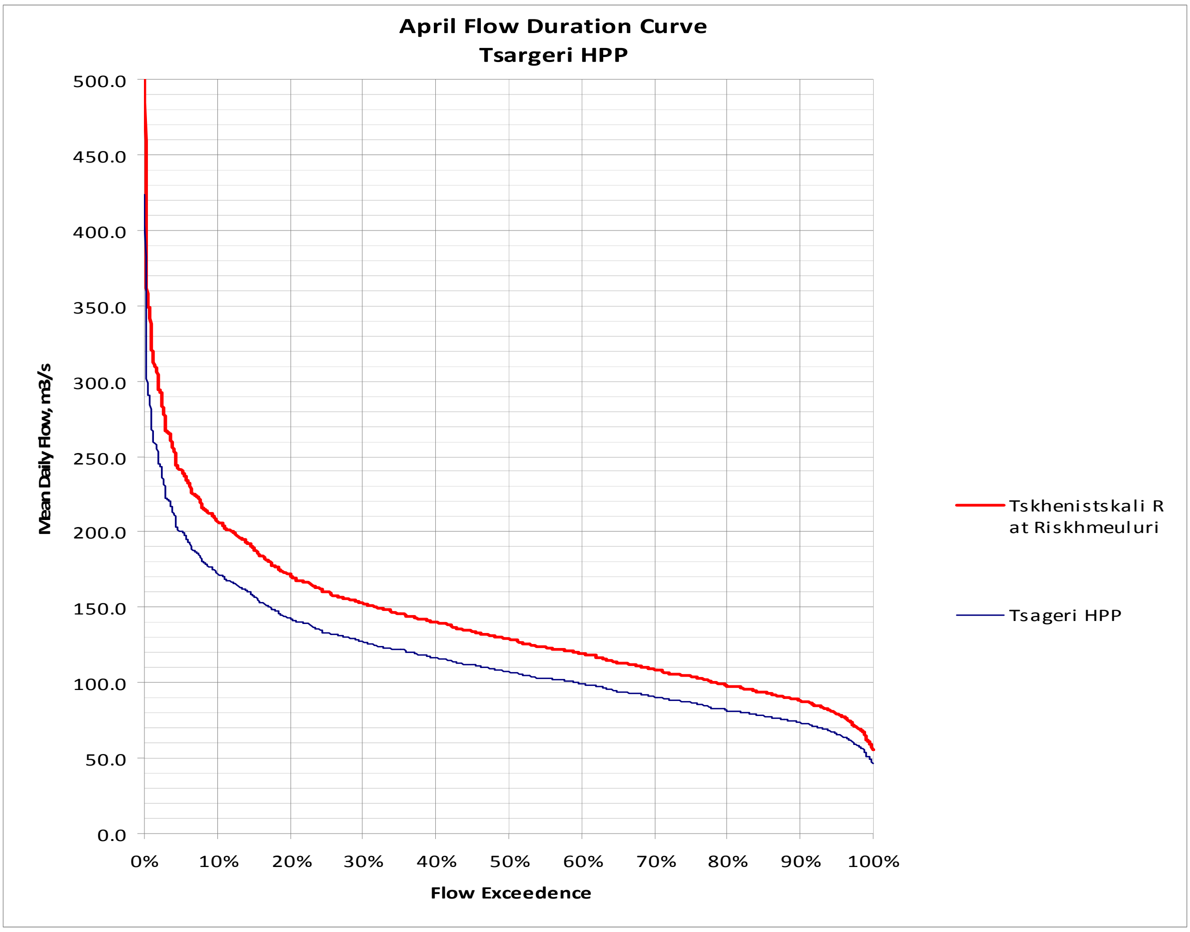
February

Area under Adjusted Flow Duration Curve in CMS-Hrs	12,913
Select Discharge equal to or exceeded % For HPP	2%
Equivalent Total Turbine Discharge at Selected exceedance %	50.03
Non usable portion of FDC at selected Exceedence % in CMS-Hrs	72
Gross Available CMS-HRS for Generation at selected Exceedence %	12,841
Monthly Average Daily Discharge	17.60
Select Env/Sanitary Flow as a % of Monthly Avg Dalily Discharge	10%
Environmental/Sanitary Flow in CMS	1.76
Non-usable Environmental/Sanitary CMS-HRS	1183
Net CMS-HRS Available for Generation	11658
Estimated Intake Elevation in Meters	665
Estimated Discharge Elevation in Meters	507
Gross Head for Generation in Meters	158
Length of Penstock/Pipeline/tunnel	11.4
Head Loss (assume 5% of gross head)	7.9
Net Head for Generation	150.1
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in KWh	13,514,281
Estimated Average Monthly Generation in MWh	13,514

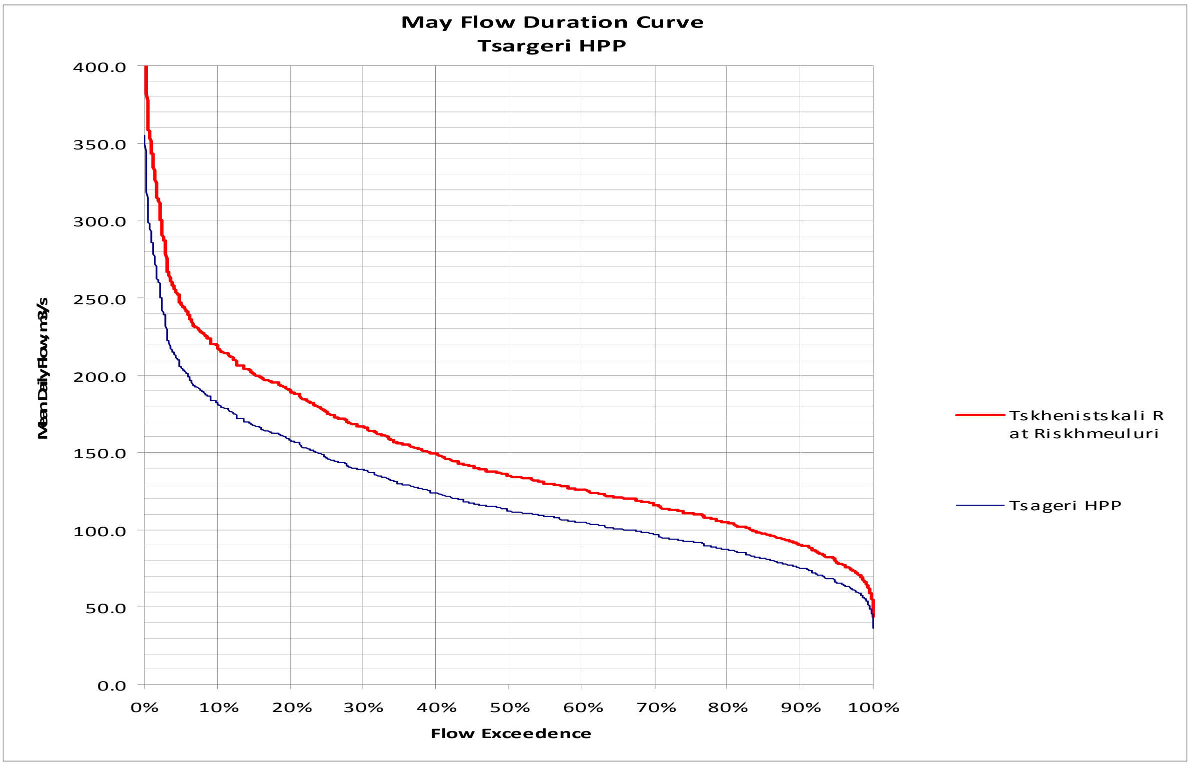


March

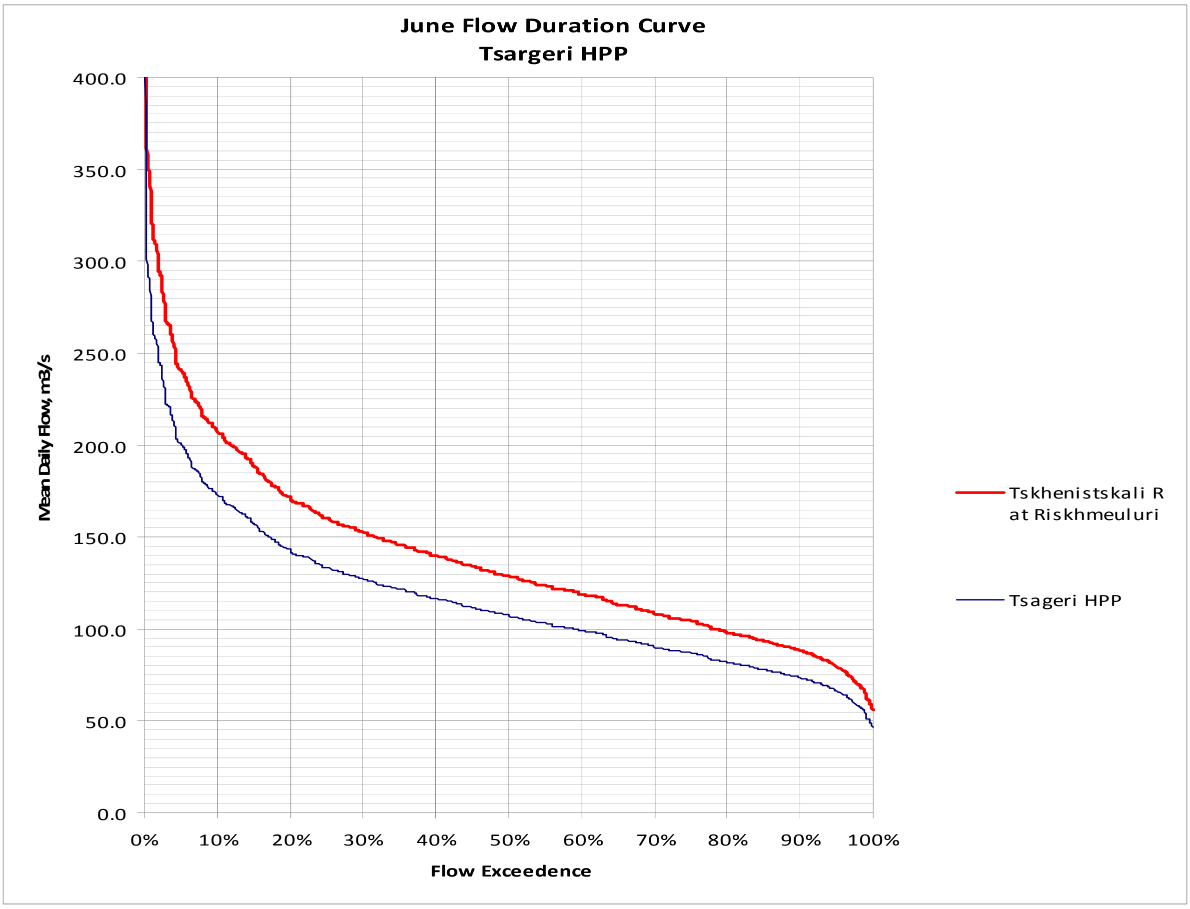
Area under Adjusted Flow Duration Curve in CMS	21,966
Select Discharge equal to or exceeded % For HPP	2%
Equivalent Total Turbine Discharge at Selected exceedance % in CMS	70.81
Non usable portion of FDC at selected Exceedence % in CMS-Hrs	19
Gross Available CMS-HRS for Generation at selected Exceedence %	21,947
Monthly Average Daily Discharge	29.56
Select Env/Sanitary Flow as a % of Monthly Avg Dalily Discharge	10%
Environmental/Sanitary Flow in CMS	2.96
Non-usable Environmental/Sanitary CMS-HRS	2199
Net CMS-HRS Available for Generation	19748
Estimated Intake Elevation in Meters	665
Estimated Discharge Elevation in Meters	507
Gross Head for Generation in Meters	158
Length of Penstock/Pipeline/tunnel in Km	11.4
Head Loss (assume 5% of gross head) in Meters	7.9
Net Head for Generation in Meters	150.1
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in KWh	22,892,503
MWh	22,893



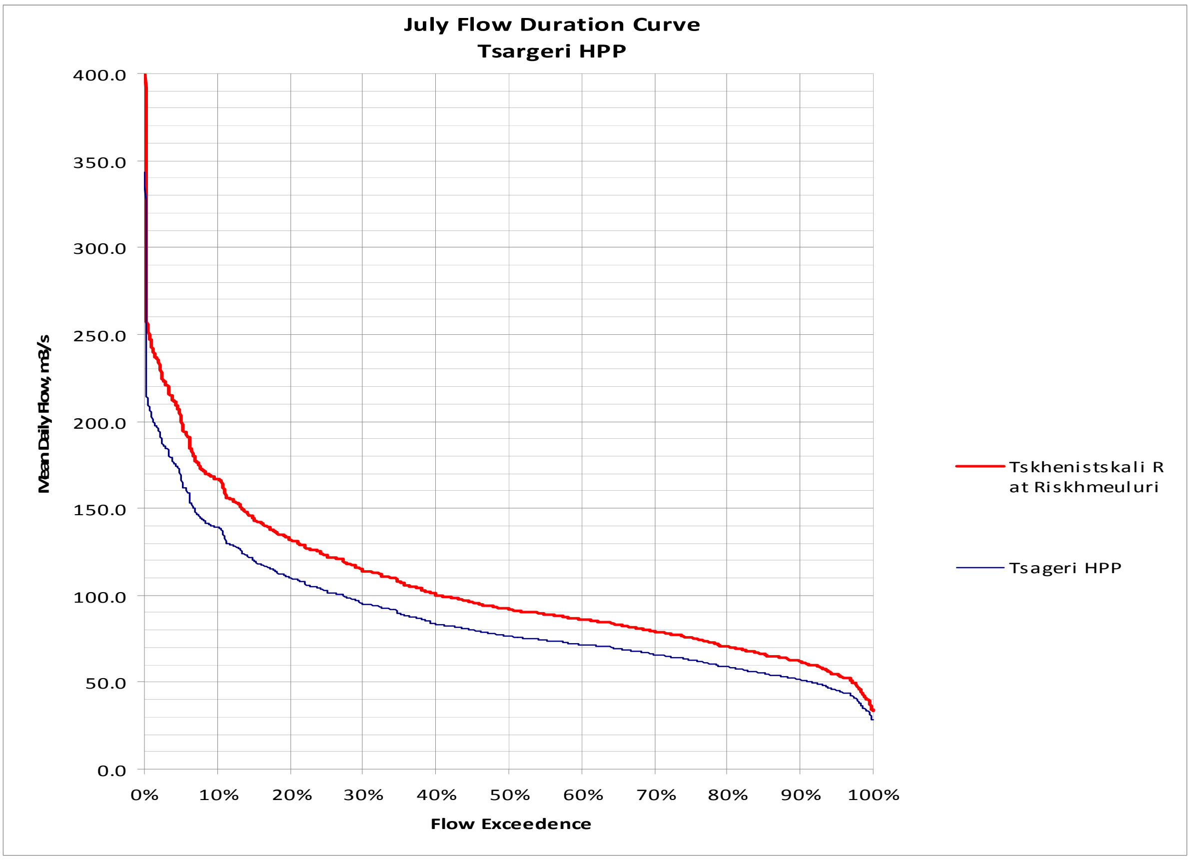
April	
Area under Adjusted Flow Duration Curve in CMS-hrs	83,786
Select Discharge equal to or exceeded % For HPP	70%
Equivalent Total Turbine Discharge at Selected exceedance % in CMS	90.39
Non usable portion of FDC at selected Exceedence % in CMS-Hrs	21747
Gross Available CMS-HRS for Generation at selected Exceedence %	62,038
Monthly Average Daily Discharge	77.71
Select Env/Sanitary Flow as a % of Monthly Avg Dalily Discharge	1%
Environmental/Sanitary Flow in CMS	0.78
Non-usable Environmental/Sanitary CMS-HRS	560
Net CMS-HRS Available for Generation	61479
Estimated Intake Elevation in Meters	665
Estimated Discharge Elevation in Meters	507
Gross Head for Generation in Meters	158
Length of Penstock/Pipeline/tunnel in Km	11.4
Head Loss (assume 5% of gross head) in Meters	7.9
Net Head for Generation in Meters	150.1
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in KWh	71,268,630
MWh	71,269



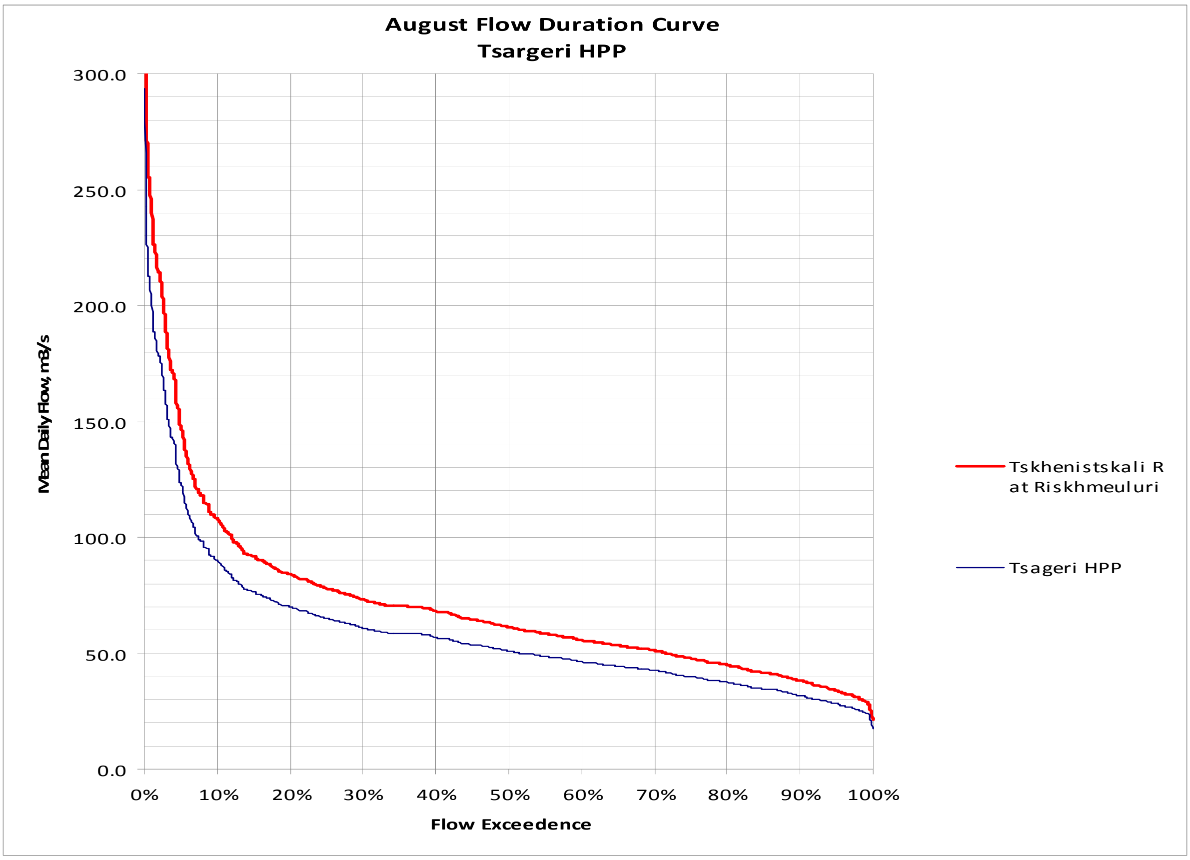
May	
Area under Adjusted Flow Duration Curve in CMS-hrs	91,664
Select Discharge equal to or exceeded % For HPP	77%
Equivalent Total Turbine Discharge at Selected exceedance % in CMS	89.98
Non usable portion of FDC at selected Exceedence % in CMS-Hrs	27230
Gross Available CMS-HRS for Generation at selected Exceedence %	64,434
Monthly Average Daily Discharge	123.37
Select Env/Sanitary Flow as a % of Monthly Avg Dalily Discharge	1%
Environmental/Sanitary Flow in CMS	1.23
Non-usable Environmental/Sanitary CMS-HRS	918
Net CMS-HRS Available for Generation	64433
Estimated Intake Elevation in Meters	665
Estimated Discharge Elevation in Meters	507
Gross Head for Generation in Meters	158
Length of Penstock/Pipeline/tunnel in Km	11.4
Head Loss (assume 5% of gross head) in Meters	7.9
Net Head for Generation in Meters	150.1
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in KWh	74,693,128
	74,693



June	
Area under Adjusted Flow Duration Curve in CMS-hrs	83,786
Select Discharge equal to or exceeded % For HPP	70%
Equivalent Total Turbine Discharge at Selected exceedance % in CMS	90.39
Non usable portion of FDC at selected Exceedence % in CMS-Hrs	21747
Gross Available CMS-HRS for Generation at selected Exceedence %	62,038
Monthly Average Daily Discharge	112.81
Select Env/Sanitary Flow as a % of Monthly Avg Dalily Discharge	1%
Environmental/Sanitary Flow in CMS	1.13
Non-usable Environmental/Sanitary CMS-HRS	812
Net CMS-HRS Available for Generation	61226
Estimated Intake Elevation in Meters	665
Estimated Discharge Elevation in Meters	507
Gross Head for Generation in Meters	158
Length of Penstock/Pipeline/tunnel in Km	11.4
Head Loss (assume 5% of gross head) in Meters	7.9
Net Head for Generation in Meters	150.1
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in KWh	70,975,650
	70,976

