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Hydropower Investment Promotion Project (HIPP)

STORI 3 HPP PRE-FEASIBILITY STUDY REPORT

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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
GSE	Georgian State Electrosystem
HIPP	Hydropower Investment Promotion Project (USAID-funded)
ha	Hectare
HP	Hydropower
HPP	Hydropower Plant/Hydropower Project
IFI	International Financial Institutions
kg/s	Kilograms per Second
kV	Kilovolt
kW	Kilowatt (a measure of power)
kWh	Kilowatt-hour (a measure of energy)
m^3/s	Cubic meters per second
masl	meters above sea level
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

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EXECUTIVE SUMMARY

STORI 3 HYDROPOWER PROJECT OVERVIEW

Project Description

The site of the proposed Stori 3 HPP is located on the Stori River near the village of Lechuri in the Telavi District of northeastern Georgia's Kakheti Region. The plant capacity will be 13.3 MW with annual energy production of approximately 55 GWh.

The Stori 3 HPP is envisioned to be the lowest plant in a possible four-HPP cascade (Stori, Stori 1, Stori 2, and Stori 3 HPPs) on the Stori River. There would be significant construction and operations advantages to a single developer if the decision were made to undertake the study, design, construction and operation of all the Stori River basin HPPs.

The Stori 3 HPP site offers seasonally variable, mean annual generation of approximately 55 GWh. There will be two intake structures, a primary power tunnel and a secondary power interconnection, surge shaft, penstock, above-ground powerhouse, tailrace, transformer substation, and transmission lines. The two intakes capture flow from the Stori River and the tributary Chontiskhevi River. The pressurized tunnel minimizes head loss in the conduits therefore maximizing the energy output from the available water.

Access to the site is fair. The locations of both the powerhouse and main diversion weir sites are adjacent to public gravel roads. An 8.5 km pioneer road is needed parallel to the tunnel to have access to core boring sites along the tunnel, access to the Chontiskhevi diversion and the downstream tunnel portal and upper penstock construction. About 15 km of 35 kV transmission line would be rehabilitated to connect the Stori 3 plant to the Napareuli substation. If Stori 2 is built before Stori 3, the transmission line will have already been rehabilitated to Napareuli.

The Stori 3 HPP development is expected to include two intakes. The intake on the Stori River will include a 10-m-high (foundation to weir crest) concrete diversion dam with 25 m-long combined spillway and Tyrolean intake, a control and sluicing structure, and a reinforced concrete power canal leading to a de-silting basin with an under-sluice. Between the de-silting basin and the power tunnel will be a 500-m-long covered power canal, 3 m wide and 3 m deep. The Stori River power tunnel will be about 5,600 m long by 3.2 m diameter. A surge shaft will be located near the downstream end of the power tunnel. The penstock would be a 2.5-m-diameter pipe, or two parallel penstocks of equivalent area, running about 400 m down the slope to the powerhouse.

The intake on the Chontiskhevi will include a low (about 3-m-high) reinforced concrete weir with wedge-wire screen intake panels, and a reinforced concrete collection chamber. The Chontiskhevi water conductor will be a 50-m-long, 2-m-wide, variable-depth covered channel excavated in the rock and overburden, leading to a connection structure built over the main power tunnel..

The power plant tailrace would be an open cut channel, about 400 m long with a 5-m bottom width, leading to a point just upstream from the gates at the existing irrigation diversion dam.

Project cost and construction schedule

The currently estimated cost of the Stori 3 HPP is USD 24.3 million or about USD1,829/kW of installed capacity. 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 5.6 km tunneling..

Financial analysis

The project is expected to sell power during 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 Stori 3 HPP Project provides a good opportunity for investment and should be further investigated by potential developers. The expected simple payback period is approximately 10 years based on parameters as shown in Section 8.0.

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	**Stori 3 Hydropower Project**
Project location (political)	**Telavi District of north eastern Georgia's Kakheti Region**
Nearest town or city	**Lechuri village**
River name	**Stori River**
Total drainage area	**180.9 km^2**
Stori River Diversion	**164.3 km^2**
Chontiskhevi River Diversion	**16.6 km^2**
Financial Estimates	
Estimated Construction Cost	**$24.3 Million**
Estimated Cost per kW capacity	**$1,829 /kW**
Simple Pay Back Period	**10 years**
Hydrological Data (Adjusted to Intake Location)	
Annual mean river flow at intake	**6.78 m^3/s**
Facility design discharge (m^3/s)	**13.4 m^3/s**
Annual average discharge through powerhouse	**6.4 m^3/s**
Preliminary design flood (100 yr return period)	**135 m^3/s**
Max. recorded flow (intra-day)	**149 m^3/s**
Intake Ponds	
Highest regulated water level (HRL)	**627 masl (design flood level)**
Minimum operating level (MOL)	**625 masl (Stori), 626 masl (Chontiskhevi)**
Sanitary or environmental flow (assumed)	**1-10% of mean monthly flow for each month**
Diversion Structures	
Stori River Diversion, Tyrolean Weir	
Crest elevation	**625 masl**
Abutment top elevation	**628 masl**
Collection channel water surface elevation	**623.5 masl**
Collection channel length	**25 m**
Collection channel width	**2 m**
Max height	**10 m from assumed bedrock to weir crest**
Trashrack	**Integral with cross-river diversion channel**
Channel-to-collection chamber discharge gate	**3-m-wide x 4-m-high**
Sluice gates (in flow collection chamber)	**2 x 2-m-wide x 3-m-tall, one upstream and one downstream**
Power intake gate (from collection chamber)	**1 x 3 m wide x 4 m high**

Chontiskhevi River Diversion, Wedge-Wire Screen Weir	
Crest elevation	**626 masl**
Abutment top elevation	**628 masl**
Collection channel water surface elevation	**624.5 masl**
Collection channel and crest length	**5 m**
Collection channel width	**1.5 m**
Max height	**3 m from assumed bedrock to weir crest**
Trashrack	**Integral with cross-river diversion channel**
Channel-to-collection chamber discharge gate	**1.5-m-wide x 1.5-m-high**
Sluice gates (in flow collection chamber)	**2 x 1.5-m-wide x 1.5-m-tall, one upstream and one downstream**
Flood Discharge Capacity	
Stori River Tyrolean Intake	
Crest elevation	**625 masl**
Crest Length	**25 m**
Capacity at design flood level (628.0 masl)	**221 m^3/s**
Chontiskhevi River Wedge-Wire Screen Intake	
Crest elevation	**626 masl**
Length	**5 m**
Max height	**3 m from assumed bedrock foundation**
Capacity at design flood level (628 masl)	**40 m^3/s**
Power water conductors	
Stori River water conductors	
De-silting basin	**2, 4-m-deep x 5.5-m-wide channels, 100 m long**
Covered power canal sections	**6.0-m-deep x 3.0-m-wide, 150-m-long and 500 m long**
Power tunnel length	**5.6 km**
Diameter (circular or horseshoe)	**3.20 m**
Slope	**0.2% minimum**
Water velocity, at design flow	**1.5 m/s above Chontiskhevi intake** **1.7 m/s below Chontiskhevi intake**

Surge Shaft	
Diameter of Shaft	**3.2 m minimum**
Total shaft height	**40 m**

Penstock	
Invert elevation at pressure tunnel portal	**608 masl**
Turbine center-line elevation	**498 masl**
Penstock length	**400 m**
Outside diameter	**2500 mm**
Powerhouse	
Type	**Above-ground**
Installed capacity	**13.3 MW (at design flow)**
Units and net capacity at high-voltage transformer terminals	**1 x 9.2 MW and 1 x 4.6 MW (at maximum head), vertical Francis units**
Rated speed	**Unit 1, 375 rpm; Unit 2, 500 rpm**
Preliminary generator voltage	**15 kV or manufacturer's recommendation**
Rated generator capacity	**14.8 MVA at 0.90 Power Factor**
Size of powerhouse	**14 m x 40 m x 15 m high**
Tailrace	
Length	**500 m**
Bottom width	**5 m**
Type	**Excavated trapezoidal open channel**
Normal tailwater elevation	**500 masl (with irrigation diversion operating)**

Transmission line	
Interconnection location	**Napareuli Substation**
Distance to interconnection (km)	**15 km (line rehabilitation) or connection to existing Stori HPPs transmission line.**
Voltage	**35 kV**
Power & Energy	
Gross head	**123.5 m**
Total head loss at rated discharge	**5.4 m**
Net head at rated discharge	**118.1m**
Estimated average annual head loss	**1.326**
Estimated average annual net head	**122.174**
Estimated average annual generation	**Approximately 55 GWh**
Nominal installed capacity	**13.3 MW**
Preliminary annual plant factor (also called CF)	**47%**

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	**Tusheti Protected Areas**

Figure 1: Georgian Project Location Map

1.0 GENERAL INTRODUCTION TO THE PROJECT

1.1 DESCRIPTION OF THE DEVELOPMENT AREA

The proposed Stori 3 Hydropower Project involves the construction of an approximately 13.3 MW run-of-river HPP on the Stori River, in the Telavi District of eastern Georgia's Kakheti Region. The approximate location is shown on the Georgian Project Location Map above. The Stori 3 powerhouse will be approximately 1.5 km downstream of Lechuri village gauging station, with the primary diversion weir approximately 6.0 km up the Stori River from the powerhouse location and a secondary diversion weir 1.0 km up the Chintiskhevi River tributary (see Figure 5 and Appendix 3).

The city of Telavi is the administrative center of the Telavi District. The district population is about 68,000people. According to the statistical data of 2009, about 22,000 people are registered in the city of Telavi and 46,000 people are registered in villages. The distance from Tbilisi to the administrative center of Telavi District is about 95 km. Lechuri is the closest village to the Stori 3 HPP.

The total area of district land equals 1,094.5 km^2. Much of the Telavi District is mountainous and the economy heavily relies on manufacturing wood products for construction and agriculture. The main economic activities of the region are wine growing, maize, wheat and other cereals, vegetables and animal husbandry.

Infrastructure of the area of the Stori HPPs is poorly developed: there is a part stone/paved/gravel road that follows the river valley that is used for a mass sheep migration to high country pastures throughout May and then again in the autumn when the weather turns cold. There is little to no development above Lechuri village. The 35 kV transmission line that once ran up the valley near the Stori HPPs has not functioned for many years. The towers are still in place but must be rehabilitated, and the insulators and conductors have been plundered.

The landscape of the Stori River Watershed is dominated by mountains that are separated by deep gorges. The average inclination of slopes is about 35^0-60^0. Forests occupy

considerable areas of the territory. Mountain slopes are covered by mixed hardwood forests up to about 1,800 to 2,000 masl with Alpine type 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, although there are no cultural or historic sites within the Stori 3 HPP study area.

Table 2: Development Area Significant Data

Project Location (Political)	**Northeastern Georgia's Kakheti Region**
Political Subdivisions	**Telavi District**
Area Population	**68,000**
Nearest Town or City	**Lechuri**
River Name	**Stori**
Economic Activity in the Area	**Primarily agriculture, logging, and processing wood products for construction**
Special Natural Resources	**Timber**
Special Cultural Resources	**Churches, monasteries and hot spring**
Critical Environmental Receptors	**Tusheti Protected Area**

1.2 DESCRIPTION OF THE LOCAL ELECTRIC POWER SYSTEM

The electric power system in the Stori River area is owned and operated by two companies. The transmission assets, including the 35 kV lines in the immediate area, are owned and operated by the Georgian State Electrosystem (GSE), the government-owned transmission and power dispatch company. The distribution system is owned and operated by the Kakheti Distribution Company, which serves the northeastern area of Georgia.

The 35 kV transmission system ends now at the Napareuli Substation, located about 15 km southeast of the Stori 3 HPP site, measured along the existing power line route. However, it once extended through Pshaveli, up the Stori River valley, and over the Abano Pass to provide power to the Tusheti area. That line has been abandoned for several decades. Up to about the site of the Stori 3 HPP it is still used, at lower voltage, as a distribution line. Beyond that point, the towers remain in place, but the conductors and insulators have been removed.

2.0 BASELINE CONDITIONS

In order to establish a comparison for environmental evaluation of the Stori 3 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

The Kakheti Region is characterized by continental subtropical climate. The precipitation increases and air temperature decreases significantly with the increase in elevation. The catchment of the Stori 3 HPP is well up towards the higher elevations of the watershed. 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 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 an Annual Precipitation Map for the Stori HPPs watershed region.

2.2 HYDROLOGY AND WATER RESOURCES:

Table 3: Hydrology Significant Data

Records available	**Daily flow measurements for 58 years (1946-1949 and 1951-2004) at Lechuri, from the Department of Hydrometeorology.**
Method of analysis	**Monthly and annual flow-duration curves, flood frequency, 30 day minimum and maximum moving averages of daily discharge values**
Drainage area at gauge	**203 km^2**
Combined drainage area at the two intakes	**180.9 km^2**
Stori River Diversion	**164.3 km^2**
Chontiskhevi River Diversion	**16.6 km^2**
Adjustment factor	**0.8912**
Maximum plant discharge	**13.4 m^3/s**
Minimum plant discharge	**As low as 2 m^3/s**
Stream flow for power generation	**Based on combined flow duration analysis and average daily discharge energy analysis. Expected normal discharge range of 2.0– 13.4 m^3/s. Reasonable potential of approximately 55 GWh/year**
Flood flows (combined)*	**Average Annual Flood (2.33 yr return period) = 40 m^3/s**
Highest recorded flow*	**149.72 m^3/s (1951)**
Calculated 100 year flood*	**135 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 Stori 3 HPP intake; meteorology stations for air temperature, precipitation, barometric pressure, relative humidity, wind speed and direction, solar insolation, 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.**

*These flood flows are based on a simple drainage area ratio adjustment of the Lechuri gauge data. They are probably slight under-estimations of flood flows at the Stori 3 and tributary diversions. That is due to the smaller drainage basins and steeper tributary areas, which results in shorter times of concentration.

2.2.1 Catchment Description including Land Cover and Current Water Resource Use

The Stori River is 38 km long and drains an area of 281 km^2. It originates at a height of 2,950 m above sea level. The river is fed mainly by snow, rain, springs, and underground waters. Its flow regime is characterized by low river discharge in winter, high flows and possible flooding in mid to late spring through early summer. The catchment area is heavily wooded with significant steep to very steep slopes, and exposed rock that can create flash flood conditions. The upper reaches of the catchment are in the Alpine zone with exposed rock, meadows, and at times over-season snowpack. The catchment is subject to avalanches in the winter that carry significant debris into the tributary and river channels. The Story River is characterized by a narrow riverbed and steep descending slopes. Downstream from the HPP sites, near the Laliskuri village, the Stori riverbed widens and the slope decreases.

A number of small rivers flow into the Stori River: right tributaries: Svianis Khevi, Saborios Khevi, Chakhunis Khevi and left tributaries: Nakodevis Khevi, Chontiskhevi, Chichakvis Khevi. The water flow in some of these small rivers is seasonal and during dry seasons there can be little to no water in these tributaries.

The main use of the hydrological resources today is irrigation. There is an irrigation diversion dam just downstream from the Stori 3 powerhouse, feeding a canal which supplies irrigation water to a major part of the downstream Stori catchment villages.

Eastern Georgia's landscape (referring to the territory east of the Likhi Range) is considerably different from that of the west, although, much like the Colchis plain in the west, nearly all of the low-lying areas of eastern Georgia including the Mtkvari and Alazani River plains have been deforested for agricultural purposes. In addition, because of the region's relatively drier climate, some of the low-lying plains (especially in Kartli and south-eastern Kakheti) were never covered by forests in the first place.

The general landscape of eastern Greater Caucasus Mountain region of Georgia comprises numerous valleys and gorges that are separated by mountains. In contrast with western Georgia, nearly 85% of the forests of the region are deciduous. Out of the deciduous species of trees, beech, oak, and hornbeam dominate. Other deciduous species include several varieties of maple, aspen, ash, and hazelnut. The Upper Alazani River Valley contains yew forests.

At elevations greater than 1,000 meters above sea level (particularly in the Tusheti, Khevsureti, and Khevi regions), pine and birch forests dominate. In general, the forests in eastern Georgia Caucasus Range occur between 500–2,000 meters above sea level, with the alpine zone extending from a range of 2,000–2,300 meters through 3,000–3,500 meters. The only remaining large, low-land forests are in the Alazani Valley of Kakheti.

Appendix 4 is the Watershed Map that outlines the watersheds that contribute to the various proposed HPPs diversion locations on the Stori River. Appendix 6 presents land cover in the watershed and demonstrates type of cover changes as a function of elevation.

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 rich in water resources. About 78 per cent of water resources of the country are concentrated west of the Likhi Mountain Range and only 22 per cent east of the Likhi Range. The Stori HPPs area is in the Eastern Caspian Sea Drainage Basin, Stori River Watershed is a tributary of the Alazani River. See Appendix 4, which is the Watershed Map.

2.2.3 Stori River:

The Stori River's upper course flows through a deep gorge with many rapids and waterfalls; the lower course at a much flatter slope joins the Alazani River. The river is fed by mixed sources; rain, snowmelt, rain on snow and groundwater springs. Table 4 displays the Stori 3 HPP intake area discharge characteristics. The flow 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.

The stream flow gauging station is the Lechuri Gauge approximately 4.5 km downstream from the Stori 3 HPP intake location. The gauge has a drainage area of 203 km^2. The gauge data used for this pre-feasibility analysis included the calendar periods: 1946-1949 and 1951-2004. A drainage basin adjustment of 0.8912 (180.9 km^2/203 km^2) was used to adjust flow record to the Stori 3 HPP intake location. Appendix 2 includes monthly and annual flow duration curves.

Table 4: Stori 3 HPP Intake Vicinity Characteristic Discharge Information (m^3/sec)

Annual average flow (m^3/s)	**6.78**
Maximum average daily flow of record (m^3/s)	**149**
Minimum average daily flow of record (m^3/s)	**0.98**
Average monthly discharge during seasonal runoff period (April, May, June, July August, September) (m^3/s)	**9.77**
Average monthly discharge during winter Season (Oct – March) (m^3/s)	**3.79**
Highest 30 day average discharge (m^3/s)	**38.36**
Lowest 30 day average discharge (m^3/s)	**4.37**
Average discharge during Georgian winter electric demand period (Dec-Feb) (m^3/s)	**2.83**
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 Stori 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 Stori 3 HPP location carries about the same concentration of suspended sediment as the Lechuri Gage and sediment monitoring station, which was located approximately 4.5 km downstream from the main diversion point. The watershed is steep-sloped, generating a high-velocity surface runoff and high river velocities. During high flow periods large volumes of suspended sediment can 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. Winter avalanches bring very significant debris loads down tributary gorges and into the Stori River itself. The river rapidly melts the underside of the avalanche but remnants persist well into late spring with large debris deposits covering the surface.

Figure 2 Avalanche Snow With Debris

Table 5 presents projected sediment values from the Lechuri Gauge for a range of return periods. The project team strongly recommends further suspended and bedload data sampling at the intake location to develop a clear understanding of sediment transport magnitudes and variations expected over a typical operations year.. The table presents sediment loads that clearly support a significant and long term operation challenge for the Stori 3 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.

Table 5: Stori River Lechuri Gauge and Stori 3 Intake Sediment Load Estimates

Total Sediment Volume (suspended + bedload) Projected for Stori 3 Development							
Percent or Frequency	0.50%	1.00%	3.00%	5.00%	10.00%	20.00%	
Return Period in Yrs	200	100	33.33333	20	10	5	Annual
Lechuri Gage Estimated Suspended Sediment in kg/s (See note 1)	7.00	6.30	5.10	4.50	3.70	2.70	unknown
Lechuri Gage Estimated Bedload Sediment Estimate in kg/s (See note 1)	3.10	2.80	2.30	2.00	1.70	1.20	unknown
Lechuri Gage total Sediment Load in kg/s (See note 1)	10.10	9.10	7.40	6.50	5.40	3.90	1.62
Stori 3 Adjusted total Sediment Load in kg/s (See note 2)	9.00	8.11	6.59	5.79	4.81	3.48	1.44
Stori-3 Intake Sediment Estimate in T x1000 (See note 3)	248.53	223.92	182.09	159.95	132.88	95.97	39.86
Stori-3 Intake Sediment Estimate in Cubic Meters x 1000	165.69	149.28	121.39	106.63	88.59	63.98	26.58

Note 1: Ref Table 16, page 17 in Stori River Hydrology Report by Baador Ukleba, Hydrologist, 2011.

Note 2: Adjusted total sediment load for Stori 3 is in the river at the intake location. It's calculated by using basic drainage basin adjustment.

Note 3: To account for only the sediment flowing into the Stori 3 intake. The ratio of the net useable area under the flow duration curve was divided by the area under the full flow duration curve as part of this calculation.

2.2.5 Meteorological Conditions

The Kakheti Region is characterized by a continental subtropical climate. As noted, the precipitation and air temperature changes with the increase in elevation.

The average temperature in January of Kakheti Region's lowland plain areas ranges between minus 2.3 and +3.0^{0}C; in the lower mountains, at 2000 m above sea level, minus 5 to minus 7^{0}C and in the high mountains, at 4000 m above sea level, minus 15 to minus 16 ^{0}C. The average temperature in July in the lowland plain ranges between +22 and + 25 ^{0}C, in the lower mountains + 12 to +15^{0}C and in the high mountains minus 4^{0}C at 4000 m above sea level.