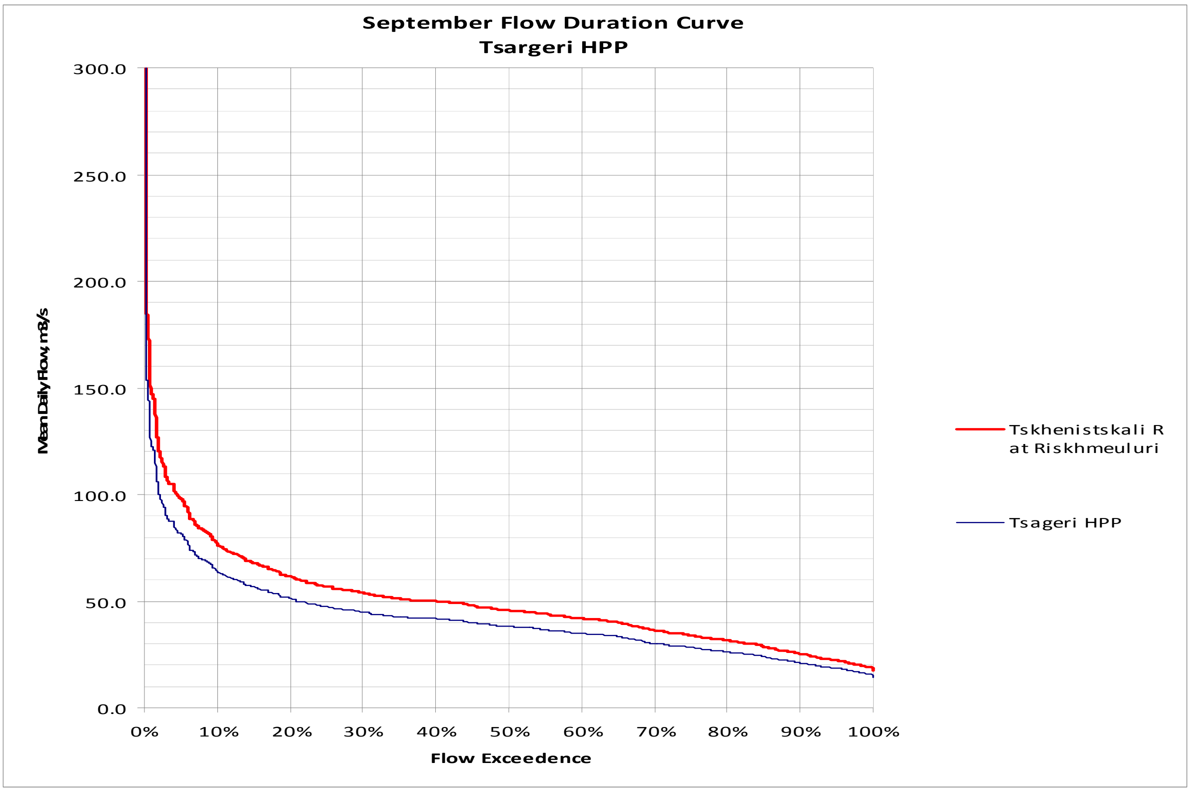


July	
Area under Adjusted Flow Duration Curve in CMS-hrs	64,635
Select Discharge equal to or exceeded % For HPP	34%
Equivalent Total Turbine Discharge at Selected exceedance % in CMS	91.64
Non usable portion of FDC at selected Exceedence % in CMS-Hrs	8877
Gross Available CMS-HRS for Generation at selected Exceedence %	55,758
Monthly Average Daily Discharge	87.03
Select Env/Sanitary Flow as a % of Monthly Avg Dalily Discharge	2%
Environmental/Sanitary Flow in CMS	1.74
Non-usable Environmental/Sanitary CMS-HRS	1295
Net CMS-HRS Available for Generation	54463
Estimated Intake Elevation in Meters	665
Estimated Discharge Elevation in Meters	507
Gross Head for Generation in Meters	158
Length of Penstock/Pipeline/tunnel in Km	11.4
Head Loss (assume 5% of gross head) in Meters	7.9
Net Head for Generation in Meters	150.1
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in KWh	63,135,851
	63,136



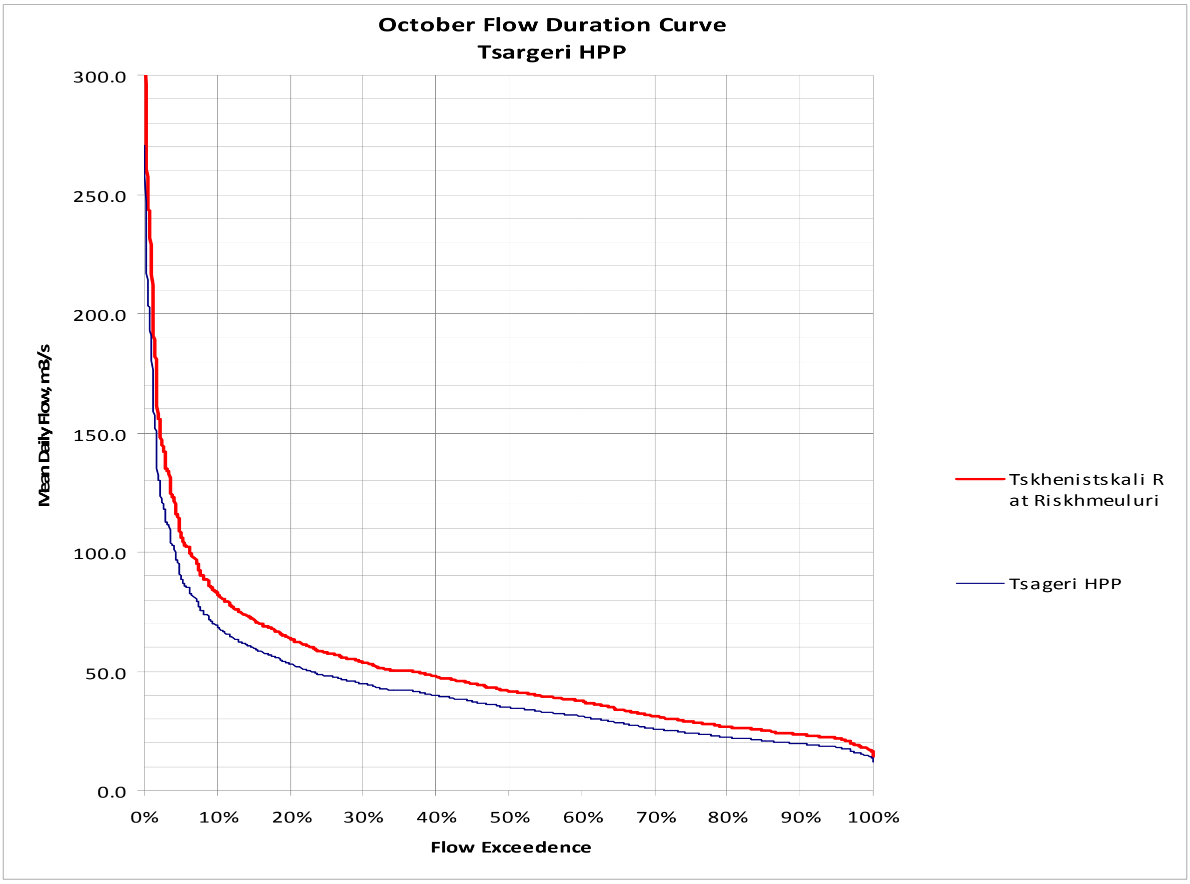
August

Area under Adjusted Flow Duration Curve in CMS-hrs	43,598
Select Discharge equal to or exceeded % For HPP	10%
Equivalent Total Turbine Discharge at Selected exceedance % in CMS	89.98
Non usable portion of FDC at selected Exceedence % in CMS-Hrs	3307
Gross Available CMS-HRS for Generation at selected Exceedence %	40,291
Monthly Average Daily Discharge	58.73
Select Env/Sanitary Flow as a % of Monthly Avg Dalily Discharge	5%
Environmental/Sanitary Flow in CMS	2.94
Non-usable Environmental/Sanitary CMS-HRS	2185
Net CMS-HRS Available for Generation	38107
Estimated Intake Elevation in Meters	665
Estimated Discharge Elevation in Meters	507
Gross Head for Generation in Meters	158
Length of Penstock/Pipeline/tunnel in Km	11.4
Head Loss (assume 5% of gross head) in Meters	7.9
Net Head for Generation in Meters	150.1
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in KWh	44,174,623
	44,175



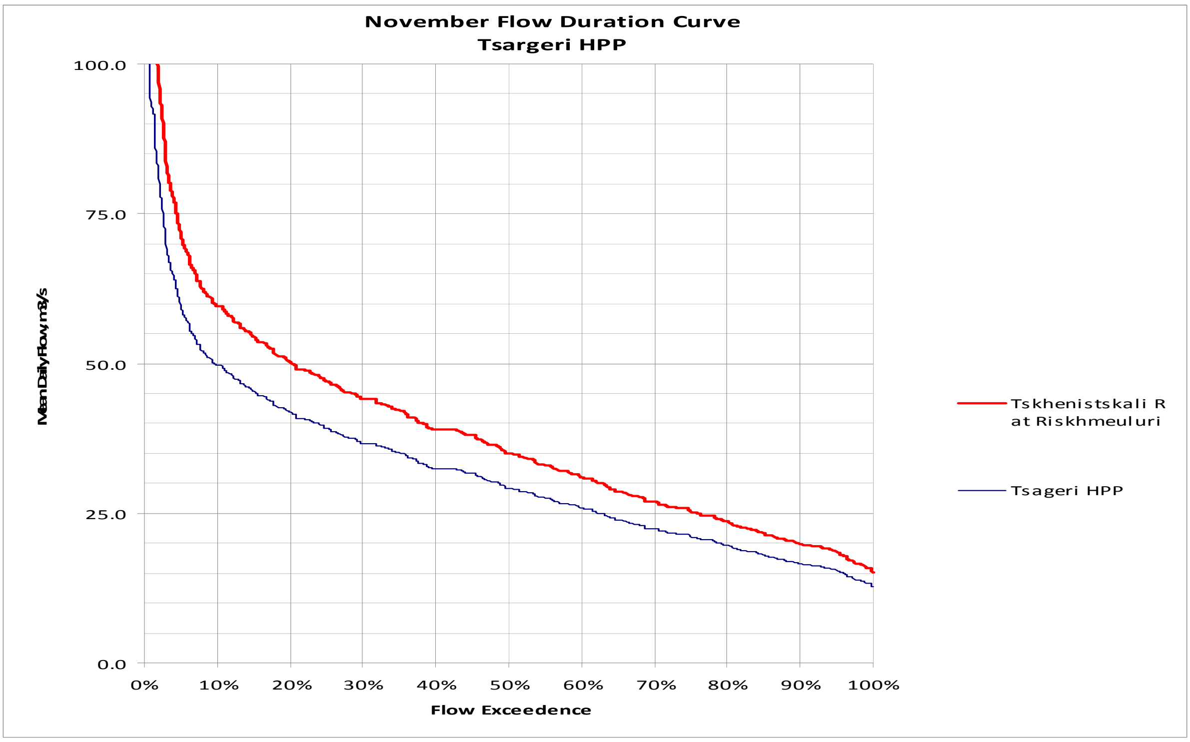
September

Area under Adjusted Flow Duration Curve in CMS-hrs	29,966
Select Discharge equal to or exceeded % For HPP	3%
Equivalent Total Turbine Discharge at Selected exceedance % in CMS	92.47
Non usable portion of FDC at selected Exceedence % in CMS-Hrs	565
Gross Available CMS-HRS for Generation at selected Exceedence %	29,401
Monthly Average Daily Discharge	40.46
Select Env/Sanitary Flow as a % of Monthly Avg Dalily Discharge	6%
Environmental/Sanitary Flow in CMS	2.43
Non-usable Environmental/Sanitary CMS-HRS	1748
Net CMS-HRS Available for Generation	27653
Estimated Intake Elevation in Meters	665
Estimated Discharge Elevation in Meters	507
Gross Head for Generation in Meters	158
Length of Penstock/Pipeline/tunnel in Km	11.4
Head Loss (assume 5% of gross head) in Meters	7.9
Net Head for Generation in Meters	150.1
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in KWh	32,056,747
	32,057



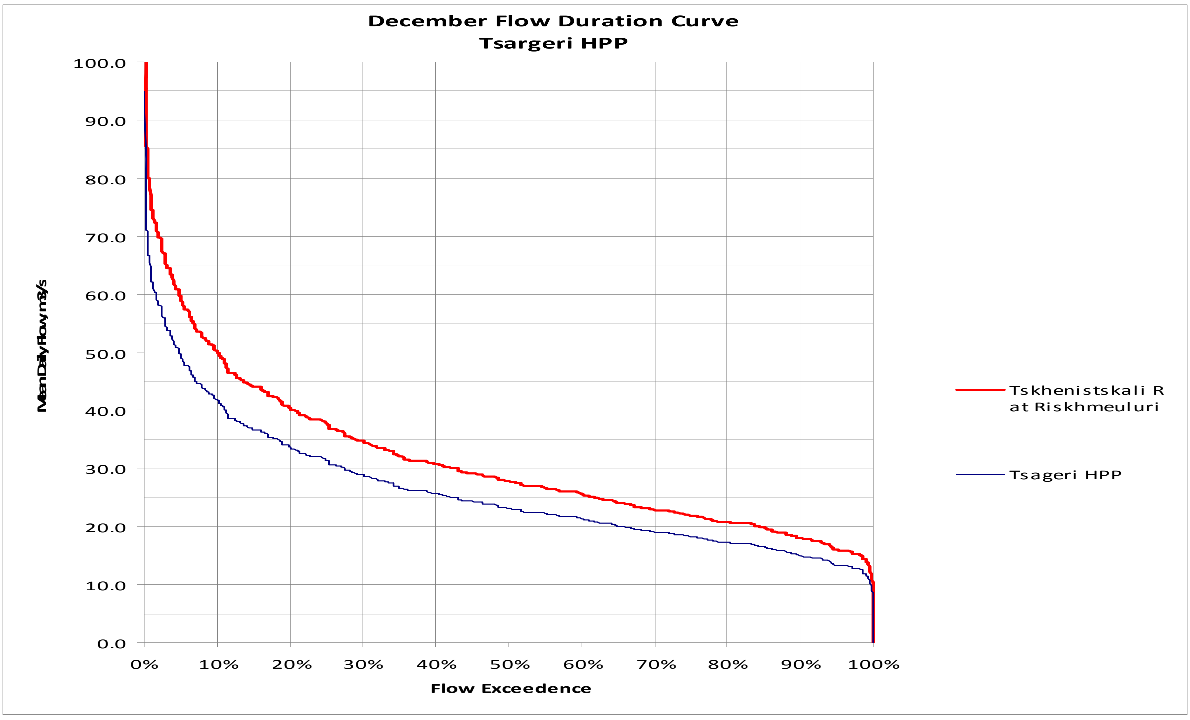
October

Area under Adjusted Flow Duration Curve in CMS-hrs	31,108
Select Discharge equal to or exceeded % For HPP	5%
Equivalent Total Turbine Discharge at Selected exceedance % in CMS	90.39
Non usable portion of FDC at selected Exceedence % in CMS-Hrs	1571
Gross Available CMS-HRS for Generation at selected Exceedence %	29,537
Monthly Average Daily Discharge	41.93
Select Env/Sanitary Flow as a % of Monthly Avg Dalily Discharge	6%
Environmental/Sanitary Flow in CMS	2.52
Non-usable Environmental/Sanitary CMS-HRS	1872
Net CMS-HRS Available for Generation	27665
Estimated Intake Elevation in Meters	665
Estimated Discharge Elevation in Meters	507
Gross Head for Generation in Meters	158
Length of Penstock/Pipeline/tunnel in Km	11.4
Head Loss (assume 5% of gross head) in Meters	7.9
Net Head for Generation in Meters	150.1
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in KWh	32,070,176
	32,070



November

Area under Adjusted Flow Duration Curve in CMS-hrs	23,285
Select Discharge equal to or exceeded % For HPP	2%
Equivalent Total Turbine Discharge at Selected exceedance % in CMS	82.73
Non usable portion of FDC at selected Exceedence % in CMS-Hrs	159
Gross Available CMS-HRS for Generation at selected Exceedence %	23,126
Monthly Average Daily Discharge	31.41
Select Env/Sanitary Flow as a % of Monthly Avg Dalily Discharge	7%
Environmental/Sanitary Flow in CMS	2.20
Non-usable Environmental/Sanitary CMS-HRS	1583
Net CMS-HRS Available for Generation	21543
Estimated Intake Elevation in Meters	665
Estimated Discharge Elevation in Meters	507
Gross Head for Generation in Meters	158
Length of Penstock/Pipeline/tunnel in Km	11.4
Head Loss (assume 5% of gross head) in Meters	7.9
Net Head for Generation in Meters	150.1
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in KWh	24,973,135
	24,973

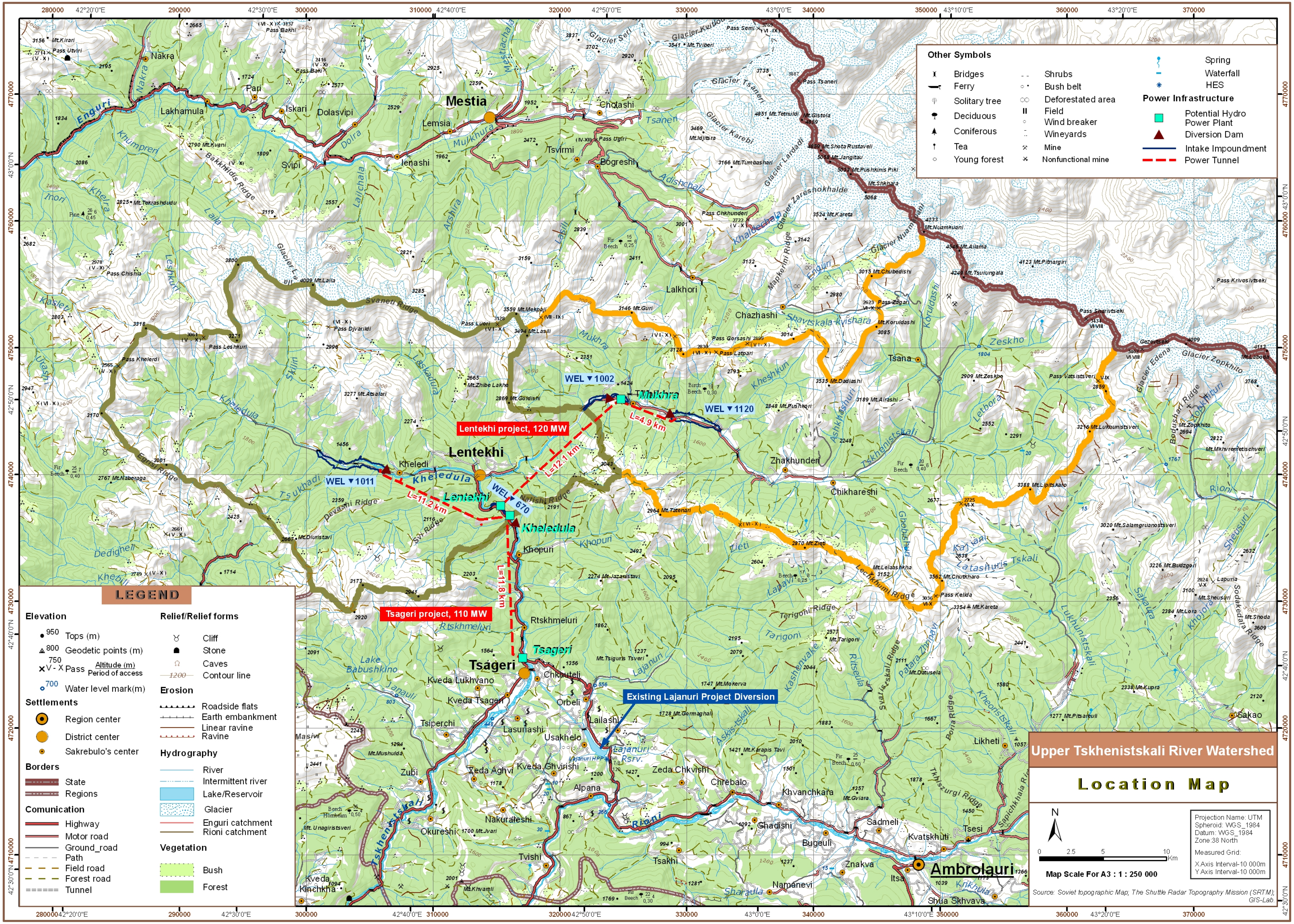


December

Area under Adjusted Flow Duration Curve in CMS-hrs	19,412
Select Discharge equal to or exceeded % For HPP	2%
Equivalent Total Turbine Discharge at Selected exceedance % in CMS	58.48
Non usable portion of FDC at selected Exceedence % in CMS-Hrs	36
Gross Available CMS-HRS for Generation at selected Exceedence %	19,376
Monthly Average Daily Discharge	26.13
Select Env/Sanitary Flow as a % of Monthly Avg Dalily Discharge	10%
Environmental/Sanitary Flow in CMS	2.61
Non-usable Environmental/Sanitary CMS-HRS	1944
Net CMS-HRS Available for Generation	17432
Estimated Intake Elevation in Meters	665
Estimated Discharge Elevation in Meters	507
Gross Head for Generation in Meters	158
Length of Penstock/Pipeline/tunnel in Km	11.4
Head Loss (assume 5% of gross head) in Meters	7.9
Net Head for Generation in Meters	150.1
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in KWh	20,207,849
	20,208