Annual average precipitation for Kakheti Region is 400-800 mm. Annual average precipitation on the north side of the Alazani River is 800-1000mm and on the south side 600-700mm. The Stori 3 HPP is considerably higher than the Alazani north side and precipitation continues to increase considerably with elevation.

For the analysis of the climatology of the Stori project area, information from Meteorological Stations located in the town of Telavi is used. The project team recognizes that Telavi is the best available data in the watershed but is at a significantly lower elevation than the HPP project. It is recommended that as soon as project approval is complete a primary meteorology station be installed centrally in the Stori Watershed.

See Appendix 6 for the Annual Precipitation Map, which shows the variations in annual precipitation for the entire watershed, HPP locations, catchment and sub-catchment boundaries.

Table 6 displays monthly values and annual mean values of climatology data at Telavi, which is the nearest large city, but is at a lower elevation than the project watershed and therefore much drier.

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 6 that does not match well the distributed rainfall data that appears in Appendix 6. At this level of analysis the discrepancy is identified 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 6: Telavi 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	0.5	1.9	5.7	11.1	16	19.6	22.9	23	18.5	13.1	7	2.5	11.8	
Lowest Average monthly Air Temperature in °C	-2.7	-1.7	1.4	6.7	11.3	14.7	17.8	17.8	14	9.2	3.8	-0.6		
Lowest Air Temperature in °C	-23	-18	-14	-5	0	7	8	8	0	-5	-8	-19		
Highest Average Monthly Air Temperature in °C	4.9	6.6	10.5	16.4	21.3	25.1	28.3	28.8	23.9	18.2	11.3	6.8		
Highest Monthly Air Temperature in °C	19	21	26	30	32	36	38	38	36	33	26	21		
Average Relative Humidity in %	71	69	69	66	70	67	62	60	68	73	76	72		
Average Monthly Precipitation in mm	26	30	48	75	134	116	76	60	67	62	45	31		770
Average Monthly Wind Speed in meters/sec.	2.2	2.7	2.9	3	2.5	2.5	2.3	2.3	2.2	2.4	2	2	2.4	

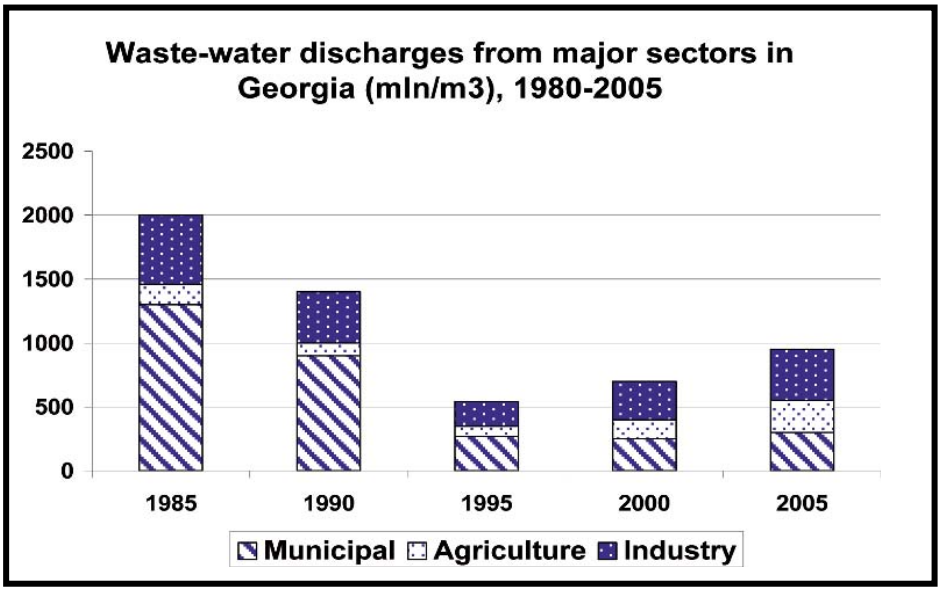
Source: Data on climate and meteorology for Telavi was provided by the Department of Hydrometeorology of Georgia.

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).

Figure 3 presents wastewater discharges from major sectors in Georgia in millions of cubic meters.

Figure 3: 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 Stori River 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, water quality sampling and resulting data should be included in any feasibility analysis to establish a **baseline** for 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

Downstream of the proposed HPPs, the Stori River is used for irrigation. Near Pshaveli village, where the river leaves the mountainous area, there is a major diversion dam which supplies irrigation water to a major part of the downstream agricultural areas. There is also a small buried (shallow) groundwater infiltration water supply for 2 villages Pshaveli and Laliskuri.

The proposed Stori 3 HPP run of river operations should have no impact on downstream water withdrawal users but during low flow periods coordination may be required to assure the local population that HPP operations are not affecting the water supply or irrigation diversions.

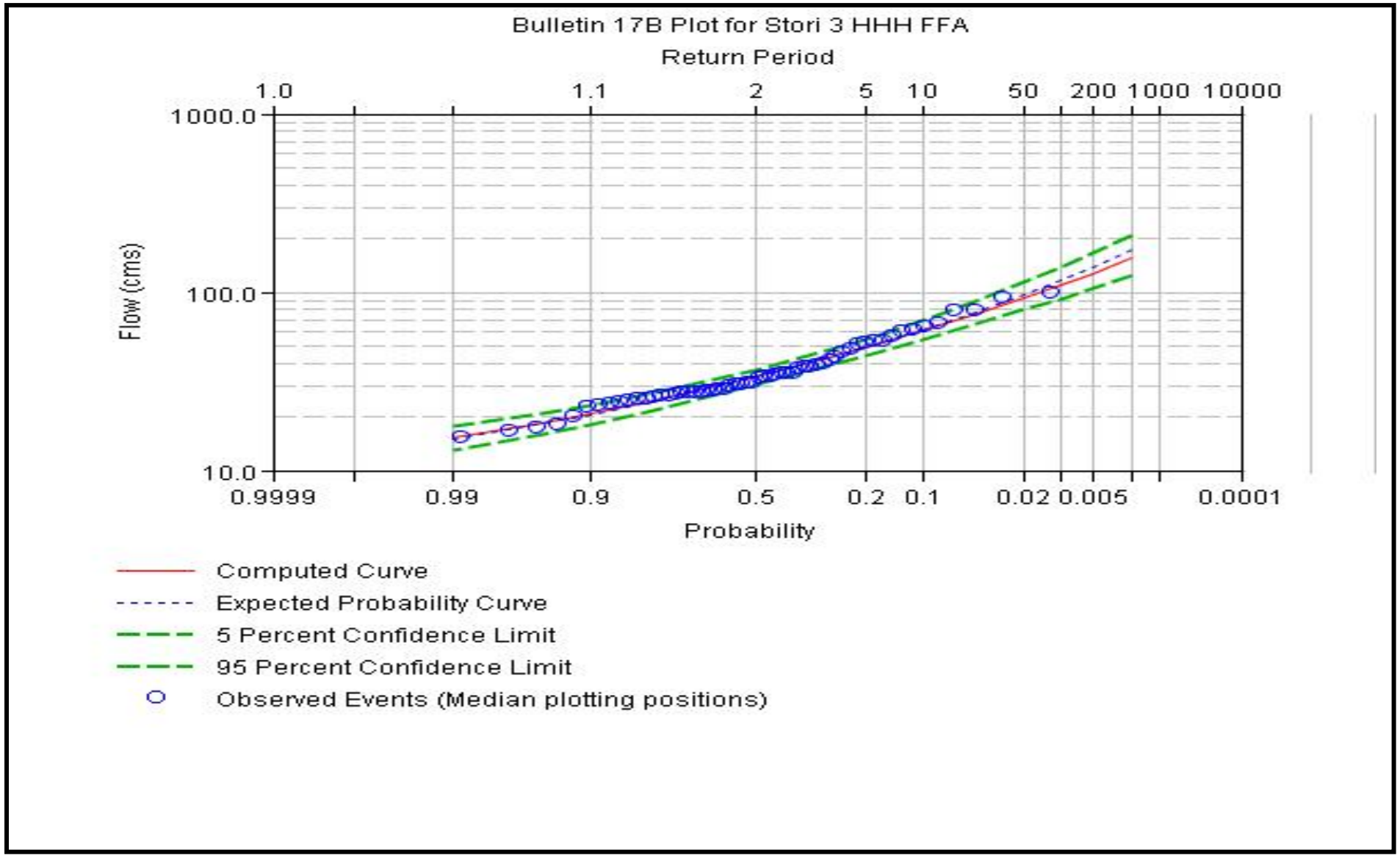
2.5 FLOODING AND FLOOD RISK

Flooding is characteristic in the Project watershed and in the project vicinity. Steep slopes, deep gorges, significant areas of exposed rock and impervious surfaces, snowmelt runoff enhanced by warm temperatures and intense precipitation all contribute to major flooding risk for the project and the local environment.

According to the local residents, during the Soviet times river bank protection projects periodically took place in the lowlands downstream of the proposed project area. Since Soviet times, there have been no river bank protection projects and consequently the river erosion processes have increased in the lowlands. As a result the river water washes away the river banks and often floods the adjacent lands and agricultural plots.

With the availability of 58 years of record at the Lechuri Gauge the U.S Army Corps of Engineers Hydrologic Engineering Center (USACE-HEC) Flood Frequency Analysis program HEC-SSP was used to check the earlier Soviet Report flood frequency values. The results are presented in the figure below. A drainage basin adjustment of 0.8912 was used to adjust these values to the proposed location of the Stori 3 intakes.

Figure 4: Stori 3 HPP Flood Frequency Analysis



2.6 BIODIVERSITY

2.6.1 Flora

The landscape of the potential HPP location area is dominated by mountains that are separated by deep gorges. The average inclination of slopes is about 35^0-65^0. Forests occupy considerable areas of the territory. Forests growing in the vicinity of proposed Stori HPPs watershed are State owned.

Forests in the Stori watershed cover the mountain belt (from 400 to 1,850 meters in elevation). Appendix 7, Land Cover Map, displays general forest cover in the watershed.

The lower sub-zone of the forest zone is within 400-1,100 meters above sea level. Dominant species are wing nut (*Pterocrya pterocarpa*), alder (*Alnus barbata*), willow (*Salixexcelsa*) and black poplar (*Populusnigra*). Underwood on riverside terraces are formed by hazelnut (*Corylusavellana*), dog-rose (*Rosacanina*), traveller's joy (*Clematisvitalba*), dogwood (*Swidaaustralis*), European black elder (*Sambucusnigra*), blackberry (*Rubuscaesius*), ivy (*hederahelix*), etc.

In the Stori river basin the mid sub-zone of the forest zone occupy the elevation between 1,100-1,600 meters above sea level. The slopes at this elevation range are steep (25^0-45^0). Within this zone the forest cover is comprised of widespread hornbeam and beech.

The upper sub-zone of the forest zone is within 1,600-1,859 m above sea level. Mixed deciduous forests are also developed (hornbeam, beech, linden, elm, maple, ash-tree, etc.). Elements of sub-alpine forests are found in the upper zone of the forest zone. These species include sycamore maple (*Acertrautvetteri*), white birch (*Betulalitwinowii*), mountain ash (*Sorbusaucuparia*) mountain oak (*Quercusmacranthera*), etc.

2.6.2 Fauna

Golden Eagles have a year-round presence in mountainous regions of Georgia. Because of its high landscape diversity and low latitude Georgia is home to about 1000 species of vertebrates, (330 birds, 160 fish, 48 reptiles, and 11 amphibians). A number of large carnivores live in the forests, namely Brown bears, wolves, and lynxes. The number of invertebrate species is presumed to be very high but data is distributed across a large number of publications and is not easily summarized. For example, Georgia has 501 species of spiders.

The following mammals are found in the Stori watershed area: brown bear (*Ursus arctos,* Red Book of Georgia National category-Endangered), badger (*Meles meles*), wolf (*Canis lupus*), fox (*Vulpes vulpes*), marten (*Martes martes*) and chamois (*Rupicapra rupicapra*).

The following bird species are relatively common throughout the watershed area: quail (*Coturnix coturnix*), grouse (*Tetrao mlokosieviczi*), various ducks (*Anas spp.*) and wild pigeon (*Columba palumbus*) (Jordania R, Boeme B, Kuznetsov A. 1999).

The following species have been reported in available literature within Telavi district: snake ring snake (*Natrix natrix*), water snake(*Natrix tessellate*) and European glass lizard (*Ophisaurus apodus*)

2.6.3 Fish Population

Local fishery is also considered a primary environmental receptor for baseline comparison. In the Stori River the dominant fish species include trout (*Salmo fario*, Red Book of Georgia, Statute-Vulnerable), khramulya (*Varicorhinus capoeta*) and barbell (*Barbus tauricus escherichi*) (Elanidze, R. 1988).

Literature on fish composition in the Stori River is a few decades old. Since then no monitoring on fish species has been conducted. Therefore, it's hard to know whether all of these species still inhabit the study area or not. The sampling of fish species should be included as part of the feasibility study and environmental assessment.

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

Table 7: Stori River Fish Spawning Periods

Fish	Spawning Period
Trout	September-October
Khramulya	April-October
Barbell	May-August

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. A copy of this report and 1:100,000 geological maps covering the Stori River watershed are included in Appendix 1.

3.2 SEISMOLOGY

The geology of the project area is characterized by crossing the boundary between two tectonic zones: the Fold system 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 several “significant” earthquakes in the vicinity of the project site. They are listed in the table below. The Stori River watershed is located on the south side of the Greater Caucasus mountain range, which is an ongoing uplift area created by the collision of tectonic plates. This inevitably creates an earthquake hazard zone along both sides of the mountain range. Through proper design and construction, the risk from earthquake damage can be mitigated.

Table 8: Significant Earthquake Data

Date	Name	Mag.	MMI	Deaths	Damage	Distance From Stori 3 HPP
April 14, 1275	Georgia	6.7		100-1000	Severe	105 km
March 9, 1830	Dagestan	6.3	9	40	Moderate	150 km
Feb 20, 1920	Gori, Tiflis	6.2		100-1000	Severe	115 km
May 14, 1970	Dagestan	5.7			Limited	150 km
Jan 9, 1975	Dagestan	5.2			Moderate	150 km
April 29, 1991	Racha: Dzhava, Chiatura, Ambrolauri	7.0	9	270	Extreme	155 km
May 15, 1991	Khekheti	4.9	5	0	Moderate	155 km
June 15, 1991	Dzhava, Tskhinvali, Ossetia	6.1	8	8	Severe	125 km
Oct 11, 2008	Chechnya	5.7		13	Severe	150 km

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 feasibility study. It is critical that a site investigation program be done for the headworks area, tunnel alignment and the powerhouse area, using test pits and core boring in all areas during the feasibility study.

Table 9: Geology Significant Data

Available data	**1:500,000 Scale Geological Map of Georgia (2003)**
Regional description	**Telavi District of north eastern Georgia's Kakheti Region**
Seismicity, including earthquake loadings	**Richter Scale 7.0, Georgian Seismic Zone 9**
Field reconnaissance	**Done in 2011. Report available in Appendix 1.**
Subsurface borings	**To be done at 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 joints and groundwater intrusion. The Geomorphology Map in Appendix 1 indicate special attention needs to be paid to major faults that may exist in the area of the Stori HPPs with particular impact on tunneling. Appropriate designs are needed for dealing with faults and water infiltration when encountered while tunneling. The Stori 3 water conductor layout has been developed to avoid tunneling through a major fault located a short distance upstream from the diversion weir.

4.0 HYDROPOWER PROJECT DESCRIPTION

4.1 PROJECT DESCRIPTION

The Stori 3 HPP development is expected to include a Tyrolean weir across the Stori River, channeling flow to a 150-m-long power canal section. a 100-m-long de-silting basin, a second 500-m-long section of covered canal, a 5,600-m-long power tunnel, and a 400-m-long steel penstock. This primary diversion collects runoff from an area of about 164.3 km^2. The de-silting channels will be 4.0 m deep and 5.5 m wide. The power canal sections will be 6.0 m x 3.0 m (with a normal flow depth of 4.5 m), and will be covered to prevent snow and ice, debris, rock, and soil from the steep canyon walls from entering the canal.

The power tunnel will have an inside diameter of 3.2 m. This diameter has been selected for both hydraulic and constructability reasons. Near the downstream end, a vertical surge

shaft will be excavated in rock. From the tunnel portal, a 400-m-long, 2.5-m-diameter penstock will convey the water to the powerhouse.

The project also includes an auxiliary wedge-wire (Coanda) screen diversion weir on the Chontiskhevi River, which collects water from a drainage area of about 16.6 km^2. The Chontiskhevi power conveyance would be a 50-m-long, 2-m-wide, variable-depth, covered channel excavated in the rock and overburden, leading to a connection structure built over the main power tunnel.

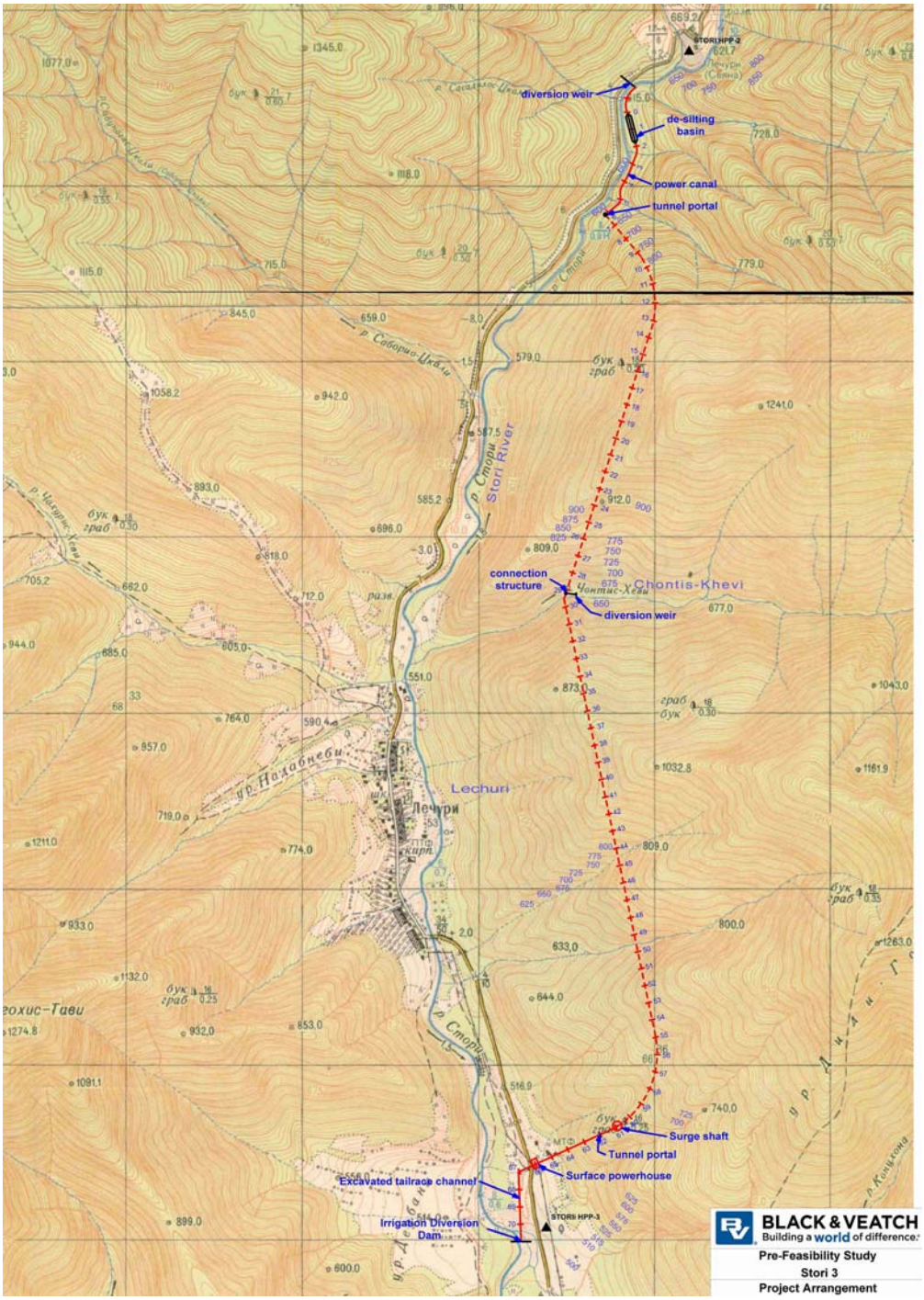
A 500-m-long excavated tailrace will provide a channel leading to the irrigation diversion dam discharge gates. This will maximize the available generating head when irrigation flows are not needed and the diversion pool is drawn down to its lowest level. When the surveying is done for the feasibility study and design, the elevations of the irrigation dam spillway, highest recorded flow and irrigation water intakes should be tied to the elevation of the powerhouse and draft tube sill to avoid flooding of the powerhouse.

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 Stori 3 plant, sufficient auxiliary backup power (probably a diesel generator) will be provided to allow black-starts when this plant is isolated from the national transmission network.