Appendix 3

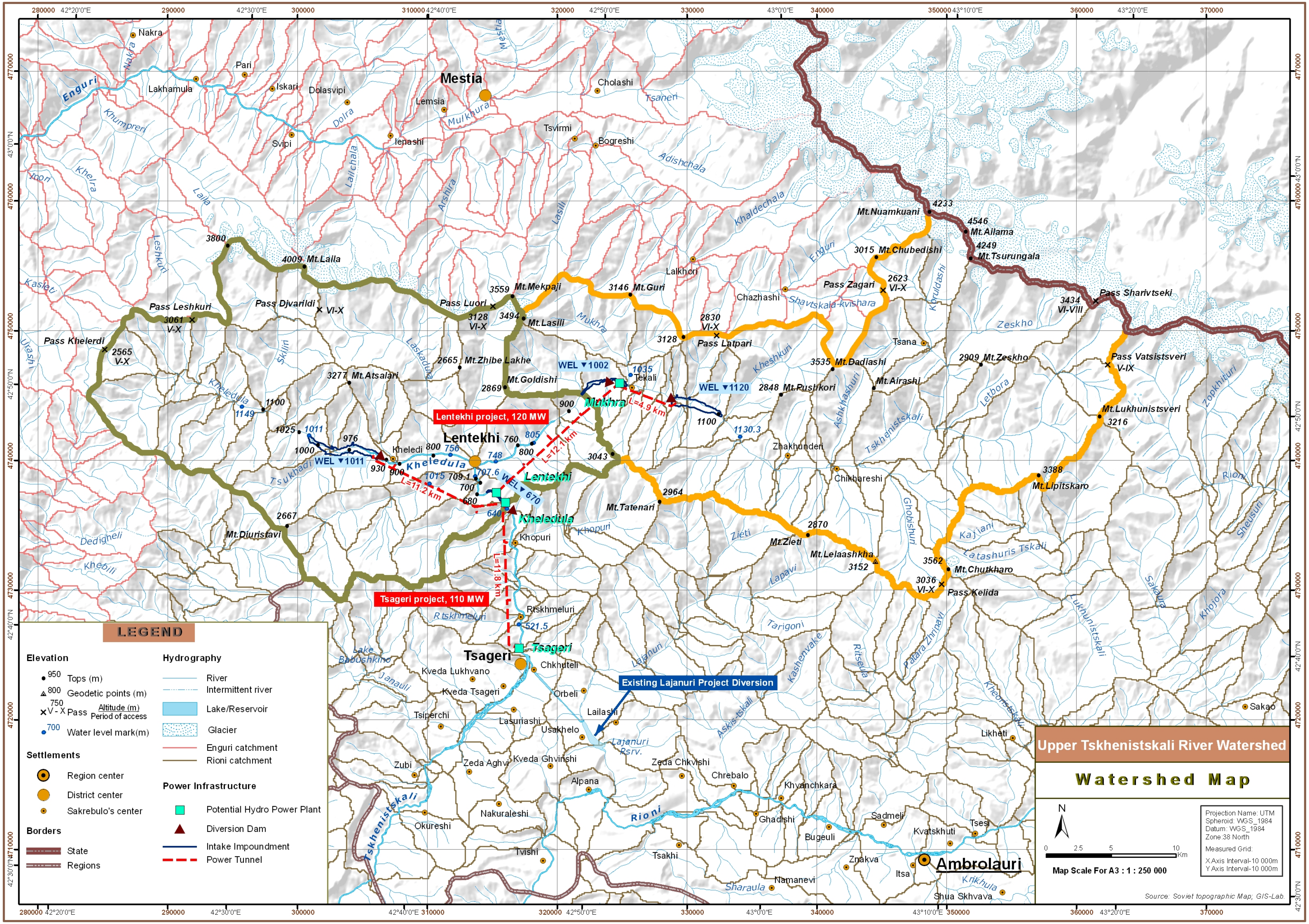
Location Map



Upper Tskhenistskali River Watershed
Location Map
Lentekhi project, 120 MW
Tsageri project, 110 MW
Existing Lajanuri Project Diversion
WEL ▼1002
WEL ▼1120
WEL ▼1011
WEL ▼670
L=4.9 km
L=12.1 km
L=11.2 km
L=11.8 km
Mukhra
Lentekhi
Kheledula
Tsageri
Mestia
Ambrolauri
LEGEND
Elevation
Tops (m)
Geodetic points (m)
Pass
Altitude (m)
Period of access
Water level mark(m)
Settlements
Region center
District center
Sakrebulo's center
Borders
State
Regions
Comunication
Highway
Motor road
Ground_road
Path
Field road
Forest road
Tunnel
Relief/Relief forms
Cliff
Stone
Caves
Contour line
Erosion
Roadside flats
Earth embankment
Linear ravine
Ravine
Hydrography
River
Intermittent river
Lake/Reservoir
Glacier
Enguri catchment
Rioni catchment
Vegetation
Bush
Forest
Other Symbols
Bridges
Ferry
Solitary tree
Deciduous
Coniferous
Tea
Young forest
Shrubs
Bush belt
Deforestated area
Field
Wind breaker
Vineyards
Mine
Nonfunctional mine
Spring
Waterfall
HES
Power Infrastructure
Potential Hydro Power Plant
Diversion Dam
Intake Impoundment
Power Tunnel
Map Scale For A3 : 1 : 250 000
Projection Name: UTM
Spheroid: WGS_1984
Datum: WGS_1984
Zone:38 North
Measured Grid:
X Axis Interval-10 000m
Y Axis Interval-10 000m
Source: Soviet topographic Map; The Shuttle Radar Topography Mission (SRTM); GIS-Lab

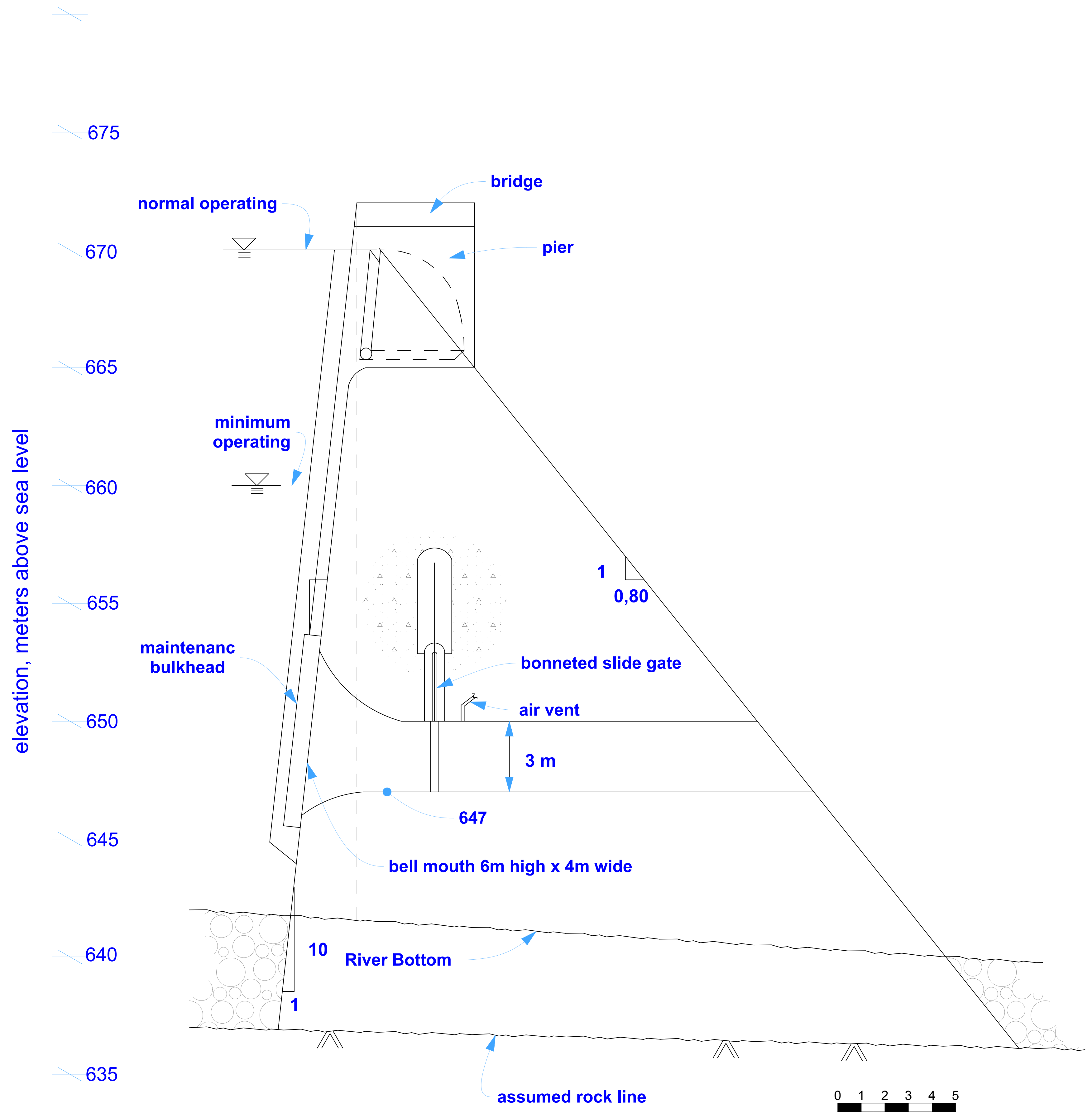
Appendix 4

Watershed Map


Upper Tskhenistskali River Watershed
Watershed Map
LEGEND
Elevation
950 Tops (m)
800 Geodetic points (m)
750 V - X Pass Altitude (m) Period of access
700 Water level mark(m)
Settlements
Region center
District center
Sakrebulo's center
Borders
State
Regions
Hydrography
River
Intermittent river
Lake/Reservoir
Glacier
Enguri catchment
Rioni catchment
Power Infrastructure
Potential Hydro Power Plant
Diversion Dam
Intake Impoundment
Power Tunnel
Lentekhi project, 120 MW
Tsageri project, 110 MW
Existing Lajanuri Project Diversion
WEL ▼1002
WEL ▼1120
WEL ▼1011
WEL ▼670
L=4.9 km
L=12.1 km
L=11.2 km
L=11.8 km
Mukhra
Lentekhi
Kheledula
Tsageri
Mestia
Ambrolauri
Mt.Nuamkuani
Mt.Ailama
Mt.Tsurungala
Mt.Chubedishi
Mt.Laila
Mt.Mekpaji
Mt.Guri
Mt.Lasili
Mt.Dadiashi
Mt.Zeskho
Mt.Pushkori
Mt.Airashi
Mt.Lukhunistsveri
Mt.Lipitskaro
Mt.Chutkharo
Mt.Lelaashkha
Mt.Zieti
Mt.Tatenari
Mt.Goldishi
Mt.Zhibe Lakhe
Mt.Atsalari
Mt.Diuristavi
Pass Leshkuri
Pass Djvarildi
Pass Luori
Pass Khelerdi
Pass Latpari
Pass Zagari
Pass Sharivtseki
Pass Vatsistsveri
Pass Kelida
Lajanuri Rsrv.
Lake Babushkino
N
0 2.5 5 10 Km
Map Scale For A3 : 1 : 250 000
Projection Name: UTM
Spheroid: WGS_1984
Datum: WGS_1984
Zone:38 North
Measured Grid:
X Axis Interval-10 000m
Y Axis Interval-10 000m
Source: Soviet topographic Map; GIS-Lab.

Appendix 5

Site HPP Figure

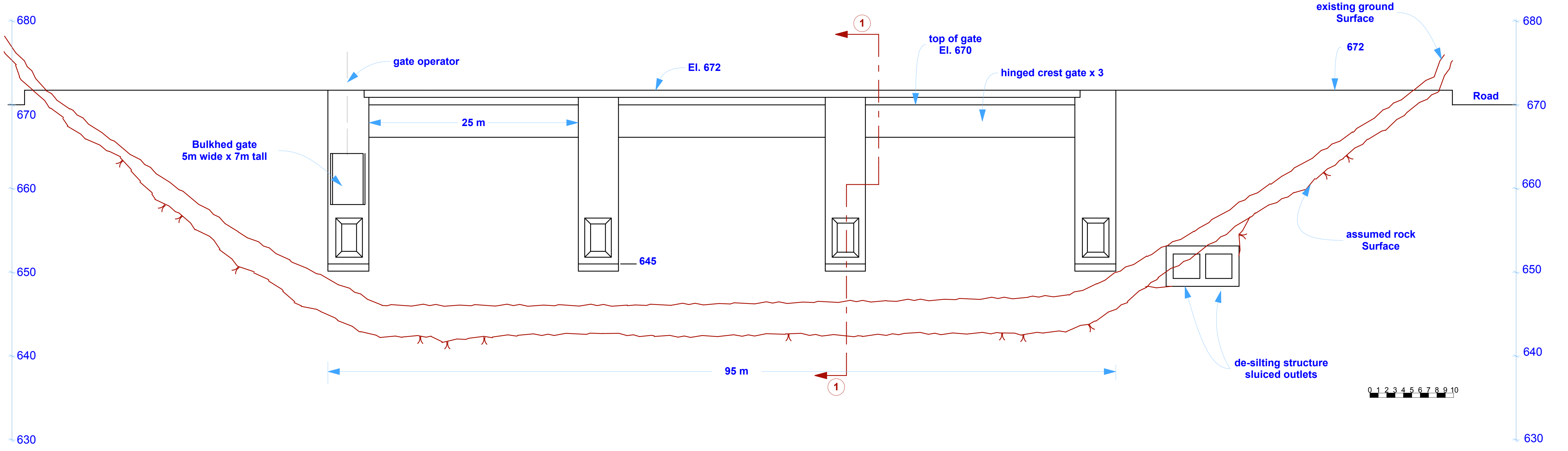


BLACK & VEATCH
Building a world of difference.

Pre-Feasibility Study
Tsageri Hydropower Project

Diversion Section

Drawing Scale	1:200	June 2011



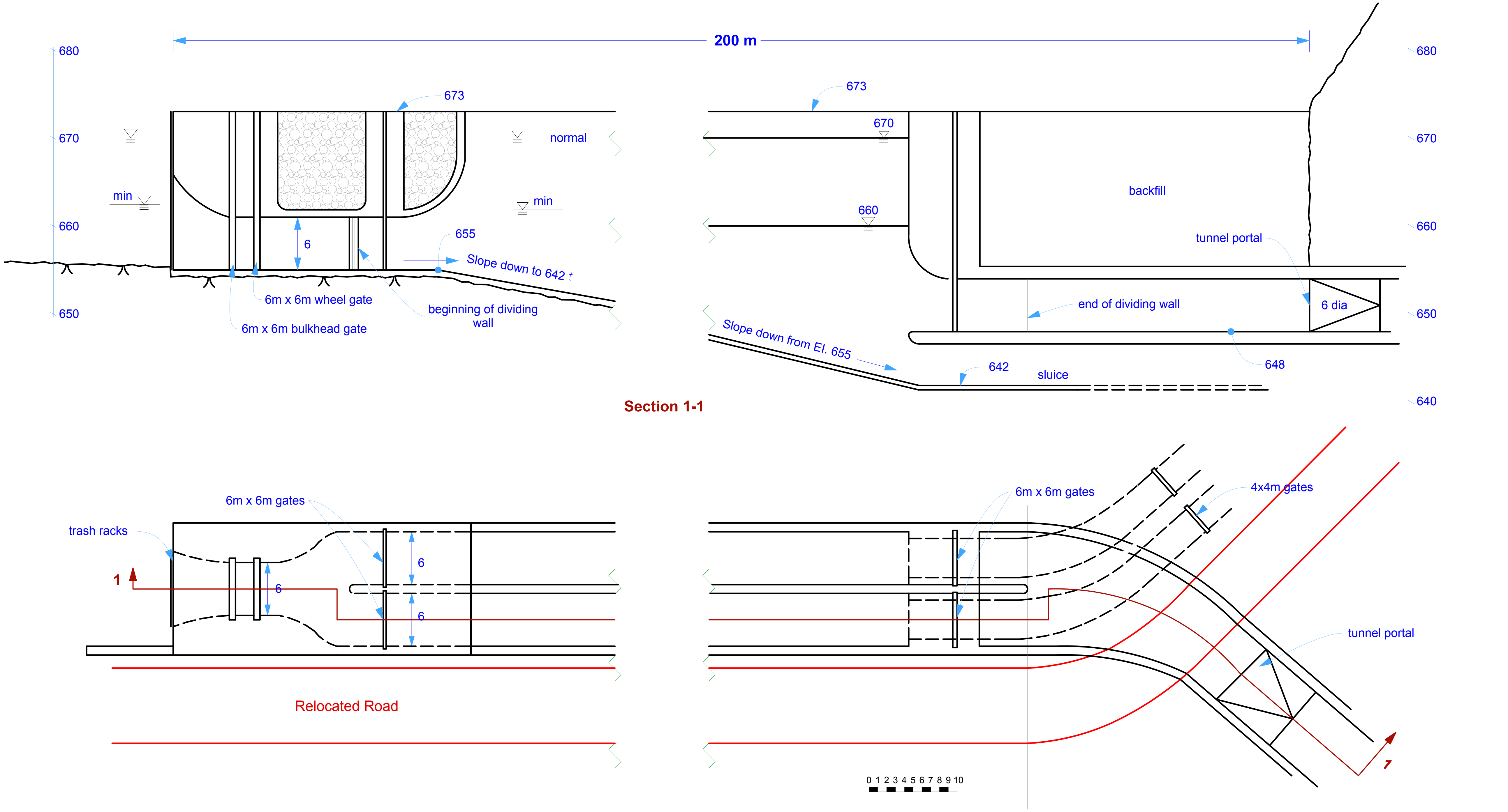
BLACK & VEATCH
Building a world of difference.

Pre-Feasibility Study

Tsageri Hydropower Project

Diversion, Upstream Elevation

Drawing Scale 1:500	June 2011



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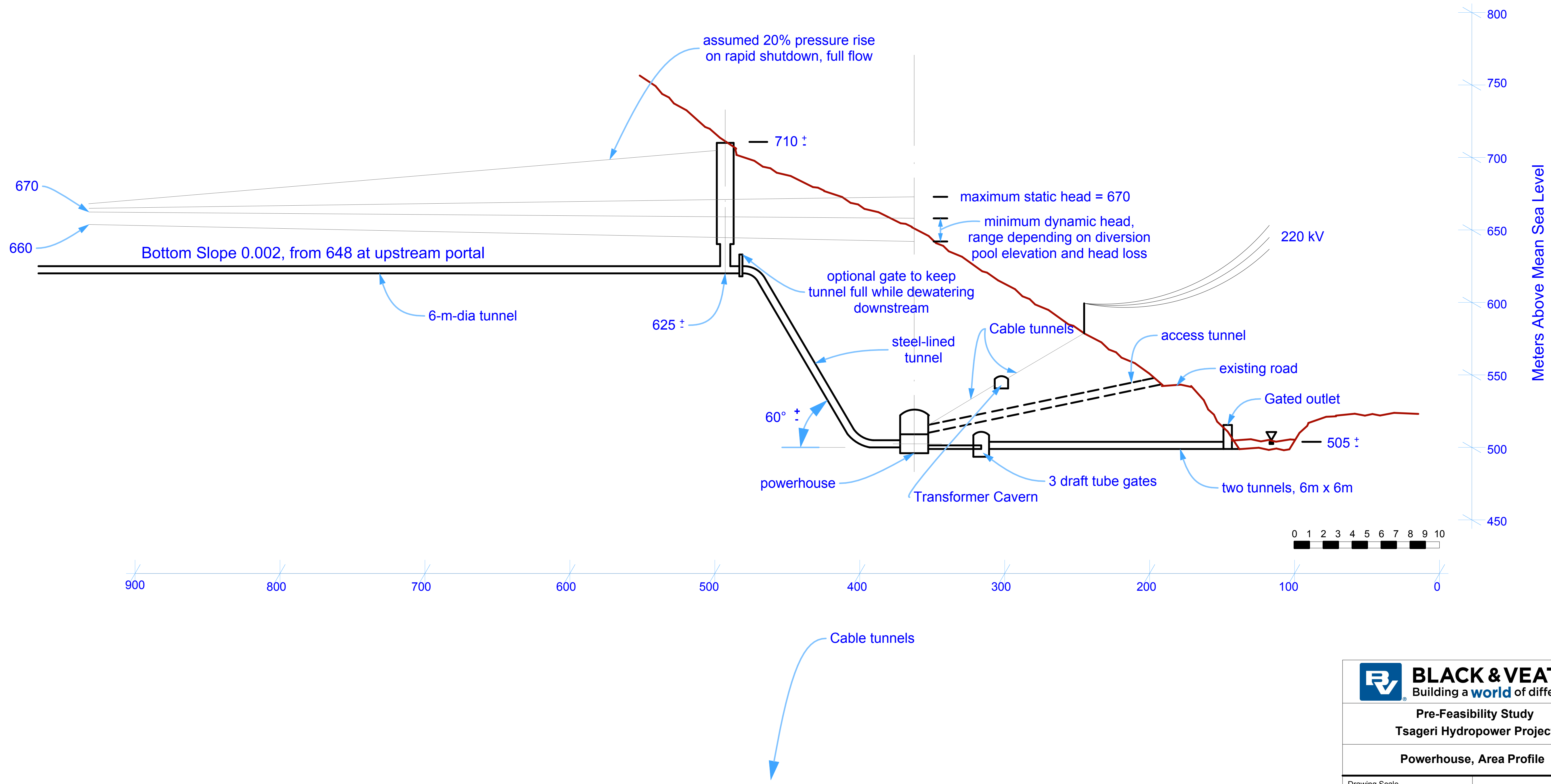
Building a world of difference.

Pre-Feasibility Study
Tsageri Hydropower Project

Intake and De-Silting Basin, Plan and Section

Drawing Scale 1:500	June 2011



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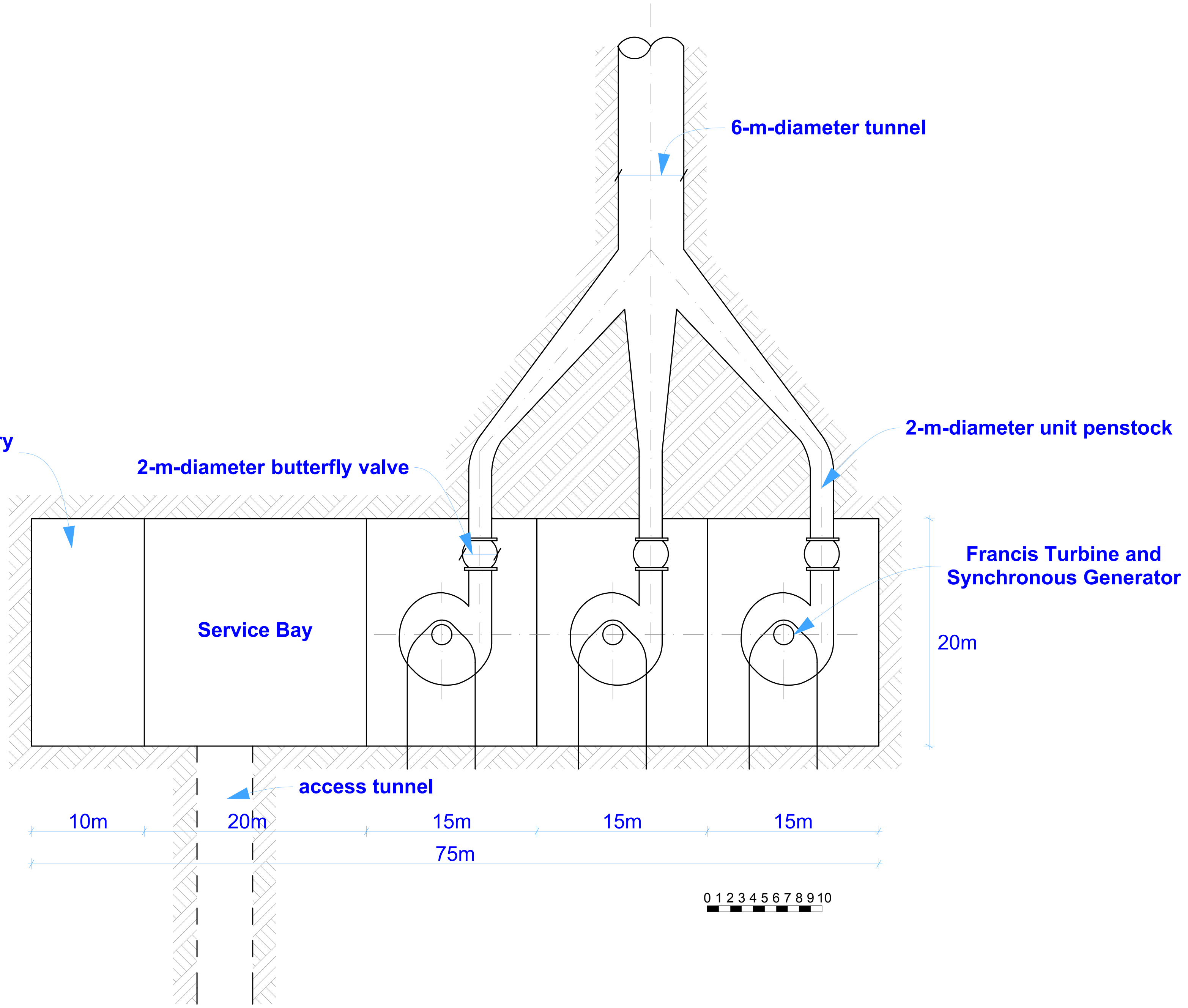
Pre-Feasibility Study
Tsageri Hydropower Project

Powerhouse, Area Profile

Drawing Scale 1:2,000	June 2011



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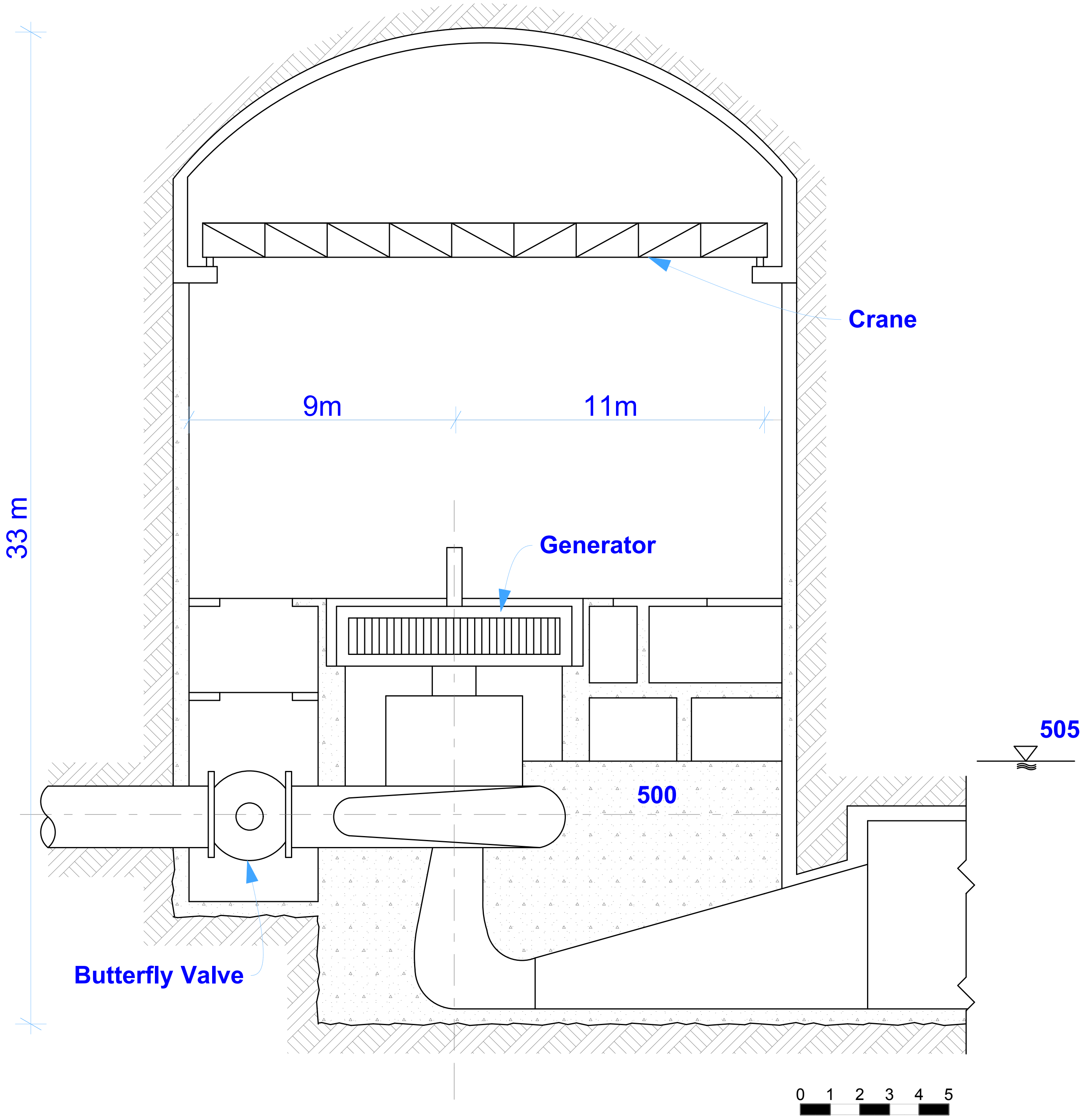
Building a world of difference.

Pre-Feasibility Study
Tsageri Hydropower Project

Powerhouse Plan

Drawing Scale 1:500

June 2011



BLACK & VEATCH
Building a world of difference.

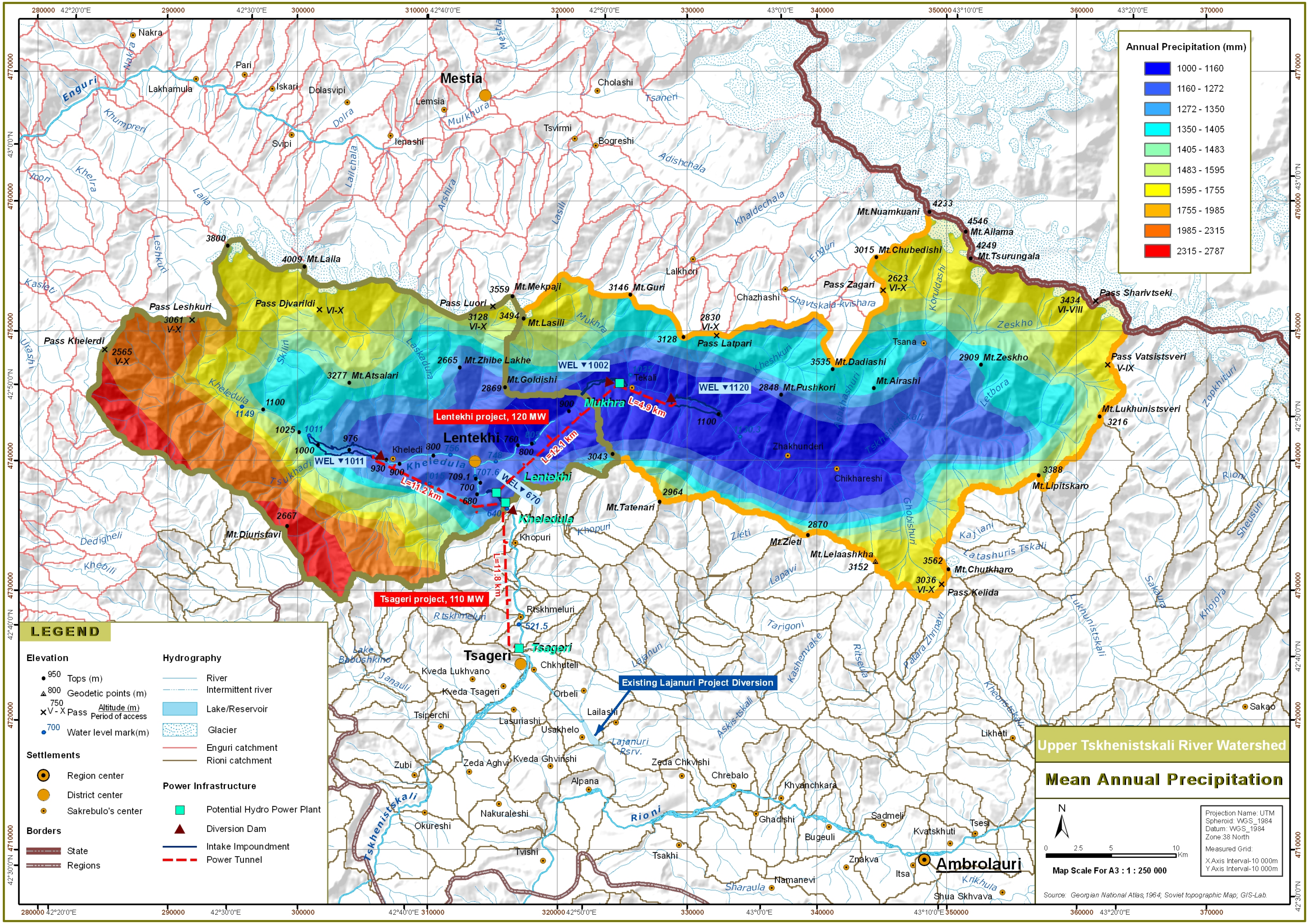
Pre-Feasibility Study
Tsageri Hydropower Project

Cross Section

Drawing Scale	1:200	June 2011

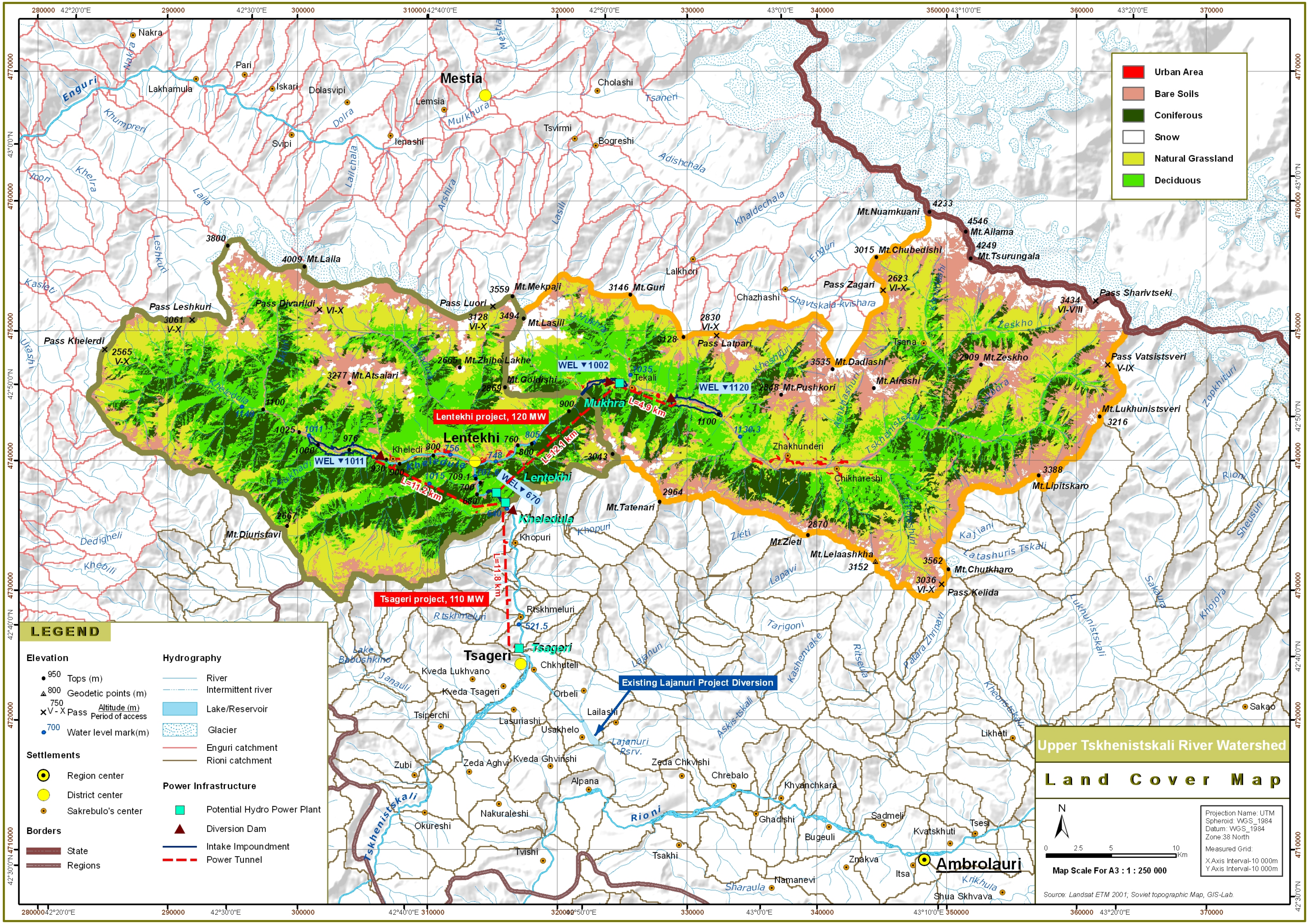
Appendix 6

Annual Precipitation Map


Upper Tskhenistskali River Watershed
Mean Annual Precipitation
Annual Precipitation (mm)
1000 - 1160
1160 - 1272
1272 - 1350
1350 - 1405
1405 - 1483
1483 - 1595
1595 - 1755
1755 - 1985
1985 - 2315
2315 - 2787
LEGEND
Elevation
950 Tops (m)
800 Geodetic points (m)
750 V - X Pass Altitude (m) Period of access
700 Water level mark(m)
Settlements
Region center
District center
Sakrebulo's center
Borders
State
Regions
Hydrography
River
Intermittent river
Lake/Reservoir
Glacier
Enguri catchment
Rioni catchment
Power Infrastructure
Potential Hydro Power Plant
Diversion Dam
Intake Impoundment
Power Tunnel
Lentekhi project, 120 MW
Tsageri project, 110 MW
Existing Lajanuri Project Diversion
L=11.2 km
L=12.1 km
L=4.9 km
L=11.8 km
WEL ▼1002
WEL ▼1120
WEL ▼1011
WEL ▼670
Mukhra
Lentekhi
Kheledula
Tsageri
Mestia
Lentekhi
Tsageri
Ambrolauri
Map Scale For A3 : 1 : 250 000
Projection Name: UTM
Spheroid: WGS_1984
Datum: WGS_1984
Zone:38 North
Measured Grid:
X Axis Interval-10 000m
Y Axis Interval-10 000m
Source: Georgian National Atlas,1964; Soviet topographic Map; GIS-Lab.

Appendix 7

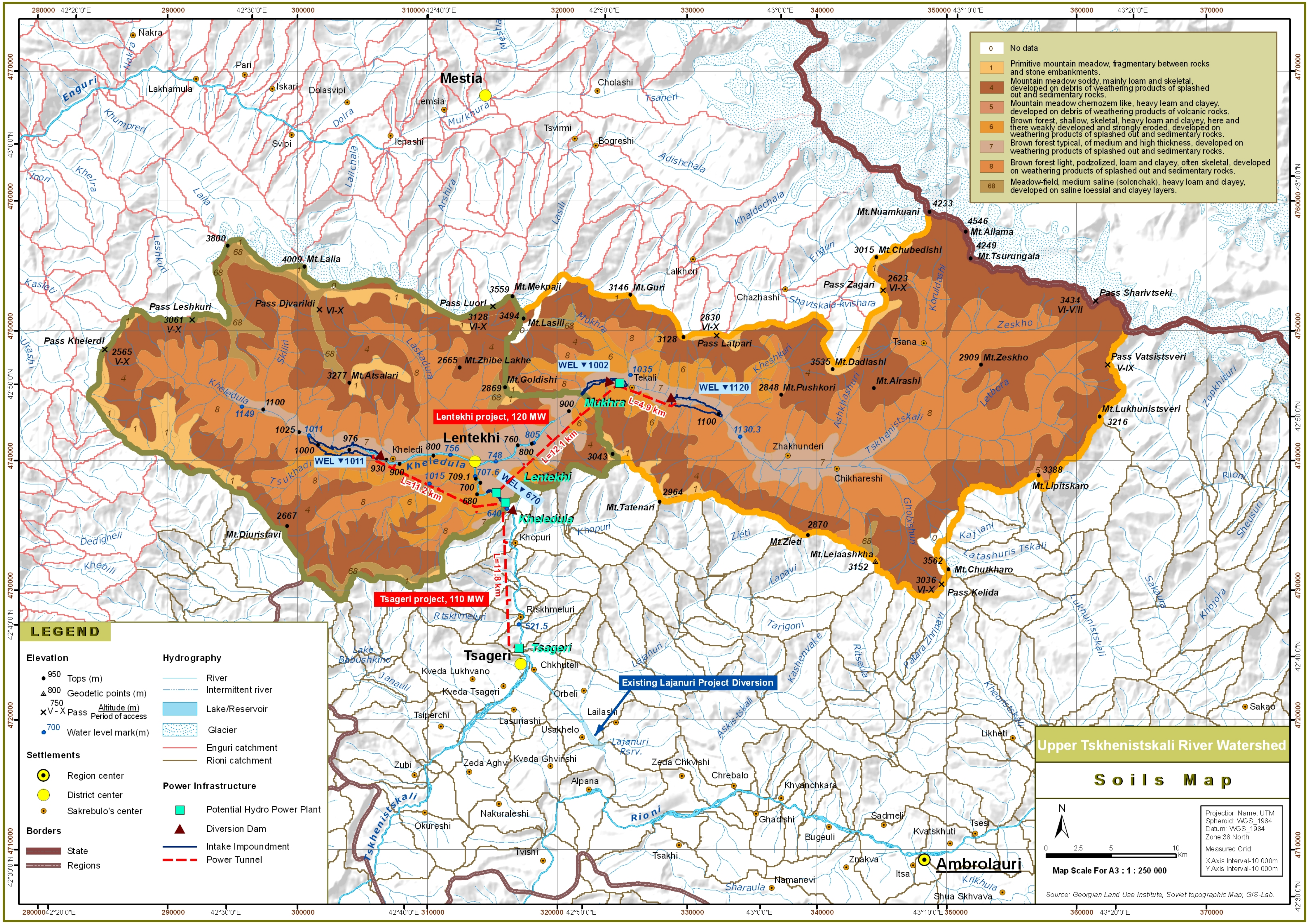
Land Cover Map



Upper Tskhenistskali River Watershed
Land Cover Map
Urban Area
Bare Soils
Coniferous
Snow
Natural Grassland
Deciduous
LEGEND
Elevation
Tops (m)
Geodetic points (m)
Pass Altitude (m) Period of access
Water level mark(m)
Hydrography
River
Intermittent river
Lake/Reservoir
Glacier
Enguri catchment
Rioni catchment
Settlements
Region center
District center
Sakrebulo's center
Power Infrastructure
Potential Hydro Power Plant
Diversion Dam
Intake Impoundment
Power Tunnel
Borders
State
Regions
Lentekhi project, 120 MW
Tsageri project, 110 MW
Existing Lajanuri Project Diversion
Mestia
Lentekhi
Tsageri
Ambrolauri
Map Scale For A3 : 1 : 250 000
Projection Name: UTM
Spheroid: WGS_1984
Datum: WGS_1984
Zone:38 North
Measured Grid:
X Axis Interval-10 000m
Y Axis Interval-10 000m
Source: Landsat ETM 2001; Soviet topographic Map, GIS-Lab.