Access to the site is fair. The intake and powerhouse are adjacent to a public gravel road (National Road 44) that leads from Pshaveli over the Abano Pass into Tusheti. This is a narrow, winding, steep road and is closed during the winter at higher elevations. It will be necessary to improve sections of this road, and relocation of short sections will be needed at the diversion site. A pioneer road will be needed to access the secondary intake, the surge shaft, the downstream portal of the tunnel, and the upper penstock. Intermediate tunnel portals could be located near the Chontiskhevi River Diversion where the tunnel will be relatively shallow. These would allow tunnel excavation at 4 faces if the developer wishes to accelerate the tunneling.

An overall view of the project arrangement is shown in Figure 5.

Figure 5: Stori 3 Hydropower Project General Layout



In the figure above, the dashed red line represents the power tunnel alignment and solid red line represents the canal, penstock, and tailrace alignments. The figure also indicates the proposed locations of the diversion dam, upstream end of the tunnel, and powerhouse on the downstream end of the penstock.

In addition, and not shown in the figure, about 15 km of 35 kV transmission line will be reconstructed to connect the Stori 3 plant to the Napareuli Substation, unless already rehabilitated by a previous developer in the Stori watershed. This would involve rehabilitation of the existing 35 kV steel lattice towers, installing new insulators and conductors, and (probably) installing a new 35 kV transformer near Pshaveli to serve the local loads. The three upstream projects—Stori HPP, Stori 1 HPP, and Stori 2 HPP—will be connected to the grid through additional sections of the old 35 kV line which will require

rehabilitation. The line to Napareuli will be designed to carry that power as well. The total flow on the rehabilitated line between Stori 3 and Napareuli is expected to be up to 50 MVA. GSE has informally advised that the existing Napareuli substation and lines in the area will probably require some upgrades to carry the power from a full development of the Stori system. This issue, and the responsibility for paying for any improvements at Napareuli and beyond (among GSE, the Kakheti Distribution Company, and the developer) will have to be addressed in detail during the feasibility study.

4.1.1 Diversion Structures

The Tyrolean weir is named for the region of Europe, in the Alps, where the design was developed. (The Tyrol region now spans the border between Austria and Italy.) The weir design is used to divert flow from steep mountain streams which may carry large volumes of debris and rocky bed load. It includes a collection channel, perpendicular to the flow of the stream, which would be constructed of reinforced concrete, similar to a trench drain. A system of closely spaced bars, parallel to the stream flow and at a small slope from upstream to downstream, prevents the larger unwanted material from entering the collection channel, while allowing water to pass down into the channel. The larger material is washed downstream by bypass flow.

The collection channel is sloped from one side of the river to the other, carrying water under open channel flow conditions into a collection chamber at the lower end of the channel. The channel for the Stori River diversion will be about 25-meters-long and have channel width of about 2 meters. The inside dimensions of the collection chamber will be about 3 m wide by up to 4.0 m in depth. The total height (including walls and an access bridge reaching above flood elevation) will be about 13 meters above the assumed bedrock level. From the collection chamber, flows enter the covered canal water conductor through a gated intake.

A set of low-level sluicing gates will be included in the collection chamber of the diversion weir, to flush sediment accumulations during high-flow periods. The sluice will be located perpendicular to and immediately before the power intake. It will be controlled by hydraulically operated slide gates installed upstream and downstream from the intake.

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

The **Chontiskhevi** diversion structure will be a wedge-wire (Coanda) screen weir, a scaled-down version of the Stori River diversion.

4.1.2 De-Silting Facility

There will be a de-silting facility a short distance downstream from the intake, following a short concrete canal section. 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-silting basin is being flushed. Two gates will be located at the upstream end of the structure and two at the downstream end, one at each end of each of the two longitudinal segments. Construction will be reinforced concrete with steel gates, railings, etc. There will be a second, lower-level set of gates, one from each of the two de-silting segments, controlling two under-sluices that return sediment from the de-stilting facility to the Stori River downstream of the diversion.

A small, single-chamber de-silting basin is proposed for the**Chontiskhevi** diversion, since the small watershed seems less likely to produce large sediment volumes.

Please refer to Table 5 above because there is an estimate of annual sediment tonnage and volume for Stori 3 as a function of return period in the table. Also, Table 5 strongly suggests necessary field data collection for sediment from Stori 3 intake location.

4.1.3 Power Tunnel

The **Stori River** power tunnel will have a total length of about 5,600 meters, with a finished inside diameter of 3.2 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 found in the area.

The power tunnel could be excavated using a TBM, or conventional drill and blast methods. The proposed alignment is shown on the Project Layout, Figure 5, above.

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

The **Chontiskhevi River** power conduit will be a 50-m-long, 2-m-wide, variable-depth canal leading to a connection structure built over the power tunnel. It will be widened for part of its length, and include an under-sluice structure, to improve fine sediment removal..

4.1.4 Surge Shaft

There will be pressure surge considerations at the Stori 3 HPP, commensurate with the length of the power tunnel. To reduce the pressure increase in the tunnel when turbines are shut down, a surge shaft will be excavated vertically through sound rock from a point near the end of the 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 500 m upstream from the powerhouse. The exact location of the surge shaft will be selected for topographic and geological reasons during feasibility and design studies.

4.1.5 Penstock

A 400-m-long buried penstock will lead to the powerhouse. A bifurcation just above the powerhouse will channel the flow to two turbine-generator units. There will be hydraulically operated butterfly valves on the inlet pipes to isolate the turbines. The penstock is assumed to be steel, but other materials—or the possibility of two parallel penstocks—can be investigated during future studies.

4.1.6 Powerhouse

The above ground powerhouse size and arrangement will be determined primarily by the site availability and the turbine-generator units selected for installation. The powerhouse will include the unit shutoff valves and most auxiliary systems, in addition to the units themselves.

The powerhouse dimensions for the assumed installation of two different size Francis units will be about 14 meters wide, 40 meters long, and 15 meters tall. It will include an overhead bridge crane with a capacity sufficient to lift the heaviest component in the turbine generator set (a 10 tonne crane capacity has been assumed for preliminary cost estimating purposes).

Draft tube gates and drainage pumps will be provided to dewater the units for inspection and maintenance. The draft tube gates and hoists will be located on an open deck outside the powerhouse.

4.1.7 Mechanical Equipment

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

Turbine selection for the Stori 3 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 two options, one Francis and one Pelton is shown in Appendix 11.

The proposed power plant will include two turbine-generator units. Vertical-shaft Francis units have been selected at this stage of study, although horizontal-shaft Francis or Pelton units may be feasible as well. The proposed Francis units will have different capacities, to make the plant operating range as broad as possible. The characteristics of the two units, based on the TURBNPRO unit selection software calculations, are shown in the following table:

Table 10: Turbine Characteristics

Unit	Speed, rpm	Runner Discharge Diameter, mm	Design Flow, m^3/s	Minimum Flow, m^3/s	Maximum Turbine Power, MW	Minimum Turbine Power, MW
No. 1, Larger	375	1273	8.9	3.88	9.54	3.7
No. 2, Smaller	500	922	4.5	1.96	4.8	1.88
Plant Total			**13.4**		**13.34**	

This installation will result in a maximum electric power output, at the high-voltage transformer terminals, of about 13.3 MW.

The Pelton turbine option includes two equal-size units, producing a mechanical output of up to about 6.65 MW each (with only one unit operating, maximizing net head). They are vertical-shaft machines and have 2 jets each, a rotational speed of 150 rpm, and a runner pitch diameter of 2,922 mm. These units are much larger than comparable Francis units at the Stori 3 rated head of 119 m.

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

Table 11: 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 two-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

4.1.8 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 relays, controls and monitoring 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 15/35 kV and oil insulated.

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 proposed power plant discharge from the Stori 2 HPP.
- Below the confluence with a significant left-bank (eastern) tributary.
- At a site where the dam length is relatively short and reasonable rock conditions appear to exist on both abutments.

The connecting canals, de-silting basin, and intake were located where there appear to be:

- Good tunnel portal conditions for the main power tunnel entrance, well below the identified fault.
- 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 combination of two short canals with a de-silting basin between, followed by a tunnel and penstock was selected for the main water conductors because of space limitations and very steep side slopes in the narrow canyon, and the generally acceptable geologic conditions along a potential tunnel alignment.

4.3 PROPOSED PROJECT COMPONENTS

In summary, the project includes the following components:

- Minimal access roads from public gravel roadway
- A bridge over the Stori river at the diversion weir
- A pioneer road to access the Chontiskhevi intake and the downstream tunnel portal.
- A 25-m-long Tyrolean weir diversion structure on the **Stori River**
- A 5-m-long wedge-wire weir on the **Chontiskhevi River**
- De-silting structures
- Sluicing structures
- Tunnel portal
- Water conductors (channels, tunnels, penstocks)
- A 40 m tall surge shaft
- Above-ground power plant
- An excavated tailrace channel
- Electrical and mechanical plant equipment, including incoming valves, turbines with governors, generators, switch gear, etc.
- Auxiliary backup power to allow black-starts when isolated from network (island mode)
- Power plant substation, including two power transformers
- 15 km of rehabilitated 35 kV transmission line (if not done by a predecessor Stori HPP developer)
- Substation expansion and equipment for interconnection at the Napareuli Substation (if not provided by a predecessor Stori HPP)

Table 12: Hydropower Development Significant Data

Maximum gross head	**123.5 meters**
Maximum generation flow	**13.4 m³/s**
Number of units	**2 Francis units**
Potential installed capacity	**13.3 MW**
Mean annual power output	**Approximately 55 GWh**
Construction time	**4 years including final feasibility, EIA and design.**
Anticipated Life-span	**30 years**

5.0 POWER AND ENERGY STUDIES

Stori 3 HPP energy assessment was completed using available Stori River discharge records (58 years of record) 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. There are differences between the two approaches that are due to differences in calculation approach. Results are considered acceptable when the energy output is within approximately 1% for each approach.

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 the Stori 3 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-hr). This analysis subtracts reserve flows for in-stream requirements to identify net m^3/s-hr 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 the Stori 3 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 (oversee/check automatic operating system) 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 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 1% 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 are 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").

Power and energy production figures were calculated using a range of plant design flows (i.e.: 10-15 m^3/s). Monthly results for a design flow of 13.4 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.

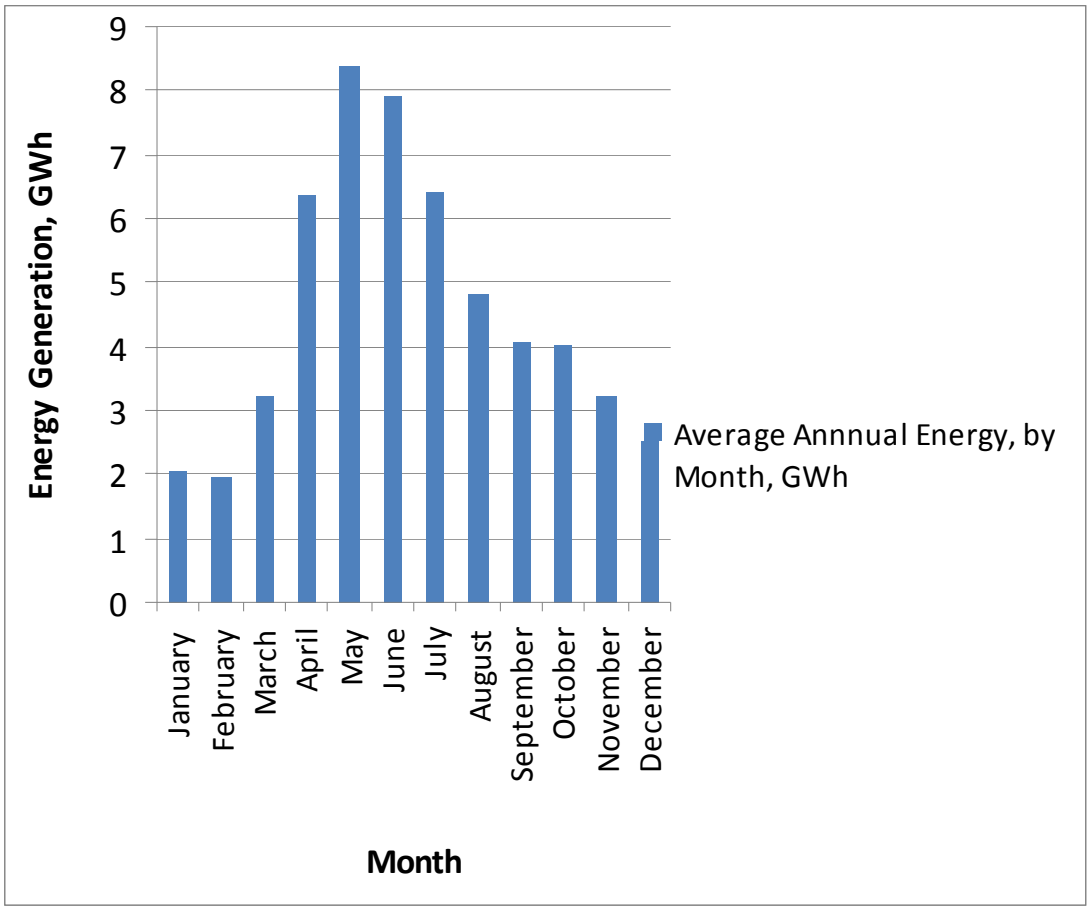
Table 13: Average Stori 3 HPP PowerProduction, 13.4 m^3/s Design Flow

Month	Mean Daily Power, MW	Minimum Daily Power, MW	Maximum Daily Power, MW
January	2.79	1.29	7.05
February	2.88	1.28	12.90
March	4.34	1.21	13.30
April	8.86	1.97	13.30
May	11.25	2.21	13.30
June	10.98	1.98	13.30
July	8.62	1.68	13.30
August	6.46	1.04	13.30
September	5.70	0.68	13.30
October	5.42	1.10	13.30
November	4.49	1.36	13.30
December	3.37	0.91	8.67
Annual	**6.26**	**0.68**	**13.30**

Table 14: Average Stori 3 HPP Energy Production, 13.4 m^3/s Design Flow

Month	Mean Daily Energy, GWh	Minimum Daily Energy, GWh	Maximum Daily Energy, GWh	Mean Annual by Month, GWh
January	0.07	0.03	0.17	2.08
February	0.07	0.03	0.31	1.96
March	0.10	0.03	0.32	3.23
April	0.21	0.05	0.32	6.38
May	0.27	0.05	0.32	8.37
June	0.26	0.05	0.32	7.90
July	0.21	0.04	0.32	6.41
August	0.16	0.02	0.32	4.81
September	0.14	0.02	0.32	4.10
October	0.13	0.03	0.32	4.03
November	0.11	0.03	0.32	3.24
December	0.08	0.02	0.21	2.51
Annual	**0.15**	**0.02**	**0.32**	**55.01**

Figure 6: Monthly Distribution of Average Annual Energy



6.0 ENVIRONMENTAL AND SOCIAL STUDIES

6.1 COMMUNITY AND SOCIO-ECONOMIC BASELINE DATA

Kakheti Region covers an area of 11,310 km² and according to the official statistical data from 2002, the population of the Kakheti Region is 407,000 people. The population density in the region is 36 people/km^2. The administrative districts of the Kakheti Region are: Akhmeta, Gurdjaani, Dedoflistskaro, Telavi, Lagodekhi, Sagaredjo, Signagi, and Kvareli Districts. There are 285 settlements in Kakheti Region - 9 towns and 276 villages.

6.1.1 Infrastructure

Infrastructure of the region is developed: Tbilisi and Telavi are connected by a good road. 35 kV high voltage transmission lines serve the city of Telavi and 10 kV transmission lines currently serve the villages in the vicinity of proposed Stori 3 HPP, but transmission lines near the proposed development site are damaged and must be rehabilitated.

There are about 34 public schools, 7 vocational school, 2 museums and 33 libraries and one theatre in the community. The populated area is rich in old churches, monasteries and other cultural relics.

6.1.2 Population and Settlements

The proposed Stori 3 HPP is located in Telavi District of Kakheti Region. The table below shows basic data of Telavi District. Some socio-economic characteristics of this district are described below.

Table 15: Telavi District Statistics

Location:	Telavi District
Administrative District:	Telavi
Area:	1,094.5 km^2
Population:	68,000
Population density:	84.4 people/km^2
Administrative center:	Telavi

Telavi administrative district is bordered by the Akhmeta District (Kakheti Region) on the west, the Gurjaani and Kvareli Districts (Kakheti Region) on the east, the Sagarejo District (Kakheti region) on the south. Telavi is the administrative centre and the biggest city of Kakheti region. Telavi city is situated at an elevation of 500-600 m above sea level on the foot-hills of the Tsiv-Gombori range. Telavi District consists of one small city and 30 villages. The distance from Tbilisi to the administrative center of Telavi is about 95 km. The total area of district land is 1,094.5 km^2. According to the statistical data of 2009, the population of Telavi Municipality is about 68,000 people. About 22, 000 people are registered in the city of Telavi and 46,000 people are registered in villages.

According to the residents, significant migration is observed in Telavi District villages. The situation is more alarming in village Lechuri: according to the residents, about 50 people have left the village. Both internal migration (migration to relatively big cities in Georgia) and external migration (migration outside Georgia: e.g. European countries) are observed in Telavi and Akhmeta District villages. During our field trips, local residents of Laliskuri, Lechuri and Alvani villages mentioned that the reason for migration is poor economic conditions: there are no salaried jobs and household/farm income is not sufficient to live on.

The major industrial activity includes wood manufacturing, mainly for construction. The leading agricultural activity is winegrowing, which is characteristic for the whole Kakheti Region. Maize, wheat and other cereals are cultivated in the rural areas of the district. Vegetables are also grown on farmlands.

The main agricultural undertaking is livestock breeding; however there are almost no pastures in villages in the vicinity of the proposed HPP area. The majority of the Tusheti population is traditionally engaged in nomadic sheep breeding. They spend warm seasons in the Tusheti Mountains, which are rich in forage, and move to villages at lower elevations in the area of Alvani village for winter pastures. In the spring, sheep driving routes starts from Alvani village of Telavi District and includes the Lechuri village and vicinity of the proposed HPP. Sheep movement starts in early May and takes about one month. The sheep migrate back down the road in the autumn when the weather in Tusheti turns cold.

Figure 7Sheep Migration

Figure 8Sheep Migration (Continued)

The closest settlement to the proposed HPP area is the village of Lechuri. The Lechuri village is located in the gorge of the Stori River. The gorge is narrow there, so the village is arranged as a line of structures along the bank of the Stori River. The Lechuri village is

located at an elevation of 560 meters above sea level. The territory of Lechuri village borders Tusheti – one of the unique historical-ethnographical mountain regions of Georgia.

Along the access road to Tusheti, upstream of the proposed Stori HPPs uppermost project of the proposed cascade, thermal waters are located called the “Torghva Baths”.

Tusheti Protected Areas: In 2003, in order to maintain the Tusheti ecosystems and protect its flora and fauna, including the native pine and birch woods, the Tusheti Protected Areas were created. The Tusheti Protected Areas, with total area of about 113,660 ha, consist of the Tusheti Strict Nature Reserve (10,694 ha), the Tusheti National Park (83,453 ha) and the Tusheti Protected Landscape (27,903 ha). The Tusheti Protected Areas begin about 50 km above (north of) Lechuri.

6.1.3 Cultural Heritage and Recreational Resources

Archeological sites, churches, towers, and related cultural and heritage sites are important baseline environmental data. The Kakheti region is rich in old churches, monasteries and other cultural relics. According to the literature review, no registered archeological and/or historical assets are located within the Stori 3 project development area. The table in Appendix 9 shows some of existing cultural resources of Telavi Districts of Kakheti Region.

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 Stori 3 HPP.

The proposed Stori 3 HPP site **baseline conditions** have been described in sections 2, 3 and 6.1 above. Appendix 10 presents tables of expected environmental receptor impacts and appropriate mitigation practices which should be included in feasibility studies. Effects on 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 on 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 Stori 3 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.

Risks to an environmental receptor from the activities are evaluated as Low, Medium, or High and should be refined further during the 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 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 Stori HPP. These tables are presented in Appendix 10

From an affected natural environmental perspective the Stori 3 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 Stori 3 HPP in an acceptable, legal, environmentally sensitive manner while complying with all regulations.

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 generated. Based on this cost estimate, we have confidence that the completed project will cost about US$ 24.3 million or $1,829 per kW of installed capacity, which is used in the financial analysis in Section 8.0

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 feasibility stage, based on various characteristics of the two turbine types. For the purpose of this cost estimate, it was assumed that two different sized Francis turbines are housed in the above ground powerhouse.

Unit costs are based on a comparable hydropower project in Georgia started in 2009 and are increased or decreased depending on, volumes, flows, kW capacity, etc. 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 Stori 3 project both numbers were consistent, so we used the slightly higher 1% of capital cost in our financial analysis in Section 8.