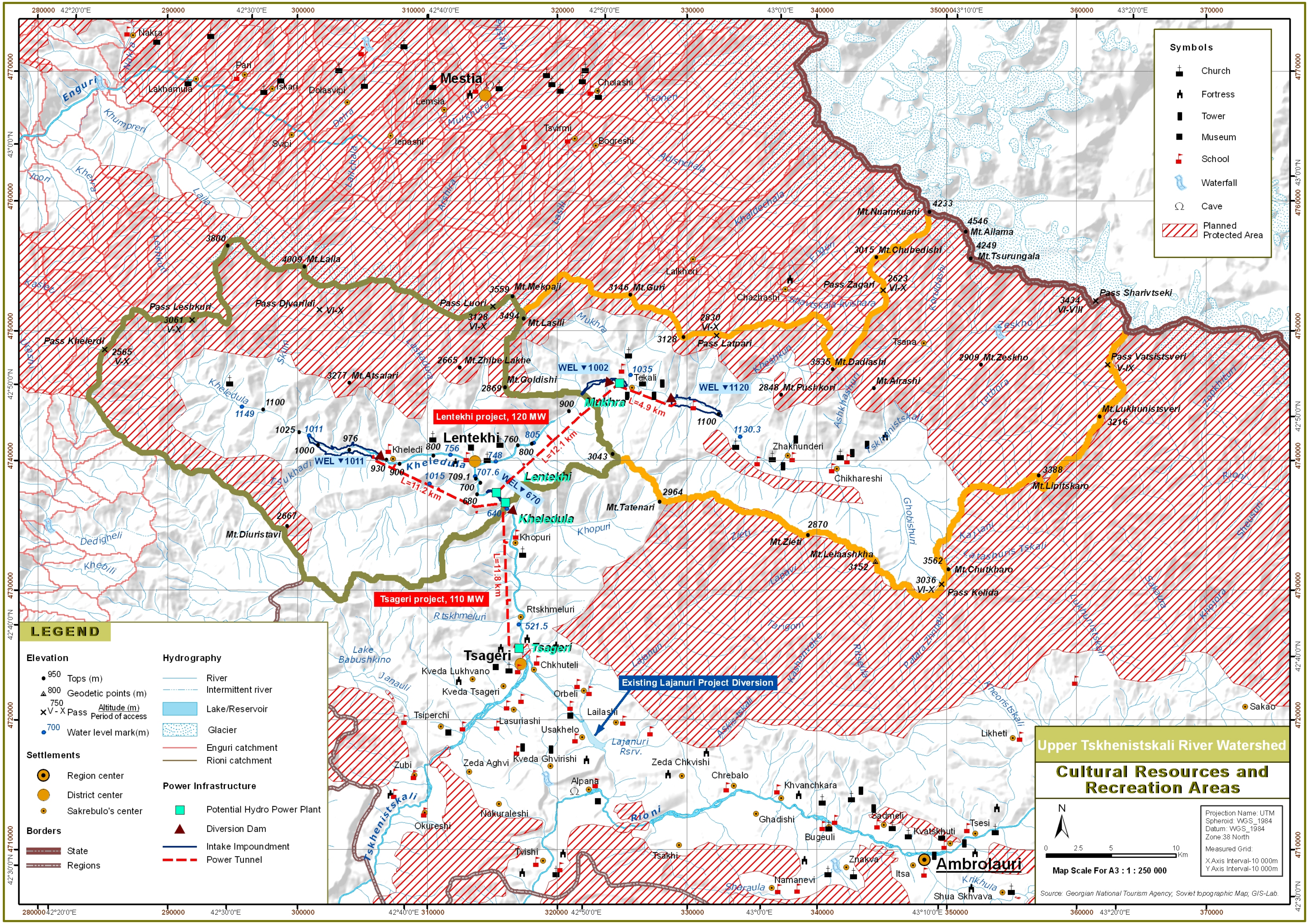
Appendix 8

Soils Map


Upper Tskhenistskali River Watershed
Soils Map
0 No data
1 Primitive mountain meadow, fragmentary between rocks and stone embankments.
4 Mountain meadow soddy, mainly loam and skeletal, developed on debris of weathering products of splashed out and sedimentary rocks.
5 Mountain meadow chernozem like, heavy leam and clayey, developed on debris of weathering products of volcanic rocks.
6 Brown forest, shallow, skeletal, heavy loam and clayey, here and there weakly developed and strongly eroded, developed on weathering products of splashed out and sedimentary rocks.
7 Brown forest typical, of medium and high thickness, developed on weathering products of splashed out and sedimentary rocks.
8 Brown forest light, podzolized, loam and clayey, often skeletal, developed on weathering products of splashed out and sedimentary rocks.
68 Meadow-field, medium saline (solonchak), heavy loam and clayey, developed on saline loessial and clayey layers.
LEGEND
Elevation
950 Tops (m)
800 Geodetic points (m)
750 V - X Pass Altitude (m) Period of access
700 Water level mark(m)
Settlements
Region center
District center
Sakrebulo's center
Borders
State
Regions
Hydrography
River
Intermittent river
Lake/Reservoir
Glacier
Enguri catchment
Rioni catchment
Power Infrastructure
Potential Hydro Power Plant
Diversion Dam
Intake Impoundment
Power Tunnel
Lentekhi project, 120 MW
Tsageri project, 110 MW
Existing Lajanuri Project Diversion
L=11.2 km
L=12.1 km
L=4.9 km
L=11.8 km
WEL ▼1011
WEL ▼1002
WEL ▼1120
WEL ▼670
Mestia
Lentekhi
Tsageri
Ambrolauri
Mukhra
Kheledula
Enguri
Rioni
Tskhenistskali
Lajanuri Rsrv.
Mt.Laila
Mt.Mekpaji
Mt.Guri
Mt.Nuamkuani
Mt.Ailama
Mt.Tsurungala
Mt.Chubedishi
Mt.Zhibe Lakhe
Mt.Atsalari
Mt.Goldishi
Mt.Lasili
Mt.Dadiashi
Mt.Airashi
Mt.Pushkori
Mt.Zeskho
Mt.Lukhunistsveri
Mt.Lipitskaro
Mt.Tatenari
Mt.Zieti
Mt.Lelaashkha
Mt.Chutkharo
Mt.Diuristavi
Pass Leshkuri
Pass Djvarildi
Pass Kheledi
Pass Luori
Pass Latpari
Pass Zagari
Pass Sharivtseki
Pass Vatsistsveri
Pass Kelida
N
0 2.5 5 10 Km
Map Scale For A3 : 1 : 250 000
Projection Name: UTM
Spheroid: WGS_1984
Datum: WGS_1984
Zone:38 North
Measured Grid:
X Axis Interval-10 000m
Y Axis Interval-10 000m
Source: Georgian Land Use Institute; Soviet topographic Map; GIS-Lab.

Appendix 9

Cultural Resources & Recreation Areas


Upper Tskhenistskali River Watershed
Cultural Resources and Recreation Areas
Symbols
Church
Fortress
Tower
Museum
School
Waterfall
Cave
Planned Protected Area
LEGEND
Elevation
950 Tops (m)
800 Geodetic points (m)
750 V - X Pass Altitude (m) Period of access
700 Water level mark(m)
Settlements
Region center
District center
Sakrebulo's center
Borders
State
Regions
Hydrography
River
Intermittent river
Lake/Reservoir
Glacier
Enguri catchment
Rioni catchment
Power Infrastructure
Potential Hydro Power Plant
Diversion Dam
Intake Impoundment
Power Tunnel
Lentekhi project, 120 MW
Tsageri project, 110 MW
Existing Lajanuri Project Diversion
Mestia
Lentekhi
Tsageri
Ambrolauri
Mukhra
Lentekhi
Kheledula
Tsageri
L=4.9 km
L=12.1 km
L=11.2 km
L=11.8 km
WEL ▼1002
WEL ▼1120
WEL ▼1011
WEL ▼670
Mt.Nuamkuani
Mt.Ailama
Mt.Tsurungala
Mt.Chubedishi
Mt.Laila
Mt.Mekpaji
Mt.Lasili
Mt.Guri
Mt.Dadiashi
Mt.Pushkori
Mt.Airashi
Mt.Zeskho
Mt.Lukhunistsveri
Mt.Lipitskaro
Mt.Chutkharo
Mt.Lelaashkha
Mt.Zieti
Mt.Tatenari
Mt.Diuristavi
Mt.Atsalari
Mt.Zhibe Lakhe
Mt.Goldishi
Pass Leshkuri
Pass Djvarildi
Pass Luori
Pass Khelerdi
Pass Latpari
Pass Zagari
Pass Sharivtseki
Pass Vatsistsveri
Pass Kelida
Enguri
Kheledula
Tskhenistskali
Rioni
Lajanuri Rsrv.
Lake Babushkino
Projection Name: UTM
Spheroid: WGS_1984
Datum: WGS_1984
Zone:38 North
Measured Grid:
X Axis Interval-10 000m
Y Axis Interval-10 000m
Map Scale For A3 : 1 : 250 000
Source: Georgian National Tourism Agency, Soviet topographic Map, GIS-Lab.

Historical, cultural and archeological resources of the Tsageri District

#	Name	Location	Dated
1	Saint Maxim Church	Village Muri	VII Century
2	Basilica style Church	Village Gvesi	VIII Century
3	Caves	Village Alpana	Middle age
4	Anchiskhati Church	Village Gagulechi	
5	Saint George's Church	Village Goni	
6	Saint George's Church	Village Zeda Sairme	1766
7	Saint Mary Church	Village Zogishi	Middle age
8	Caves	Village Zubi	Middle age
9	Castle, Church	Village Tabori	V-VII Century
10	Saint Mary Church	Village Isunderi	XIX Century
11	Saint George's Church	Village Lailashi	Middle age
12	Sameba Church	Village Makhuri	XIX Century
13	Saint George's Church	Village Tskheta	XII Century
14	Saint George's Church	Village Nakuraleshi	VII Century
15	Saint Mary Church	Village Sairme	Middle age
16	Saint George's Church	Village Tvishi	
17	Saint Mary Church	Village Utskheri	Middle age
18	Cave monastery	Village Khvamli	Middle age
19	Saint George's Church	Khvamli	Middle age
20	Tabori Castle-Church	Village Tabori	IX-X Century
21	Leshkashi Castle	Village Leshkashi	Middle age
22	Muri Castles	Village TmurisTsikhe	Middle age
23	Gveso Castle	Village Gveso	Middle age

Source: Ministry of Culture of Georgia

Appendix 10

Environmental and social impacts Significant Data

Appendix 10: Description of Tables

This appendix presents a tabular summary of potential environmental and social receptor impacts from the development of a hydropower project in the Upper Tskhenistskali River basin near the Tsageri project. These tables are based on the "EU Strategic Environmental Assessment Principles" that uses a subset of categories developed that best fits this level of analysis (Ref: http://ec.europa.eu/environment/eia/home.htm). Sections 2 and 3 and Section 6 of this document present a description of environmental and social baseline conditions. Section 6.2 presents environmental and social impacts and mitigation practices for each impacted receptor. The tables include a range of qualitative values for impacts and recommendations for mitigation practices that are considered standards of practice today. This prefeasibility report does not go into any detail with respect to recommended mitigation practices and should be used as a guideline with respect to the types of practice to be incorporated during a feasibility study for the different phases of the project (construction or operations. Decommissioning has not been included at this time).

The table column headers are described as follows:

Column 1: Receptors

Receptors are the environmental and social category that an impact is evaluated for. For this prefeasibility report these include:

- Water Resources
  - Surface Water Resources
  - Surface Water Quality
  - Flood Risk
- Soils, Geology, and Landscape
- Air Quality
- Biodiversity
  - Terrestial Flora
  - Terrestial Fauna
  - Fisheries
- Community, Socio-Economic, and Public Health
  - Cultural and Historic Assets
  - Population
  - Recreation
  - Public Health

Receptors are evaluated with a Sensitivity level that is defined as follows:

Sensitivity of receptors, based on Value and Vulnerability

Classification	Sensitivity Level			
Vulnerability	**High (H)** e.g. potential pathways exist for environmental change in receptors as a result of project, receptor is in a declining condition, dependent on a narrow range of environmental conditions	**Medium (M)** *e.g.* few pathways exist for environmental change in receptors as a result of project, receptor is only expected to recover from disturbance over a prolonged period of time, if at all, or impact potential is high but duration is short	**Low (L)** *e.g.* limited or no pathways exist for environmental change in receptors as a result of project, receptor is in stable or favourable condition &/ or dependent on wide range of environmental conditions	**None (N)** *e.g.* no pathways exist between environmental changes and receptors, receptor is insensitive to disturbance
Value	**High (H)** – receptor is rare, important for social or economic reasons, legally protected, of international or national designation	**Low (L)** – receptor is common, of local or regional designation		

Column 2: Impact
This column is a description of the effect on the receptors during each of the project phases, construction followed by operations.

Column 3: Duration
Duration is the expectation for the length of time an impact will occur to a given receptor. The following table displays the rating values for duration:

Guidelines for determining the period of the project lifecycle

	Duration of effect			
Classification	**Long Term (LG)**	**Medium Term (MD)**	**Short Term (SH)**	**Very Short Term (VSH)**
Guideline	10+ years	3-10 years	1-3 years	<12 months
Project phase	Operation	Operation	Construction (or part thereof)	Part of construction period

Column 4: Risk Level
Risk Level qualitatively addresses the exposure and vulnerability a receptor will have from the project or in some cases how specific risks could cause the project to increase exposure and vulnerability to the receptor. An example of this is Seismic Risk as it pertains to Soils, Geology, and Landscape during each project phase. Risk level also includes whether the impact is Irreversible or Reversible and Temporary or Permanent. The following displays the rating values for Risk Level:

Risk Level Rankings Definitions and Description

Risk Level	**Description**
Very Low (VL)	Rarely occurs, and/or of very low magnitude, and/or rarely causes significant loss or life or property damage

Low (L)	Can occur during the life of the project, and/or can be of modest magnitude, and/or rarely causes loss of life but can cause property some damage
Medium (M)	Occurs several or more times during the life of a project, and/or of significant magnitude, and/or can cause some loss of life and significant property damage
High (H)	Occurs often or on a regular basis and/or of a very high magnitude, and/or causes large loss of life and major property damage
Irreversible	Impact causes irreversible change to the receptor
Reversible	Impact causes reversible changes to the receptor
Temporary	Impact is of a temporary nature and receptor will return to original conditions after activity concludes
Permanent	Impact from activity is permanent changing the original receptor conditions to a new state.

Column 5: Mitigation Practices

Mitigation practices are guidelines and recommendations for a type of prevention activity that will reduce impacts to a receptor, provide necessary data and information for decisions during a project phase, provide heath and safety guidelines, and environmental prevention practices to minimize impacts to the receptors.

Table-1 Affected Environmental Impacts and Proposed Mitigation Measures Environmental Receptor Category: Water Resources

Water Resources				
Receptors (Vulnerability (H, M, L, None) and Value (H, L)	**IMPACT (Description of effect)**	**Duration (occurs during construction, operation or decommissioning phase and LG/MD/SH/VSH term) and frequency**	**Risk Level (VL, L, M, H, and Irreversible/ reversible; temporary/ permanent**	**Mitigation Practices**
Surface Water Resources (quantity) M/L ---------------------- M/L	**Construction Phase (HPP and Transmission Facility)**: • Altered surface runoff contribution to water courses and ditches, etc as a result of land disturbance • Temporary Diversion of River away from Dam and intake structure • Large construction/tunnel volume debris disposal -------------------------- **Operation Phase:** effects on surface water resources during facility operations	SH SH SH ---------------------------- LG	VL/R/T VL/R/T ------------------------------------ L/R/T	Very high sediment and bed load transport by upper Tskhenistskali river. Assume site preparation include in-water, bank side, and/or adjacent property. River flow and river channel may be temporarily redirected for site construction. Well understood process. Few if any uncertainties, assume runoff controls and spill prevention plans and monitoring are included in construction. Locate area for construction debris that can contribute to generation of usable land in the future. ---------- Run of river hydropower operations returns all diverted flow used for generation to the receptor river. Long penstock facilities must meet appropriate receptor guidelines for bypass flows as required.
Surface Water Quality M/L -------------------------	**Construction Phase(HPP and Transmission Facility)**: • Altered surface runoff water quality to water courses and ditches, etc as a result of land disturbance • Temporary Diversion of River away from Dam and intake structure ---------------------------	SH SH ----------------------------	VL/R/T VL/R/T ------------------------------------	Very high sediment and bed load transport by upper Tskhenistskali River. Assume site preparation can include in-water, bank side, and/or adjacent property. River flow and river channel may be temporarily redirected for site construction. Well understood process. Few if any uncertainties, assume runoff controls and spill prevention plans and monitoring are included during construction. --------------------

M/L	**Operation Phase:** effects on surface water resources during facility operations	LG	L/R/T	Run of river hydropower operations returns all diverted flow used for generation to the receptor river. Long penstock facilities must meet appropriate receptor guidelines for bypass flows as required.
Flooding Risk M/L ------------------------ M/L	**Construction Phase (HPP and Transmission Facility):** • **Increase to flood discharge from failure of dam during construction** -- **Operations Phase:** **Prevent failure of dam and other project components in the event of a flood that would severely increase the impact from the flooding event**	VSH ------------------------------ VSH	L/R/T ------------------------------------- M/R/T	• Construction to adhere to all design requirements. • Dispose of large volumes of construction debris in locations that will not increase flood levels, or impact floodplain negatively • Design to address appropriate levels of Flood Risk in planning construction phase. • Monitoring of river discharge upstream on main stem and significant tributaries (flash flood warning) • Emergency Evacuation Plan developed • Emergency site shut down plan to be developed. -- Insure all facilities are operating correctly including, spillway gates, trash racks, and shut off gates (tunnel and powerhouse), etc. Monitor Dam for seepage, leaks, and structural integrity. Monitor Tunnel for leaks and structural integrity Prepare Emergency operations plan that includes flooding events Prepare Emergency shut down and evacuation plan.

Table-2 Affected Environmental Impacts and Proposed Mitigation Measures Environmental Receptor Category: Soils, Geology, and Landscape

Soils, Geology and Land Use				
Receptor s	**IMPACT (Description of effect)**	**Duration LG/MD/SH/VSH term)**	**Risk Level (VL, L, M, H, and Irreversible/ reversible; temporary/ permanent**	**Mitigation Practices**
Soils, Geology, Landscape **(Vulnerability (H, M, L, None) and Value (H, L)** H/L ---------------------- H/L	**Seismic Risk** **Construction Phase (HPP and Transmission Facility)**: • Impacts on infrastructure and public due to seismic activity --------------------------- • **Operation Phase:** Impacts on infrastructure and public due to seismic activity that causes HPP to fail	VSH , -------------------- VSH	H/R and IR/T and P depending on seismic characteristics ------------------ H/R and IR/T and P depending on seismic characteristics	Well understood process. The project structures to be built in the area have to have appropriate design specifications which are in line with the national and international standards. Severe activity can lead to failure, flooding, property damage and loss of human life. Emergency site shut down and Evacuation plans should be included in construction management planning. ------------------ Well understood process but magnitude is unknown. Severe seismic activity can lead to failure, flooding, property damage and loss of human life downstream of HPP. Emergency site shut down and Evacuation plans including Tsageri Town and downstream should be included in HPP Operations Plan
Soils, Geology, and Landscape **(Vulnerability (H, M, L, None) and Value (H, L)** H/L	**Landslides and Mudslides** **Construction Phase (HPP and Transmission Facility)**: improper stockpiling of materials, poor siting, of storage and lay down areas, blasting activities and/or destruction of vegetation cover could increase receptor impacts if land slide or mud slide occurs at HPP site or upstream.	VSH	M/R/T	Erosion and sediment control plan (includes issues like: proper site siting and engineering design based on best management practices, accumulated sediment disposal plan, grading and smoothing steep slopes, re-vegetation activities etc) at national and international standards should be developed. Emergency shut down and Evacuation plans should be developed to protect receptors, property, and human life.

--------------------- H/L	-------------------------- **Operation Phase:** Minimize increasing the impacts from this natural occurrence from HPP operations	------------------------------- SH	---------------------------------- L/R/T	Early Warning Monitoring to include Weather and watershed and upslope areas from HPP site and known land slide and mud slide locations Proper scheduling of construction activities Monitoring of vibration from construction equipment (and blasting activities) ----------------------- Monitoring site conditions on a regular basis; implementation of pre-prepared emergency shut down and Evacuation plans ; Monitoring of Early Warning system
Soils, Geology, and landscape **(Vulnerability (H, M, L, None) and Value (H, L)** M/H	**Visual impact on landscape Construction Phase (HPP and Transmission Facility)**: Visual impact is important in this mountainous setting and impacts to this receptor are significant. Construction activities may cause visual disturbance of landscape (new project units (e.g. dam, powerhouse) will be constructed). Construction activities may cause removal of vegetation cover, changes in land use pattern. Waste generation due to construction activities may create visual impact on landscape as well as impact on land. Management and disposal of construction debris -------------------------- **Operation Phase:** No more additional alterations of landscape are expected during the operation phase. Water body such as impoundment may be considered to create pleasant scenery.	SH ------------------- SH	VL/R/T ---------------------- VL/R/P	Proper storage and utilization of topsoil and excavation materials. Restoration of soil cover, re-vegetation and reforestation activities to national and international standards Proper scheduling of construction activities. Develop construction management plan. Development appropriate waste management plan which includes management of solid, liquid, hazardous waste material and are in line with national and international environmental regulations. Construction debris should be disposed of according to current accepted practice, local and national laws. Where possible use construction in a sustainable manner that provides opportunities for agriculture, local industry, and does not impact local floodplain ----------------------- Monitoring the landscape restoration activities.

Table-3 Affected Environmental Impacts and Proposed Mitigation Measures Environmental Receptor Category: Air Quality

Air Quality				
Receptor s	**IMPACT (Description of effect)**	**Duration LG/MD/SH/VSH term)**	**Risk Level (VL, L, M, H, and Irreversible/ reversible; temporary/ permanent**	**Mitigation Practices**
Air Quality **(Vulnerability (H, M, L, None) and Value (H, L)** **L/H** **----------------------** **L/L**	**Construction Phase (HPP and Transmission Facility)**: construction activities may increase the level of emission in the air and dust, especially under windy conditions. --------------------------- **Operation Phase:** during operation there would not be any significant emission level.	SH --------------- VSH	L/R/T ----------------- VL/R/T	Well understood process. Air management plan should be developed, which includes activities like construction machinery maintenance scheduling, Exhaust gas quality, water spray on construction site to minimize dust, checking construction equipment and/or benzene quality etc. -------------------- Ensuring compliance with air management plan, emergency generator exhaust controls.

Table -4 Affected Environmental Impacts and Proposed Mitigation Measures Environmental Receptor Category: Biodiversity

Biodiversity				
Receptor s	**IMPACT (Description of effect)**	**Duration LG/MD/SH/VSH term)**	**Risk Level (VL, L, M, H, and Irreversible/ reversible; temporary/ permanent**	**Mitigation Practices**
Terrestrial flora **(Vulnerability (H, M, L, None) and Value (H, L)** **L/L** **-------------------** **L/L**	**Construction Phase (HPP and Transmission Facility)**: project might have following primary and secondary impacts on the terrestrial flora: • Construction of HPP, new roads and/or Transmission lines may cause removal of vegetation (forests, topsoil); • Alien species invading the existing ecosystem; -------------------------- **Operation Phase:** there would be minor or no impact on flora during the operation phase	MD ------------ VSH	M/R/T ----------------- VL/R/P	Well understood process. Restoration and reinstatement of soil cover; re-vegetation and/or reforestation activities. -------------------------- Monitoring restoration activities.
Terrestrial fauna **(Vulnerability (H, M, L, None) and Value (H, L)** **L/L**	**Construction Phase (HPP and Transmission Facility)**: project might have following primary and secondary impacts on the terrestrial fauna: • Disruption of sites of breeding and sheltering; • Animal mortality due to construction activities (e.g. accidents and/or mortality of birds due to Transmission lines) • Alien species invading the existing ecosystem; • number of equipments and/or possible blasting activities	MD	M/R/T	Wildlife management plan should be developed. Noise management plan. Proper scheduling of construction activities; Monitoring of vibration and blasting activities from construction equipment

______________ **L/L**	may cause the increase the noise/vibration level during the construction process, which may disturb wildlife (affect species behaviour) -------------------------- **Operation Phase:** impacts affecting fauna elements during operation are: • Ecological barrier effect (movement is disabled or hindered • Mortality of animals on roads; • Mortality of birds on power lines	------------ VSH	------------------ VL/R/P	--------------------------- Implementing and monitoring the wildlife management plan.
Fishery **(Vulnerability (H, M, L, None) and Value (H, L)** **L/L** **------------------------** **L/L**	**Construction Phase HPP**: Impact on fish species due to construction in the riverbed and altering the river flowthrough temporary diversion channel, and blasting activities. -------------------------- **Operation Phase:** impacts on fish species due to diverting river flow to the powerhouse (mortality fish species in the turbines/generators). Exposure of bypass section of river to very low to no flow.	MD --------------- MD	M/R/T -------------------------- M/R/T	Installing fish protecting/screening facilities at the entrance of the HPP feeding tunnels/channels. Scheduling of construction activities. Avoiding the stockpiling in the riverbed. Proper scheduling of construction activities; Monitoring of vibration and blasting activities from construction equipment ---------------- Well understood process. Permanent monitoring of sanitary water flow;, compliance with environmental and instream flow requirements with monitoring.

Table-5 Affected Environmental Impacts and Proposed Mitigation Measures Environmental Receptor Category: Cultural Resources

Cultural Resources and Recreation				
Receptor s	**IMPACT (Description of effect)**	**Duration LG/MD/SH/VSH term)**	**Risk Level (VL, L, M, H, and Irreversible/ reversible; temporary/ permanent**	**Mitigation Practices**
Cultural and historic assets **(Vulnerability (H, M, L, None) and Value (H, L)** L/H	**Construction Phase HPP and Transmission Facility)**: Based on available information, there are no potential archaeological sites in the vicinity of construction area. However, during actual project development phase certain archaeological objects might occur in construction area, which should be protected from damage. Construction activities (e.g. blasting) could cause negative impact on the cultural/archaeological resources in the vicinity of construction area	VSH	VL/R/T	Identifying historical and cultural assets. Development of noise and construction management plan. Proper scheduling of construction activities Monitoring of vibration from construction equipment and blasting activities
L/H	**Operation Phase:** No damage on archaeological/cultural resources is expected from operational phase.	VSH	VL/R/P	N/A

Table-6 Affected Environmental Impacts and Proposed Mitigation Measures Environmental Receptor Category: Community, Socio-Economic and Public Health

Community, Socio-Economic and Public Health				
Receptor s	**IMPACT (Description of effect)**	**Duration (LG/MD/SH/VSH term)**	**Risk Level (VL, L, M, H, and Irreversible/ reversible; temporary/ permanent**	**Mitigation Practices**
Agricultural Land **(Vulnerability (H, M, L, None) and Value (H, L)** M/H ------------------------ M/H	**Construction Phase (HPP and Transmission Facility)**: Impact associated with land acquisition and thereby loss of agricultural land, which may cause loss of income earning means; disposal of debris; limit access to agricultural property -------------------------- **Operation Phase:** new infrastructure (e.g. access roads) may positively impact on local population, provide better access to markets for agricultural products	MD ------------------------ LG	M/R/P ------------------ M/R/P	Develop compensation mechanism for occupied agricultural land.; coordinate construction activities to minimize impacts to agricultural properties, appropriate selection of disposal areas, materials storage areas;, Monitoring the implementation of compensation scheme ---------------------------- N/A
Population **(Vulnerability (H, M, L, None) and Value (H, L)** L/H ----------------------- L/H	**Construction Phase (HPP and Transmission Facility)**: machinery and/or possible blasting activities may cause the increase the noise/vibration level during the construction process, Construction activities cause traffic delays, which affect local population within the vicinity of project. New job opportunities and economic benefits to community -- **Operation Phase**: The noise/vibration source during the operation will be generators and turbines located in the powerhouse. Since they are located in	SH -------------------- N/A	M/R/T -------------------- N/A	Well understood process. Noise management plan Blast warning plan for construction crews and local residents. Proper scheduling of construction activities Monitoring of vibration from construction equipment (and blasting activities) ------------------ N/A

	the close building, it will have not any considerable nuisance.			
Recreation (Vulnerability (H, M, L, None) and Value (H, L) **M/H** **--------------------** **M/H**	**Construction Phase (HPP and Transmission Facility)**: visual impact due to construction; activities may impact recreation in the region. Waste generation due to construction activities may create visual impact. Delay or prevent access to recreational locations --------------------------- **Operation Phase:** new reservoir and new infrastructure (e.g. better roads) may positively impact on recreational activities	MD ---------------- LG	M/R/T ----------------- VL/R/P	Proper scheduling of construction activities. Develop construction management plan. Development appropriate waste management plan which includes management of solid, liquid, hazardous waste management and are in line with national and international environmental regulations. Provide construction schedules and coordinate with recreational locations to minimize access issues for visitors. ------------------- Operations practice should coordinate with recreational activities so as to assure safe access (fishing), adequate water in bypass channels to support instream activities, and provide access to river for such activities if project limits access.
Roads, Infrastructure, and Communities **(Vulnerability (H, M, L, None) and Value (H, L)** **L/H** **----------------------** **L/H**	**Construction Phase (HPP and Transmission Facility)**: it is expected that during construction new access roads will be build. Load on the existing roads will increase due to construction machinery. Traffic increase will affect Noise, Air Quality, community safety, and Public Health Receptors. Construction provides jobs and economic benefits to community --------------------------- **Operation Phase:**	MD -------------- LG	L/R/T --------------------- VL/R/P	Develop construction management plan that addresses materials delivery, storage, noise, and air quality issues that are sensitive to local communities and meet all Georgian environmental and legal requirements. Include job training for local population where appropriate. ------------------------ Ensure compliance with local and regional laws that effect the community
Public Health **(Vulnerability (H, M, L, None) and Value**	**Construction Phase (HPP and Transmission Facility)**: construction activities might cause health impact to	MD	M/R/P	Health and safety plan should be in line with national and international standards. Occupational health and safety measures should be identified and

(H, L) **M/H** **-------------------------** **L/H**	the workers (e.g. construction related accidents). Also see Air Quality, Population Receptors --------------------------- **Operation Phase:** operational activities might cause health impact to the workers and/or local population.	----------------------- MD	--------------- M/R/P	implemented. Necessary precautionary measures should be implemented in order to avoid and minimize risk of accidents (e.g. fire, flooding etc) ---------------- Ensure compliance with health and safety plan

Appendix 11

Turbine Information

Option 1

Four Pelton Turbines

22.5 m^3/s each

Representative Turbine Selection

created using

TURBNPRO™
Version 3

Hydro Info Systems
P.O. Box 11013
Fairfield, NJ 07004 USA

Phone: (973) 403-8210
FAX: (973) 403-7914
E-Mail: info@turbnpro.com

TURBNPRO Version 3 - PELTON TURBINE SOLUTION SUMMARY

Solution File Name: c:\progra~1\turbnpro\tsag-4xp.dat

TURBINE SIZING CRITERIA

Rated Discharge:	794.5	cfs	/	22.50	m3/s
Net Head at Rated Discharge:	508.5	feet	/	155.0	meters
Gross Head:	534.8	feet	/	163.0	meters
Efficiency Priority:			5		
System Frequency:			50 Hz		
Minimum Net Head:	453.4	feet	/	138.2	meters
Maximum Net Head:	529.5	feet	/	161.4	meters

PELTON TURBINE SOLUTION DATA

Arrangement: VERTICAL WITH RUNNER ON TURBINE SHAFT
Intake Type: 6 - JET
Runner Pitch Diameter: 132.5 inches / 3365 mm
Unit Speed: 150.0 rpm
Multiplier Efficiency Modifier: 1.000
Flow Squared Efficiency Modifier: 0.0000

	(US Cust.)	(SI Units)
Specific Speed at Rated Net Head (turbine) -		
At 100% Turbine Output:	12.6	48.1
At Peak Efficiency Condition:	11.5	44.0
Specific Speed at Rated Net Head (per jet) -		
At 100% Turbine Output:	5.2	19.6
At Peak Efficiency Condition:	4.7	18.0

SOLUTION PERFORMANCE DATA

At Rated Net Head of: 508.5 feet / 155.0 meters

% of Rated Discharge	Output (KW)	Efficiency (%)	cfs	m3/s
** 116.7	35678	89.4	926.9	26.25
100	30786	90.0	794.5	22.50
* 83.3	25702	90.1	662.1	18.75
75	23098	90.0	595.9	16.88
50	15207	88.9	397.2	11.25
25	7391	86.4	198.6	5.63

** - Overcapacity
* - Peak Efficiency Condition

At Maximum Net Head of: 529.5 feet / 161.4 meters

Max. Output (KW)	Efficiency (%)	cfs	m3/s
37862	89.3	945.8	26.79

At Minimum Net Head of: 453.4 feet / 138.2 meters

Max. Output (KW)	Efficiency (%)	cfs	m3/s
30014	89.3	875.2	24.79

Solution File Name: c:\progra~1\turbnpro\tsag-4xp.dat

MISCELLANEOUS DATA

Maximum Runaway Speed (at Max. Net Head):	266 rpm
D/B Ratio (Runner Pitch Dia./Bucket Width):	3.13
Maximum Hydraulic Thrust (at Max. Net Head):	50365 lbs / 22893 kg
Hydraulic Thrust per Jet (at Max. Net Head):	25183 lbs / 11447 kg
Estimated Axial Thrust:	146104 lbs / 66411 kg
Approximate Runner and Shaft Weight:	140564 lbs / 63893 kg

DIMENSIONAL DATA

Intake Type: 6 - JET

	inches	mm
Inlet Diameter:	81.9	2081
Nozzle Diameter:	39.6	1005
Jet Orifice Diameter:	12.6	321
Needle Stroke:	12.0	305
Inlet Piping Spiral Radius:	279.4	7096

Jet to Jet Included Angle: 60 Degrees

Housing/Discharge Geometry:

	inches	mm
Centerline to Housing Top:	90.6	2301
Housing Diameter:	417.0	10591
Discharge Width:	312.7	7944
Tailwater Depth:	74.3	1888
Discharge Ceiling to T.W.:	79.5	2019
Centerline to Tailwater:	206.3	5240

Shafting Arrangement: VERTICAL WITH RUNNER ON TURBINE SHAFT

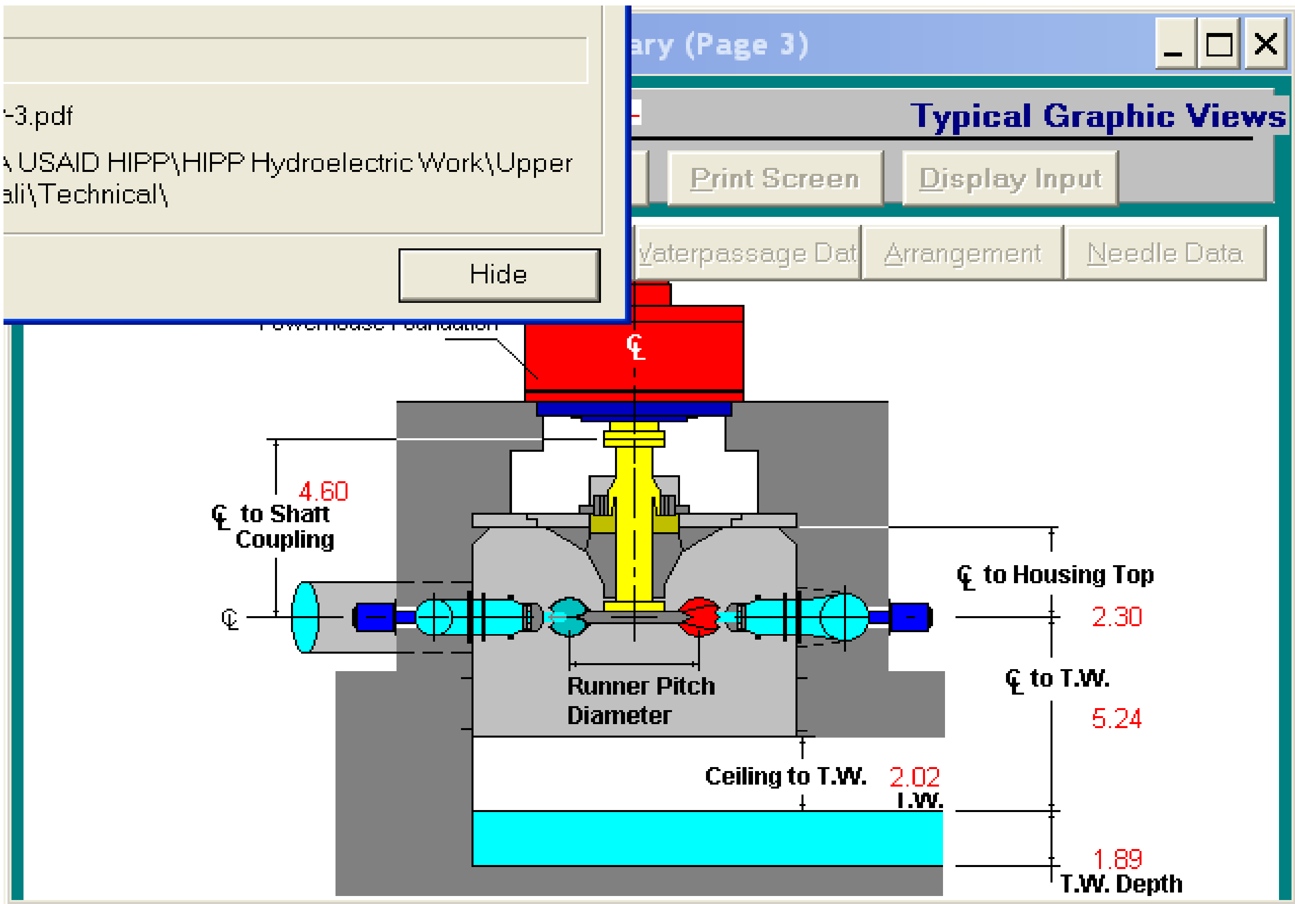
	inches	mm
Centerline to Shaft Coupling:	181.2	4602
Turbine Shaft Diameter:	34.3	872

Miscellaneous:

	inches	mm
Runner Outside Diameter:	174.8	4439
Runner Bucket Width:	42.3	1074

**** All information listed above is typical only. Detailed characteristics will vary based on turbine manufacturer's actual designs.