Table 16: Stori 3 HPP Estimated Capital Expenditure

	Units	Amt	Unit Cost	Total US$	Year 1	Year 2	Year 3	Year 4	Year 5
Land purchase	ha	1	$10,000	$10,000	$10,000				
Preparatory & infrastructure works	LS			$804,000	$804,000				
Stream diversion and cofferdams	LS			$281,000	$140,500	$140,500			
Pioneer road to Chontiskhevi intake & portal	m	8,500	$150	$1,275,000	$1,275,000				
Stori River Tyrolian Weir	LS			$279,000			$279,000		
Chontiskhevi Tyrolian Weir	LS			$70,000			$70,000		
Stori River Canal	m	500	$831	$416,000		$416,000			
Stori River De-silting Structure	LS			$622,000		$311,000	$311,000		
Stori River Portal	LS			$204,000		$102,000	$102,000		
Headrace Tunnel including rockbolts & shotcrete	m	5,500	$696	$3,826,000		$1,147,800	$1,530,400	$1,147,800	
Surge Shaft	m	40	$1,391	$56,000				$56,000	
Penstock 2500 mm steel buried	m	400	$1,299	$520,000			$520,000		
Power house in steel	LS			$1,110,000			$555,000	$555,000	
Tailrace box culvert	LS			$77,000			$77,000		
Tailrace Excavation and burms	m	400	$84	$34,000				$34,000	
Transformer Switchyard	MW	13.30	$7,747	$103,000			$51,500	$51,500	
Electric and mechanical parts (turn-key)	MW	13.30	$558,391	$7,427,000		$1,485,400	$2,970,800	$2,970,800	
Grid connection transmission line (if needed)	km	15	$13,979	$210,000				$210,000	
Subtotal of Schedule Items				**$17,324,000**					
Geology (investigation field, lab and office) @ 1%	LS			$173,000	$173,000				
Feasibility study @ 1%	LS			$173,000	$173,000				
EIA @ 1%	LS			$173,000	$173,000				
EPCM @ 14%	LS			$2,425,000	$1,455,000	$485,000	$485,000		
Contingencies (Assumptions Variable) @ 20%	LS			$4,053,600	$840,700	$817,540	$1,390,340	$1,005,020	$0
Total				$24,321,600	$5,044,200	$4,905,240	$8,342,040	$6,030,120	$0
MW Capacity	13.30		CAPEX/kW	**$1,829**					

7.3 CONSTRUCTION SCHEDULE

The construction schedule is envisioned to be one year for Geotechnical investigation, 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. **It may be advantageous to build the pioneer road parallel to the tunnel zone early for access to boring sites.** The 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 5.6 km of tunneling. It appears that work on the diversion weir may 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 may be too high and the velocities too high for cofferdams to hold. All flow impediments, such as cofferdams, may need to be removed before the spring runoff period.

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.

Currently Georgia only needs new power capacity to meet its winter demand. The developer of the Stori 3 HPP may therefore need to 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 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 Stori 3 HPP power to markets in other countries, there must be transmission access at affordable tariffs. Investigations by 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 Stori 3 HPP should work closely with GSE, EnergoTrans and the Georgian National Energy and Water Supply Regulatory Commission.

Table 19 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 Stori 3 HPP based on the monthly flow-duration curves (see Appendix 2) and an assumed bypass of 1-10% of the low monthly flows as flow reserved for in-steam habitat and environmental functions and values. This environmental bypass is not used during high flow periods when excess water is running over spillways. 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. These calculations are shown in Tables 17 and 18 for the Georgian and Turkish markets respectively. The net price for Georgia and Turkey are distributed according to the apparent demand pattern throughout the year. The monthly generation capacity of Stori 3 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 (we assumed 1% of generated capacity was used within the project) and operating costs at 1% of the capital expenditure are deducted to get net operating revenue. Based on this, the expected payback period (not including the cost of capital) is calculated at approximately 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 17Georgian Market Net Tariff Calculation

Georgian Market	US$	GEL
Gross Tariff $/kWh	0.041402	
Dispatch tariff ($/kWh)	0.000882	
Transmission tariff 1 ($/kWh)	0.002941	
Transmission tariff 2 ($/kWh)	0.001059	
Net Tariff from Georgia $/	0.036520	

Table 18Turkish Market Net Tariff Calculation

Turkish Market Tariff Calculation	US$	YTL
Tariff $/kWh	0.065000	
Transmission Tariff Georgia		
Dispatch tariff ($/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 ($/kWh)	0.002632	
Transmission tariff 1 ($/kWh)	0.002632	
Transmission tariff 2 ($/kWh)	0.002632	
Transmission tariff 3 ($/kWh)	0	
Other	0	
Total Transmission costs in Turkey	0.007895	0.015
Net Tariff from Turkey $/kWh	0.052220	

Table 19: Stori 3 HPP Financial Analysis & Payback Period (13.3 MW and 13.4 m^3/s)

Month	Total CMS-HR Under Curve	Saleable CMS-HR per month	Saleable kWh	Price / kWh	Revenue		
January	2,243	2,018	2,054,713	0.0375	77,052		
February	2,094	1,908	1,942,823	0.0375	72,856		
March	3,516	3,162	3,219,999	0.0375	120,750		
April	6,931	6,311	6,426,948	0.0520	334,201		
May	9,846	8,299	8,451,297	0.0520	439,467		
June	9,477	7,839	7,982,576	0.0520	415,094		
July	7,450	6,344	6,459,795	0.0520	335,909		
August	5,083	4,732	4,819,085	0.0520	250,592		
September	4,608	4,035	4,109,114	0.0520	213,674		
October	4,373	3,946	4,018,103	0.0520	208,941	Weighted Average Tariff	
November	3,406	3,176	3,234,592	0.0375	121,297		
December	2,712	2,439	2,483,316	0.0375	93,124		
Totals	61,738	54,209	55,202,362	Total Revenue / Yr	2,682,959	$0.0486	
				(Site Electricity) @ 1%	($26,830)	7% of rev	1% of Cap
Design discharge =	13.4	m3/s		(operating costs)	($243,216)	$185,929	$243,216
CF =	46%			Net Operating Revenue	$2,412,913		
Annual average m3/s through powerhouse =	6.2			Estimated Capital Exp.	$24,321,600		
				Pay Back Period	10.08		

This simple payback period represents only the engineering, construction and operating costs. It does not address considerations such as the time value of money, borrowing, interest, internal rate of return on assets or equity, etc.

Appendix 1

Geology Report & Associated Maps

CLIENT COMPANY DELOITTE

USAID Hydropower Investment Promotion Project (HIPP)

Prospect for construction of low-power Hydro Power Plants in Kakheti Region and in its tributaries

(Pre-designing phase)

Tbilisi 2011

INTRODUCTION

Geological-engineering works envisage evaluation of prospects for arrangement of underground small hydro power plants, power tunnels and water diversion structures on the Stori River in Kakheti region at the pre-design phase

Collecting and compiling of geological, geological-engineering, hydrological and other literature materials about the region was undertaken at this pre-design phase. analysis of the issues and determination of reconnaissance routes and survey locations utilizing 1: 50 000 scale maps were carried out within the scope of this work.

A geological-engineering survey was designed based on study of collected information and reconnaissance routes data and also aerial and satellite photography interpretation that was accompanied by a 1:50000 scale geological-engineering map with sections and indication of hydro-power plant locations.

Region Physical-Geographic Description

The study area is located in Telavi administration district, at 180-190 km distance by road from Tbilisi. This distance can be reduced to 100 km if you travel through Gombori Pass, but it is closed during 3 months in winter. The study area covers the mid-part of the course of the river Stori which is the left tributary of the river Alazani ; from the village Pshaveli to the resort Torgva bathes. The followings are the main orographic elements on the territory: Speroza ridge, Nakerala ridge of meridional direction and Ortsveri-Didgverdi ridges which form the watershed of the rivers Alazani and Stori.

The mentioned ridges and their branches are characterized with steep (40-60°) slopes and narrow, rocky crests. Medium and high mountain parts of the region are completely jagged with the network of deep gorges. Difference in heights between the bottom of the gorges and watershed crests is 500-1000m. The study area is characterized with a dense hydrographic network. River network frequency coefficient for the left flank of Caucasus Main ridge is 2.2 km/km^2 on average; the river Alazani with its tributaries is one of the big hydrographic units of the region. The study area is located in the gorge of the river Stori which is one of the big left tributaries of the river Alazani.

The Stori River takes its source from the left slope of the Main Caucasus Ridge, from the bottom of the mount Skhamoni. The gorge of the Stori River is deep and characterized with steeply inclined slopes and V-shaped transversal profile, the bottom of the gorge has canyon form.

A huge number of tributaries flow into the Stori River within the study area among which the most important are the right tributaries – Sviana and Gojaura and the left tributaries – Nakodebi and Irmissatamasho. All these rivers have abundant water and are characterized with steep slope-like gorges.

The rivers of the left slope of the Main Caucasus Ridge are fed by snow, rain and underground waters. Snow is melting in April and August. Snow water in the rivers is 10% of the water supply and underground waters amount to 60% and the other 30% is rain water. The closeness of the Caucasus Main Ridge and its arrangement on the left slope impacts the regional climatic conditions. As is the case for the whole line of the left slope of the Main Ridge, the study area climate is in vertical zones and covers the I (up until 1100 m elevation) and II (1100-2000m) zones. This is the zone with moderate dampness and warm climate, cool spring and two high rainfall periods a year: in the spring and in the autumn. Average annual temperature is 5-11°; average temperature in January minus 3to minus 5°C; average temperature in August 15-22°C. The watershed gets 160-170 days of precipitation per year. Annual precipitation amounts to 1200-1500 mm.

Forest-cover up to about 1000m elevation is generally represented by deciduous forest (oak, hornbeam) and at 1170-2200 m elevation– is characterized by mixed forest above which subalpine and alpine zones begin. Inhabited areas are located in the lower part of the course of the river Stori. (Pshaveli village). Locals are Georgian people (Kakhetian and Tushian) who generally do cattle breeding (sheep breeding). The main highway in the region of study area is the earth road driven in the gorge of the Stori River, which connects Torghva Baths to the villages and the regional center.

According to seismic zoning scheme of Georgia, study area is located in the area of magnitude 9.0.

Geomorphology

According to geological-engineering zoning of Georgia, the study area enters the Main Caucasus ridge zone. It is distinguished with specific morphologic and dynamic characters and is represented with high, medium high and medium mountain relief which is still undergoing the uplift process.

The main factors that contribute to relief origination are depth erosion and moraine formations. Relief peculiarities are determined by the erosion-resistant character of the rocks.

1. Alpine relief is developed in the north of project watershead and is characterized by strict and deeply dissected erosive, erosive-denudative and glacial-erosive relief which is built with intensively dislocated Pliensbachian and Toarcian shaly - sandstony isocline folded sediments.

The main sublatitudinal watershed and meridional Nakerala and Speroza ridges are big morphological units which are characterized with narrow and wavy crests. The ridges are dissected with deep V-shaped gorges. Pyramid-shapes are typical for the peaks of the ridges. The inclination of the slopes of the gorges of the rivers Alazani, Stori and others is 40-60°. Their slopes in some places are saw-edged which is explained by exotectonic phenomena.