Solution File Name: c:\progra~1\turbnpro\tsag-4xp.dat
Intake Type: 6 - JET
Runner Diameter: 3365 mm
Net Head at Rated Discharge: 155.00 meters
Unit Speed: 150.0 rpm



Solution File Name: c:\progra~1\turbnpro\tsag-4xp.dat
Intake Type: 6 - JET
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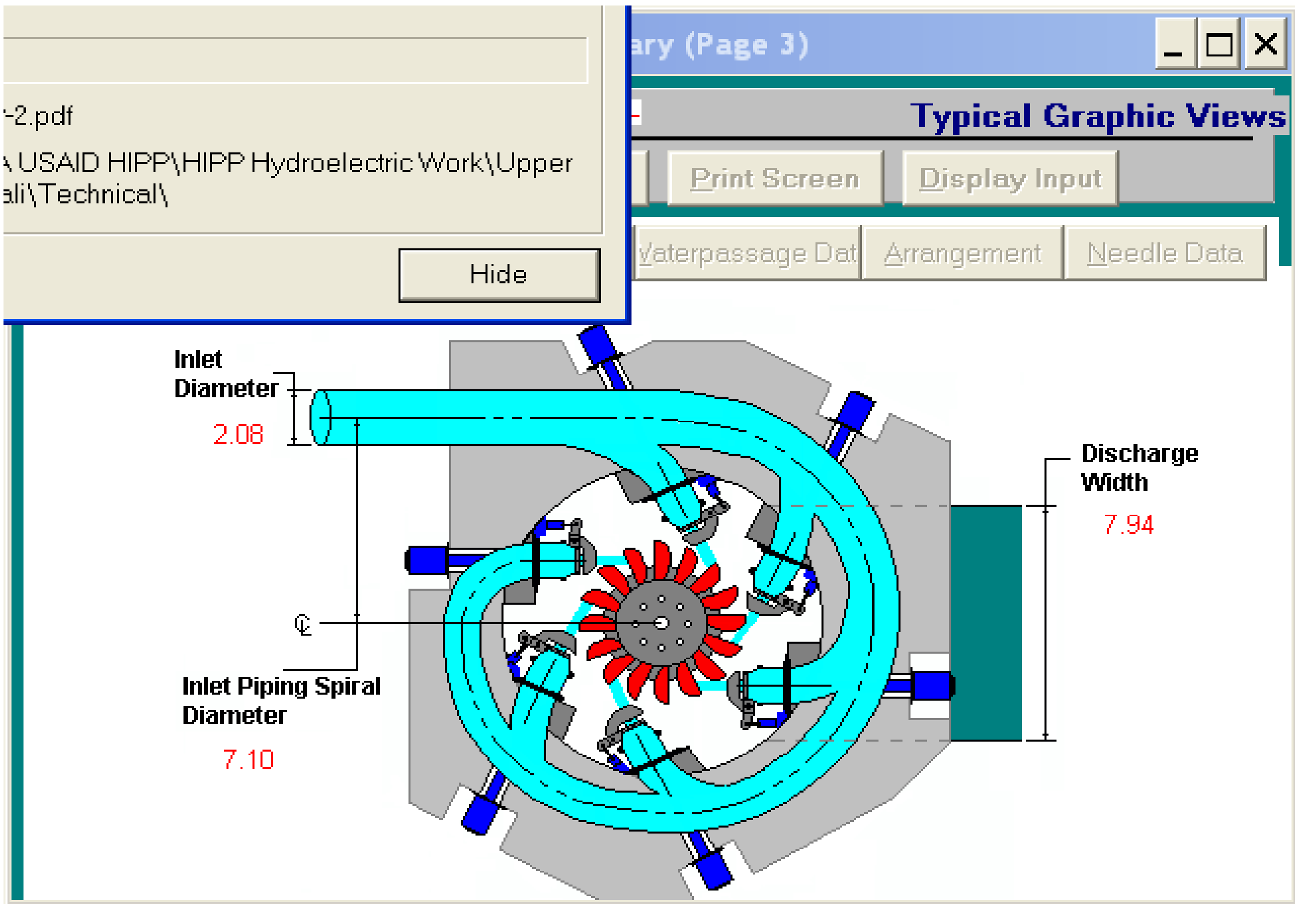
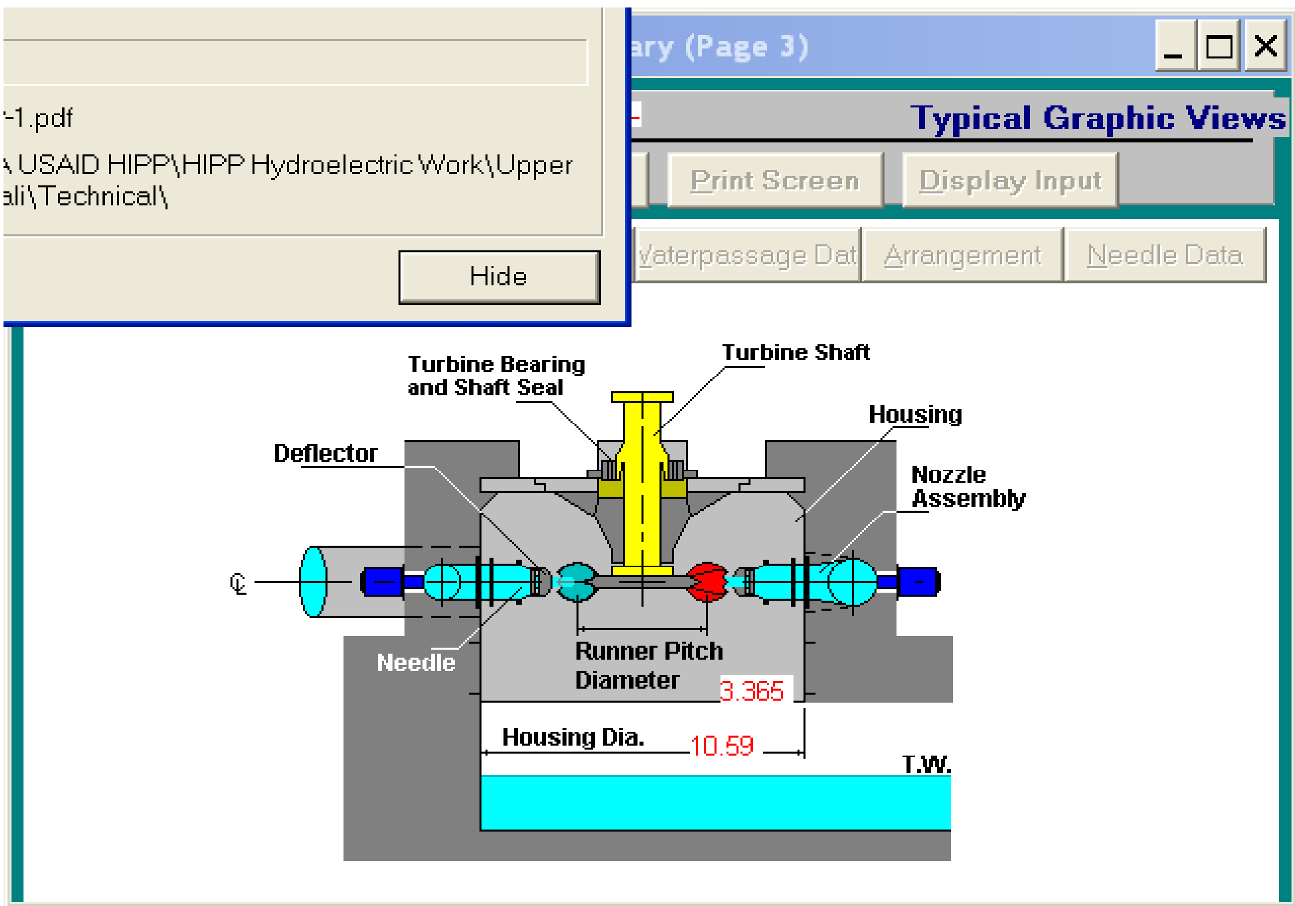
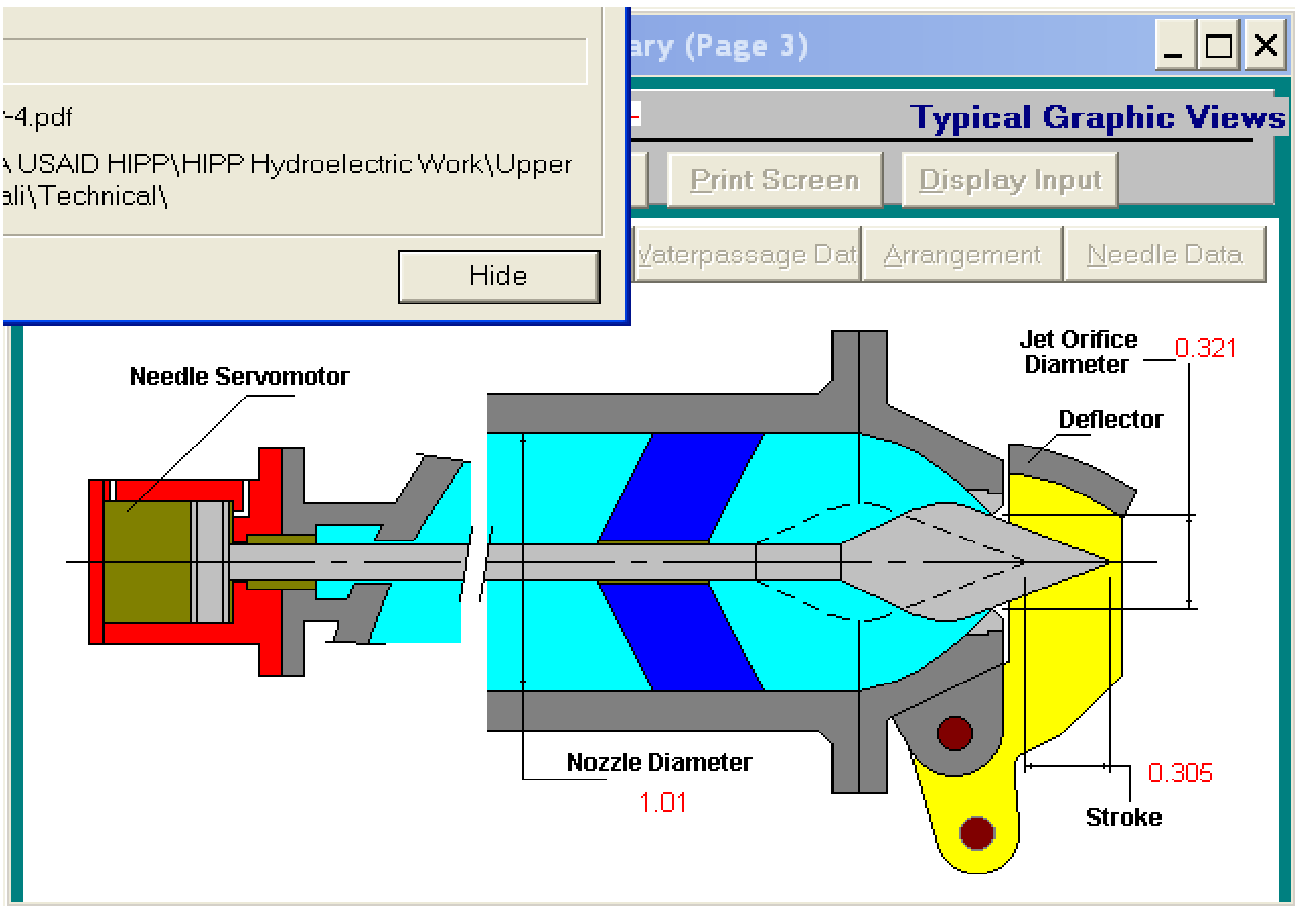


Solution File Name: c:\progra~1\turbnpro\tsag-4xp.dat
Intake Type: 6 - JET
Runner Diameter: 3365 mm
Net Head at Rated Discharge: 155.00 meters
Unit Speed: 150.0 rpm

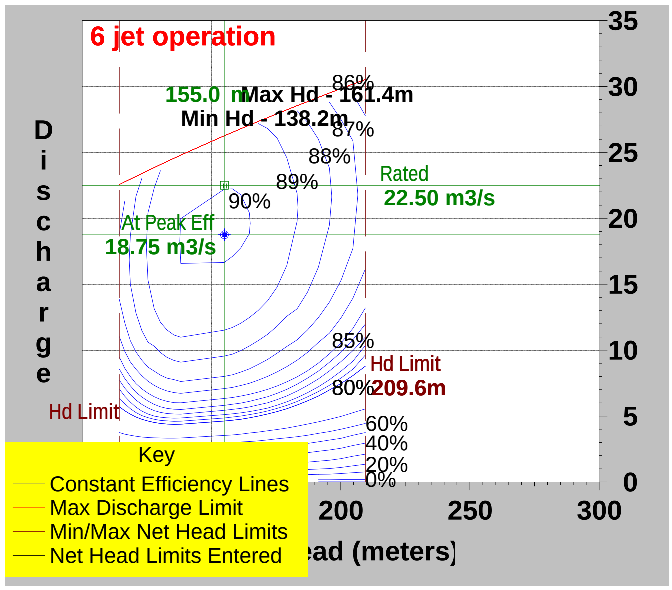


Solution File Name:	c:\progra~1\turbnpro\tsag-4xp.dat
Intake Type:	6 - JET
Runner Diameter:	3365 mm
Net Head at Rated Discharge:	155.00 meters
Unit Speed:	150.0 rpm



Solution File Name: c:\progra~1\turbnpro\tsag-4xp.dat

Intake Type:	6 - JET
Runner Pitch Diameter:	3365 mm
Net Head at Rated Discharge:	155.00 meters
Unit Speed:	150.0 rpm
Peak Efficiency:	90.1 %
Multiplier Efficiency Modifier:	1.000
Flow Squared Efficiency Modifier:	0.0000



NOTE: Discharge is in cubic meters per second

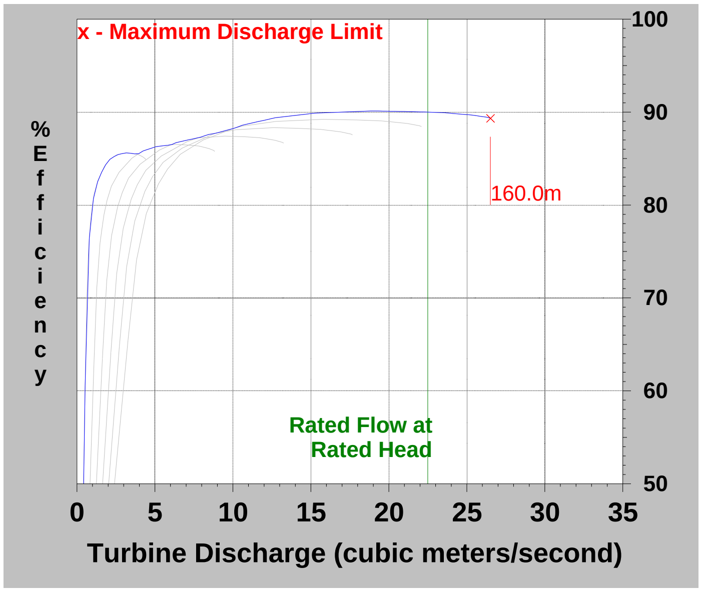
Solution File Name: c:\progra~1\turbnpro\tsag-4xp.dat
Intake Type: 6 - JET
Runner Pitch Diameter: 3365 mm
Net Head at Rated Discharge: 155.00 meters
Unit Speed: 150.0 rpm
Multiplier Efficiency Modifier: 1.000
Flow Squared Efficiency Modifier: 0.0000

Performance Data Shown is for a Net Head of: 160

Power (KW)	Efficiency (%)	Discharge (m3/s)	Operating Jets	Notes
37180	89.33	26.52	6	Max Discharge Limit
36510	89.51	25.99	6	-
35817	89.64	25.46	6	-
35103	89.73	24.92	6	-
34386	89.80	24.39	6	-
33665	89.88	23.86	6	-
32941	89.94	23.33	6	-
32202	89.97	22.80	6	-
31463	90.00	22.27	6	-
30724	90.03	21.74	6	-
29981	90.05	21.21	6	-
29237	90.06	20.68	6	-
28492	90.08	20.15	6	-
27747	90.09	19.62	6	-
27002	90.11	19.09	6	-
26789	90.11	18.94	6	Best Efficiency at Net Head
26247	90.09	18.56	6	-
25487	90.06	18.03	6	-
24729	90.02	17.50	6	-
23970	89.99	16.97	6	-
23213	89.96	16.44	6	-
22456	89.93	15.91	6	-
22101	89.21	15.78	5	Best Efficiency for 5 Jet Operation
21699	89.89	15.38	6	-
20929	89.80	14.85	6	-
20158	89.69	14.32	6	-
19389	89.59	13.79	6	-
18622	89.48	13.26	6	-
17856	89.38	12.73	6	-
17502	88.31	12.63	4	Best Efficiency for 4 Jet Operation
17074	89.19	12.20	6	-
16295	88.98	11.67	6	-
15519	88.78	11.14	6	-
14746	88.58	10.61	6	-
13958	88.25	10.08	5	-
13187	88.01	9.55	5	-
12993	87.41	9.47	3	Best Efficiency for 3 Jet Operation
12420	87.77	9.02	5	-
11666	87.59	8.49	4	-
10900	87.30	7.95	4	-
10150	87.10	7.42	3	-
9404	86.90	6.89	3	-
8660	86.70	6.36	3	-
8573	86.51	6.31	2	Best Efficiency for 2 Jet Operation
7913	86.42	5.83	2	-
7186	86.33	5.30	2	-
6451	86.10	4.77	2	-
5714	85.81	4.24	2	-
4982	85.50	3.71	1	-
4275	85.60	3.18	1	-
4242	85.61	3.16	1	Best Efficiency for 1 Jet Operation
3556	85.43	2.65	1	-
2827	84.91	2.12	1	-

TURBNPRO Version 3 - PELTON TURBINE HILL CURVE

Power (KW)	Efficiency (%)	Discharge (m3/s)	Operating Jets	Notes
2085	83.51	1.59	1	-
1343	80.67	1.06	1	-
504	60.56	0.53	1	-



Option 2

Three Francis Turbines

30.0 m^3/s each

Representative Turbine Selection

created using

TURBNPRO™

Version 3

Hydro Info Systems
P.O. Box 11013
Fairfield, NJ 07004 USA

Phone: (973) 403-8210
FAX: (973) 403-7914
E-Mail: info@turbnpro.com

TURBNPRO Version 3 - FRANCIS TURBINE SOLUTION SUMMARY

Solution File Name: c:\progra~1\turbnpro\tsag-3xf.dat

TURBINE SIZING CRITERIA

Rated Discharge:	1059.3	cfs	/	30.0	m3/s
Net Head at Rated Discharge:	508.5	feet	/	155.0	meters
Gross Head:	534.8	feet	/	163.0	meters
Site Elevation:	1640	feet	/	500	meters
Water Temperature:	68	Degrees F	/	20	Degrees C
Setting to Tailwater:	-16.4	feet	/	-5.0	meters
Efficiency Priority:			5		
System Frequency:			50 Hz		
Minimum Net Head:	475.7	feet	/	145.0	meters
Maximum Net Head:	528.2	feet	/	161.0	meters

FRANCIS TURBINE SOLUTION DATA

Arrangement: VERTICAL WITH RUNNER ON TURBINE SHAFT
Intake Type: SPIRAL CASE
Draft Tube Type: ELBOW
Runner Diameter: 80.7 inches / 2049 mm
Unit Speed: 300.0 rpm
Multiplier Efficiency Modifier: 1.000
Flow Squared Efficiency Modifier: 0.0000

Specific Speed at Rated Net Head -	(US Cust.)	(SI Units)
At 100% Turbine Output:	29.6	112.9
At Peak Efficiency Condition:	28.3	107.9

SOLUTION PERFORMANCE DATA

At Rated Net Head of: 508.5 feet / 155.0 meters

% of Rated Discharge	Output (KW)	Efficiency (%)	cfs	m3/s
** 109.1	45507	91.4	1155.6	32.7
100	42354	92.8	1059.3	30.0
* 90.9	38697	93.3	963.0	27.3
75	31565	92.3	794.5	22.5
50	19337	84.8	529.7	15.0
25	7301	64.0	264.8	7.5
+ 49.3	18954	84.4	521.7	14.8

** - Overcapacity
* - Peak Efficiency Condition
\+ - Peak Draft Tube Surging Condition

At Maximum Net Head of: 528.2 feet / 161.0 meters

Sigma Allowable	Max. Output (KW)	Efficiency (%)	cfs	m3/s
0.064	47746	91.4	1167.3	33.1

At Minimum Net Head of: 475.7 feet / 145.0 meters

Sigma Allowable	Max. Output (KW)	Efficiency (%)	cfs	m3/s
0.065	41026	91.3	1115.9	31.6

Solution File Name: c:\progra~1\turbnpro\tsag-3xf.dat

MISCELLANEOUS DATA

Maximum Runaway Speed (at Max. Net Head):	503 rpm		
Turbine Discharge at:			
Runaway Speed (at Rated Net Head & 100% gate):	504 cfs	/	14.3 m3/s
Synchronous Speed-No-Load (at Rated Net Head):	84 cfs	/	2.4 m3/s
Site's Atmospheric Pressure minus Vapor Pressure:	31.2 feet	/	9.5 meters
Sigma Allowable (at 100% Output & Rated Net Head):	0.048		
Sigma Plant (at 100% Output & Rated Net Head):	0.094		
Maximum Hydraulic Thrust (at Max. Net Head):	163026 lbs	/	74103 kg
Approximate Runner and Shaft Weight:	35252 lbs	/	16024 kg
Vel. at Draft Tube Exit (at Rated Head & Discharge):	4.3 fps	/	1.3 m/s

DIMENSIONAL DATA

Intake Type: SPIRAL CASE

	inches	/	mm
Inlet Diameter:	84.0		2134
Inlet Offset:	126.4		3210
Centerline to Inlet:	142.5		3620
Outside Radius A:	168.4		4277
Outside Radius B:	159.7		4056
Outside Radius C:	147.7		3751
Outside Radius D:	134.5		3416

Draft Tube Type: ELBOW

	inches	/	mm
Centerline to Invert:	257.4		6539
Shaft Axis to Exit Length:	387.2		9835
Exit Width:	242.0		6147
Exit Height:	145.2		3688

Shafting Arrangement: VERTICAL WITH RUNNER ON TURBINE SHAFT

	inches	/	mm
Centerline to Shaft Coupling:	121.7		3090
Turbine Shaft Diameter:	25.1		637

Miscellaneous:

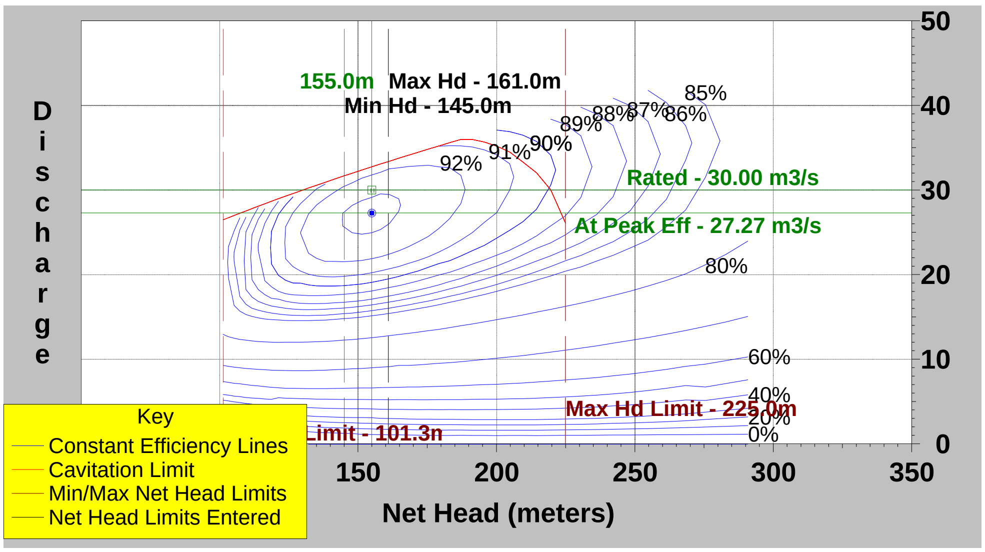
	inches	/	mm
Wicket Gate Height:	15.2		386
Wicket Gate Circle Diameter:	121.7		3090

**** All information listed above is typical only. Detailed characteristics will vary based on turbine manufacturer's actual designs.

TURBNPRO Version 3 - FRANCIS TURBINE HILL CURVE

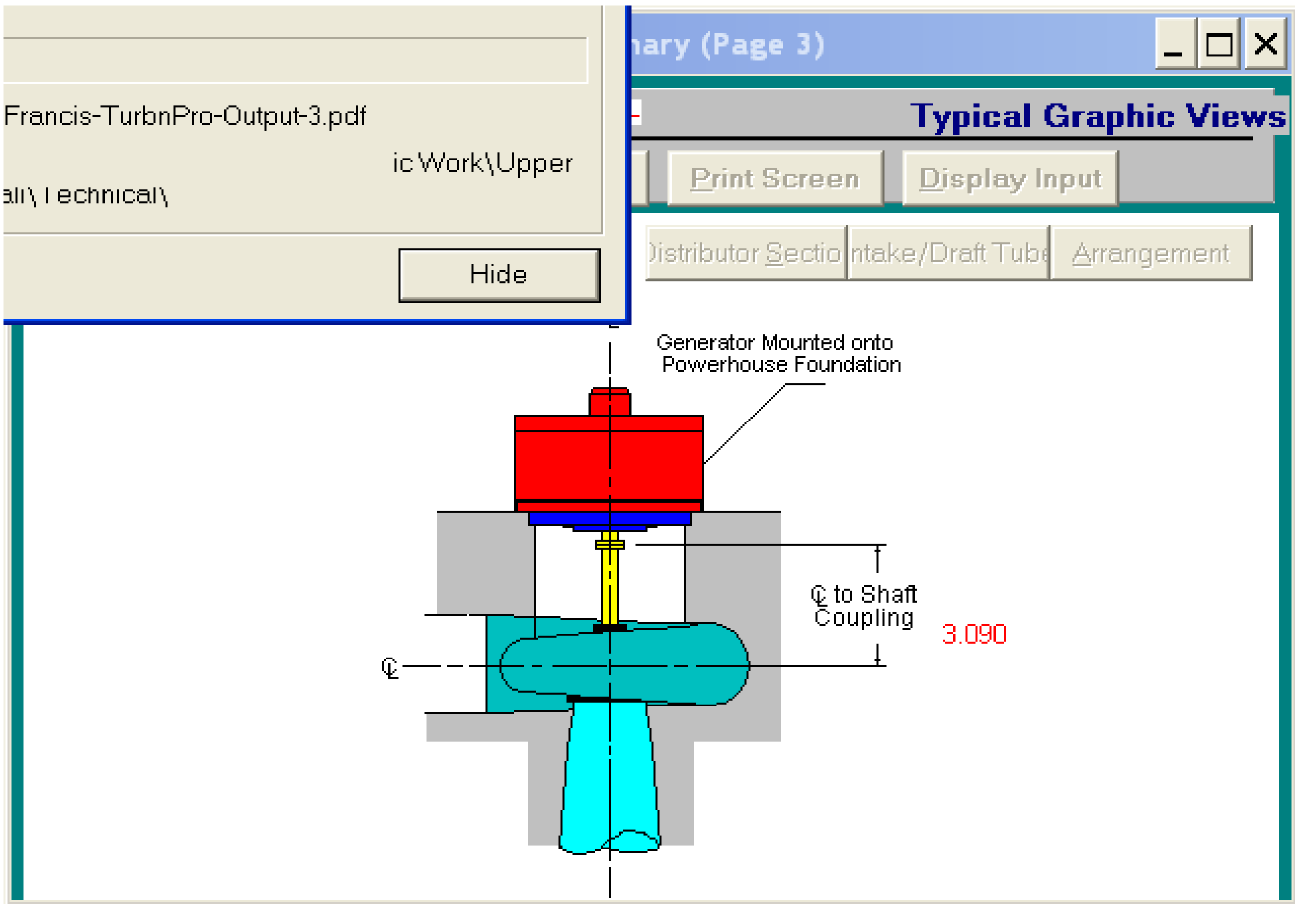
Solution File Name: c:\progra~1\turbnpro\tsag-3xf.dat

Runner Diameter: 2049 mm
Net Head at Rated Discharge: 155.00 meters
Unit Speed: 300.0 rpm
Peak Efficiency: 93.3 %
Multiplier Efficiency Modifier: 1.000
Flow Squared Efficiency Modifier: 0.0000



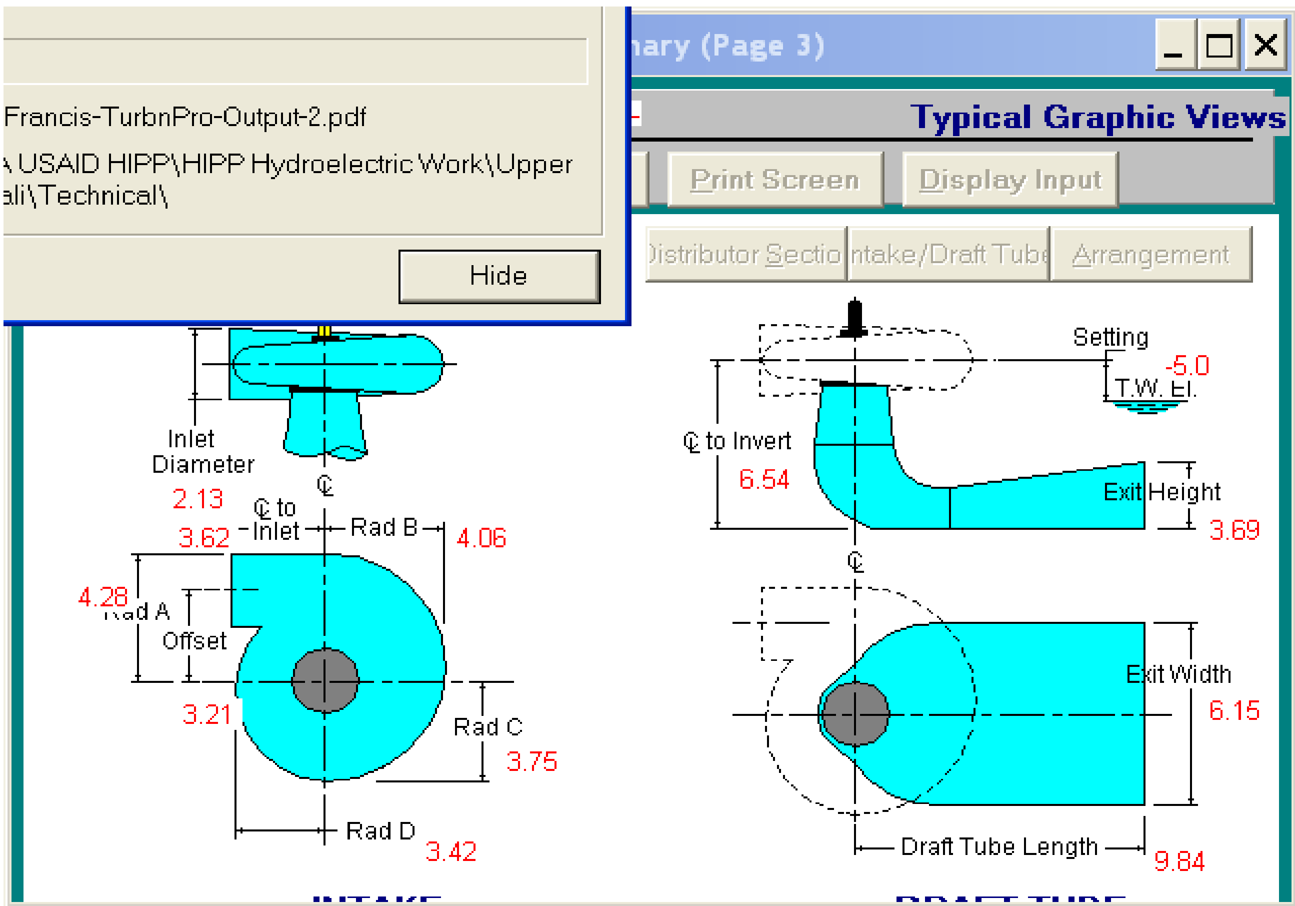
NOTE: Discharge is in cubic meters per second

Solution File Name: c:\progra~1\turbnpro\tsag-3xf.dat
Runner Diameter: 2049 mm
Net Head at Rated Discharge: 155.00 meters
Unit Speed: 300.0 rpm



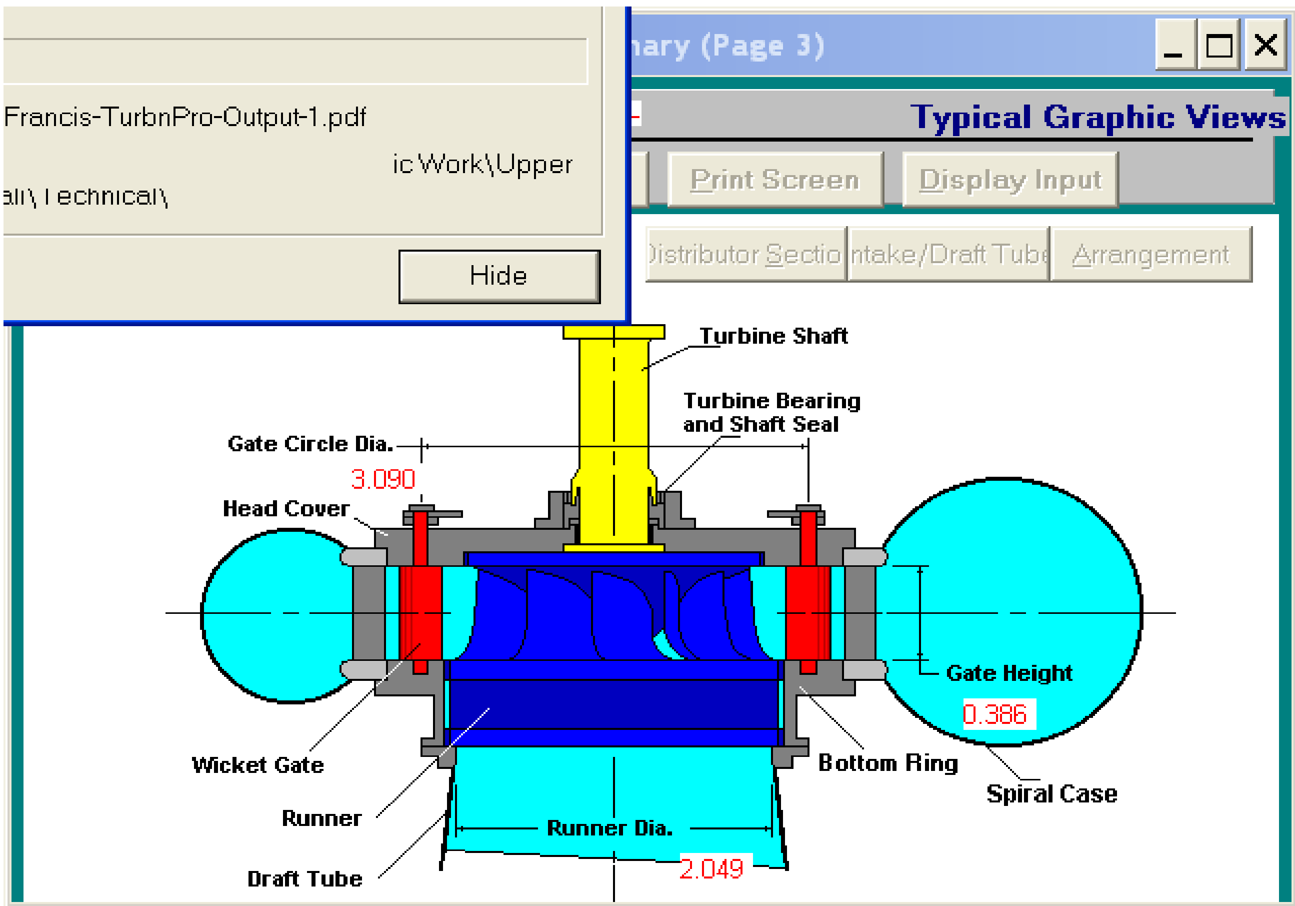
TURBNPRO Version 3.0 - FRANCIS TURBINE SOLUTION GRAPHICS

Solution File Name: c:\progra~1\turbnpro\tsag-3xf.dat
Runner Diameter: 2049 mm
Net Head at Rated Discharge: 155.00 meters
Unit Speed: 300.0 rpm



TURBNPRO Version 3.0 - FRANCIS TURBINE SOLUTION GRAPHICS

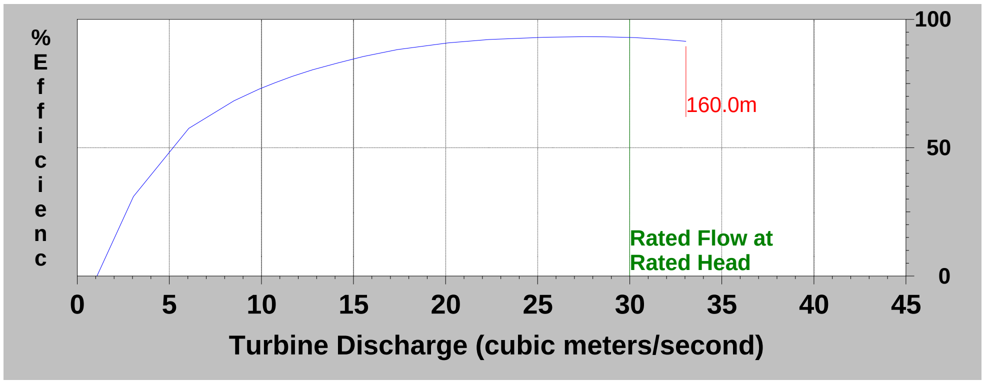
```
Solution File Name: c:\progra~1\turbnpro\tsag-3xf.dat
Runner Diameter:                2049   mm
Net Head at Rated Discharge:    155.00  meters
Unit Speed:                     300.0   rpm
```



Solution File Name: c:\progra~1\turbnpro\tsag-3xf.dat
Runner Diameter: 2049 mm
Net Head at Rated Discharge: 155.00 meters
Unit Speed: 300.0 rpm
Multiplier Efficiency Modifier: 1.000
Flow Squared Efficiency Modifier: 0.0000

Performance Data Shown is for a Net Head of: 160

Power (KW)	Efficiency (%)	Discharge (m3/s)	Notes
47450	91.4	33.06	-
45537	92.4	31.40	-
43409	93.0	29.75	-
41104	93.2	28.10	-
40308	93.2	27.55	Best Efficiency Condition
38652	93.1	26.45	-
36133	92.9	24.79	-
33550	92.4	23.14	-
30905	91.6	21.49	-
28186	90.5	19.83	-
25380	88.9	18.18	-
22556	86.9	16.53	-
19689	84.3	14.88	-
16851	81.2	13.22	-
14072	77.5	11.57	-
11353	72.9	9.92	-
8707	67.1	8.26	-
6216	59.9	6.61	Low efficiency; not used in energy calculation
3717	47.8	4.96	Low efficiency; not used in energy calculation
1720	33.2	3.31	Low efficiency; not used in energy calculation
234	9.0	1.65	Low efficiency; not used in energy calculation



Appendix 12

Financial Model Output

RETScreen Financial Analysis - Power project

Financial parameters

General		
Fuel cost escalation rate	%	0.0%
Inflation rate	%	0.0%
Discount rate	%	0.0%
Project life	yr	30
Finance		
Incentives and grants	$	
Debt ratio	%	70.0%
Debt	$	163,683,087
Equity	$	70,149,895
Debt interest rate	%	7.20%
Debt term	yr	10
Debt payments	$/yr	23,520,707
Income tax analysis	☑	
Effective income tax rate	%	20.0%
Loss carryforward?		No
Depreciation method		Straight-line
Depreciation tax basis	%	8.0%
Depreciation period	yr	13
Tax holiday available?	yes/no	No

Annual income

Electricity export income		
Electricity exported to grid	MWh	520,344
Electricity export rate	$/MWh	65.00
Electricity export income	$	33,822,360
Electricity export escalation rate	%	
GHG reduction income	☑	
Net GHG reduction	tCO2/yr	0
Net GHG reduction - 30 yrs	tCO2	0
GHG reduction credit rate	$/tCO2	
Customer premium income (rebate)	☐	
Other income (cost)	☐	
Clean Energy (CE) production income	☐	

Project costs and savings/income summary

Initial costs			
Feasibility study	0.7%	$	1,663,167
Development	0.7%	$	1,663,167
Engineering	0.7%	$	1,663,167
Power system	71.1%	$	166,316,713
Balance of system & misc.	26.7%	$	62,526,768
Total initial costs	**100.0%**	**$**	**233,832,982**
Annual costs and debt payments			
O&M		$	2,338,330
Fuel cost - proposed case		$	0
Debt payments - 10 yrs		$	23,520,707
Total annual costs		**$**	**25,859,037**
Periodic costs (credits)			
Annual savings and income			
Fuel cost - base case		$	0
Electricity export income		$	33,822,360
Total annual savings and income		**$**	**33,822,360**

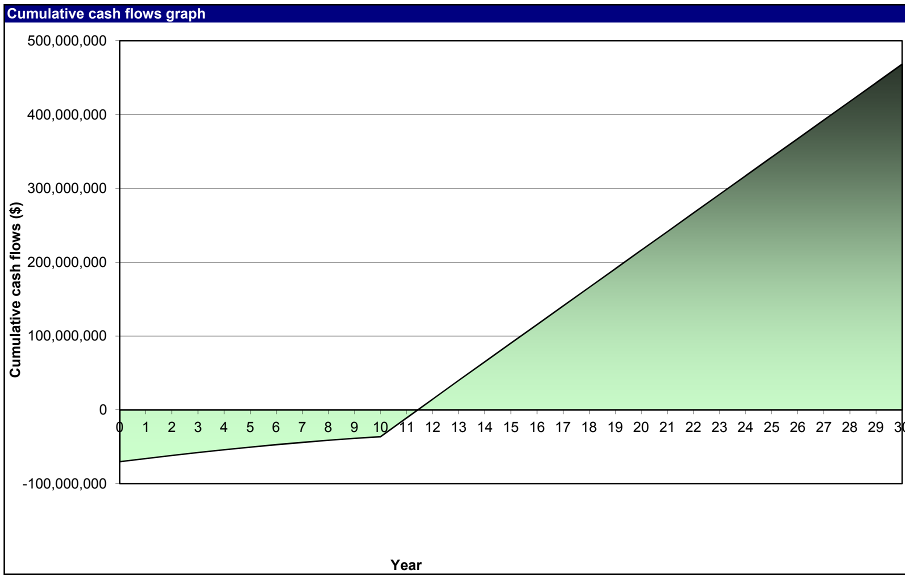
Financial viability

Pre-tax IRR - equity	%	17.6%
Pre-tax IRR - assets	%	6.7%
After-tax IRR - equity	%	13.2%
After-tax IRR - assets	%	4.6%
Simple payback	yr	7.4
Equity payback	yr	11.4
Net Present Value (NPV)	$	468,305,881
Annual life cycle savings	$/yr	15,610,196
Benefit-Cost (B-C) ratio		7.68
Debt service coverage		1.34
Energy production cost	$/MWh	27.53
GHG reduction cost	$/tCO2	No reduction

Yearly cash flows

Year	Pre-tax	After-tax	Cumulative
#	$	$	$
0	-70,149,895	-70,149,895	-70,149,895
1	7,963,323	4,311,348	-65,838,547
2	7,963,323	4,142,356	-61,696,191
3	7,963,323	3,961,197	-57,734,994
4	7,963,323	3,766,995	-53,967,999
5	7,963,323	3,558,810	-50,409,189
6	7,963,323	3,335,636	-47,073,553
7	7,963,323	3,096,393	-43,977,161
8	7,963,323	2,839,924	-41,137,236
9	7,963,323	2,564,990	-38,572,246
10	7,963,323	2,270,261	-36,301,985
11	31,484,030	25,475,019	-10,826,966
12	31,484,030	25,475,019	14,648,052
13	31,484,030	25,475,019	40,123,071
14	31,484,030	25,187,224	65,310,295
15	31,484,030	25,187,224	90,497,519
16	31,484,030	25,187,224	115,684,743
17	31,484,030	25,187,224	140,871,967
18	31,484,030	25,187,224	166,059,191
19	31,484,030	25,187,224	191,246,416
20	31,484,030	25,187,224	216,433,640
21	31,484,030	25,187,224	241,620,864
22	31,484,030	25,187,224	266,808,088
23	31,484,030	25,187,224	291,995,312
24	31,484,030	25,187,224	317,182,536
25	31,484,030	25,187,224	342,369,760
26	31,484,030	25,187,224	367,556,985
27	31,484,030	25,187,224	392,744,209
28	31,484,030	25,187,224	417,931,433
29	31,484,030	25,187,224	443,118,657
30	31,484,030	25,187,224	468,305,881

Cumulative cash flows graph



USAID Hydropower Investment Promotion Project (USAID-HIPP)

Deloitte Consulting Overseas Projects - HIPP

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