The early glacial formations played an important role in forming this relief and remaining moraine formations can be observed.

2. Medium high mountain, rocky, steep, slope-like relief is developed on the folded substrata of the lower Lias Stori Suite (absolute altitudes 1000-2500m). This type of relief is developed in the middle part of the project watershed and lithologically is represented with thick-layered, massive quartzy sandstones, quartzites, metamorphic shales and others that are erosion-resistant.

The stori anticline structural rocks are dissected with numerous tectonic faults and fractures processed by erosion that is well seen in the canyon-type gorges of the river Stori and its tributaries: Purtkalos Gele, Irmis Satamasho and Nakodebi.

The slopes of the gorge are rocky and almost vertical in those places where the outcrops of quatzy sandstone packs exist, which make the gorge impassable. The tributaries of the river Stori are hung everywhere. In the riverbeds of the tributaries 10m height and more vertical drops and waterfalls are observed. Origination of the cascades developed in the gorge of the river Stori is connected with technogenic phenomena. The river Stori canyon-like gorge is dissected along the rocks direction and consequently the riverbed in some places are as narrow as 3-4 m. The peculiarity of the gorge relief is that no inert materials are accumulated in its riverbeds besides low-capacity colluvial sediments.

3. Medium mountain relief is developed in the left part of the project watershed which is characterized with intensively dissected, erosive-denudative relief. Structurally, it belongs to mega-anticlinorium of the folded system of the Caucasus Main Ridge left slope. The relief covers Kazbegi-Lagodekhi Jurassic shaly zone.

Erosive, intensively dissected medium mountain relief is developed on Jurassic sandstone-shaly folded substrata (absolute altitudes 1000-2000m).

The ridges are of meridional direction on the territory where such type of relief is developed. Relief is constructed with alternation of rather soft clay-shales and sandstones. The oval crests, wide saw-edged slopes and flat-bedded gorges are typical on heights.

The forms of such type relief are developed in the intensively dislocated structures of Lias series shales of project watershed (absolute altitudes 2400-2800 and 1500-1700m).

Hydro-geological conditions

From the hydrogeological standpoints, the study area enters the water-bearing complexes of Lower Jurassic origin, the Lower, middle and Upper Lias sedimentary rocks.

The basic water supply factor of the Stori River in the study area is surface water, which is explained by steep dipping of the slopes of the gorges and difficulties in water-penetration in structural rocks. Fractures of base rocks are often filled with clay that hinders penetration of rain

water and snow melt into the depth of fractured rocks. Therefore, surface water seldom contribute significantly to deep circulation waters.

According to lithological-geological zones the following water-bearing horizons are distinguished:

Lower Lias volcanogenic-sedimentary suite water-bearing horizon

Lower Lias volcanogenic-sedimentary rocks that are connected to water-bearing horizons are spread in the central and eastern parts of the study area. According to hydro-geological zoning of Georgia, it belongs to the water-bearing system of Kazbego-Mtatusheti fractured waters.

The water-bearing character of volcanogenic-sedimentary rocks is connected to the rocks fracturing level because one of the feeding sources for these rocks is circulation of underground water.

The discharge of separate springs is mainly within the range of 0.1-2.0 l/sec.; rarely does one exceed 3.0 l/s. A spring's temperature depends on their hypsometric locations and the depth of inflow water. The above mentioned water-bearing horizon underground waters are often slightly mineralized. They are generally fed with atmospheric precipitations and river water. In cases of spring discharge on the surface, they quickly flow down into the riverbeds of the gorges, due to their steep slopes.

These waters are of hydrocarbonate- calcium - sodium or hydrocarbonate- sulphate- calcium – sodium composition. Their overall mineralization is 0.4-0.6 gr/l. Overall hardness of waters is equivalent to 3.90-5.30 mg/l; dry residue is 290-535 mg/l.

Middle and Upper Lias shaly and shaly-sandstonywater-bearing horizon.

As previously stated, lithologically, the water-bearing horizon is represented by alternation of clay-shales and sandstones.

According to hydrological zoning of Georgia it belongs to Kazbegi-Mtatusheti water-bearing system of fractured waters. The specific amount of water is connected to a deeply developed fractured system in Middle and Upper Lias clay-shales and sandstones. Springs occurring in the water-bearing level of these rocks have low discharge rates which range from 0.1-1.0 l/sec, rarely does one exceed 2.0 l/sec. The spring, having 3.0 l/sec discharge within the study area is observed in the gorge between Torghva Bath and Torghva Bridge.

Together with heights changeability, the temperature of spring waters in this water-bearing horizon varies within the range of 6-17°C. An exception is Torghva Bath thermal-mineral spring with a temperature of 37°C, which has medical quality and is used by local people. Mineral thermal water is associated with intensively dislocated line of shales. It flows from the base rocks of the narrow gorge of one of the headwaters of the river Stori as a spring. The water's mineral composition is: $M_{0.517}\ \frac{HCO_3^{1}\ 40\ CO^{II}_3\ 30\ CE^{1}\ 30}{Na^{-} + K^{-}\ {}^{93}}$

The water is of sulphur-hydrogen-chloride-hydrocarbonate-sodium composition. Chemical analyses taken from the samples of other springs are: $M_{3.55}$ $\frac{CE^1\ 87}{/Na^- + K^-/\ 90}$

$M_{2.31}$ $\frac{CE^1\ 81}{/Na^- + K^-/\ 89}$

The waters belong to chloride-carbonate-Sodium-calcium type. The headwaters of the Stori River are on the left slope of the Caucasus Main ridge, about 1 km to the south of the Mount Didgveri, with summit elevation of 2950m and it connect to the Alazani River from the left side in the neighborhood of the Saniore village. The length of the river is 38 km. The overall elevation difference within the watershed is 2577m; with an average inclination of 67.8%. The catchment basin area is 281 sq/km with an its average elevation of 1610m.

The main tributaries of the Stori River are: the gorge of the river Chechakba which is 20km long and a nameless ravine with a length of 14km.

The river network density is 0.71 km/km^2

The north border of the watershed is the Caucasus Main ridge and the west and east borders are the Nakerala and Sakanapo branches of the Caucasus Main Ridge.

The catchment basin's length is 32km; width in the headwaters is 20 km and in mid-course is 9 km on average. Geomorphologically, in catchment area there are mountainous and lowland areas. The mountainous part covers the most important part of catchment area to the north from the village Pshaveli. This interval of the catchment area is dissected with watersheds of numerous small tributaries and narrow gorges.

Geological Engineering- Geotechnical Conditions

The complexity of the study area geological-engineering-geotechnical conditions is determined with surface changes of the lithological-genetical complexes of rocks and also with variability of geotectonic conditions and paleogeographic condition in their area of influence. So, formational (lithologica-genetical) principles were assumed as a basis for drawing up geological-engineering maps, which integrated geotechnical complexes of the rocks which come closer in geneses and composition. Based on above discussion the following formations are observed in the study area: intrusive, metamorphic, terrigene and terrigene-metamorphic, terrigene and quaternary, which integrate different geological-engineering complexes of rocks.

A great part of project hydro-technical construction of power and pressure tunnels, diversion structures, hydro power plants and tail races will be under the ground, in rocky and semi-rocky conditions. The part of the construction to be in the upper layers of the section of these rocks, will be in the quaternary sediments. Quaternary sediments in the gorge of the Stori River are limited and are generally alluvial and alluvial-proluvial formations.

Solidity indicators for above mentioned rocks (uniaxial compression strength) vary within a wide range. For example: the limit for Lower Jurassic (Lias) rocky group varies within a range of 660-2190 kg/ cm^2 (66-219 Mpa). The rocky geological-engineering group contains the same age diabases and their volume weight is quite high about 2850-2900 kg/cm^3 (285-290 Mpa), and the same age clay shales belong to semi-rocky group and their solidity limit vary within a wide range. Because of the weathering processes in the upper part of the section, the solidity limit is lowered about 50 kg/ cm^2 (5 Mpa) but in the lower part – is higher. For instance, for aspid shales the same indicator is – 600-1100 kg/ cm^2 (60-110 Mpa): for clay shales – 650-800 kg/ cm^2 (65-80 Mpa). Due to such variable construction conditions, indicators for physical-mechanical characters for separate formations are given below:

Intrusive formation Complex which enters the intrusive formation isn't widely spread in the study area. Lithologically, it is mainly represented with diabases and rarely albitophyre-pyroclastolites. Such rocks are observed in the Stori River gorge as separate dykes and directional bodies of layering as well. Diabases are gray and greenish-gray and consist of plagioclase, pyroxene and chlorite foliated debris. The structure is of diabase and porphyric by means of an ophite structure of the basic mass. Diabases belong to the rocky group and their average physical-mechanical indicators are as follows:

volume weight – 2,829-2,848 kg/m^3;
water-absorption 0.17-0.22%;
compression strength limit in air-dried state 1320-1420 kg/ cm^2;
compression strength limit after saturated 1264-1338 kg/ cm^2;
softening coefficient 0.8-0.95;
compression strength after freezing 15 times 775-1158 kg/ cm^2;
freezing resistance coefficient 0.61-0.83;
hardness coefficient 16;
processing category – X;

Diabases on the surface are fractured; fractures are mainly vertical and diagonal. As a consequence of which rocks are often characterized with dismembering in forms of boulders. Hydrogeologically, the mentioned formational rocks are open and characterized with good draining qualities. The distribution of albitophyre-pyroclastolites is extremely limited and therefore their description as independent geological-engineering unit is not included.

Metamorphic formations

Lower Jurassic J_1 litholgoical-genetical complex

These sediments are represented with Lower Lias aspid shales, marbles and marble-like limestones, quartzites and quartzy sandstones. The lithological-genetical complex of rocks which integrates the Lower Lias shaly suite intersects the gorge of the river Stori from the north-west to

the south-east direction forming a geologic feature of 2.0 – 2.5 km width. Interlayers of sandstones entering this complex sometimes are silicified and plays a minor role. Diabases are represented as the same directional bodies of intersecting layering.

The distribution of clay shales in metamorphic formation is dominant which are often represented with layers of 40-45 thickness.

The Lower Lias metamorphic suite is confined with faults from north and south parts where Mid-Lias terrigene-metamorphic formation is overthrust on these formations. Rocks inclination is northern and north-eastern.

Aspid shales generally are dark gray, sometimes black and rarely greenish-gray color; Lipidplastic structure and shaly texture are typical for them. They are intensively dissected by deep fractured system on the surface, which causes their shaly dismembering. These rocks intense dismembering is one of the reasons for rock avalanches and rockslides.

Marble and marble-like limestones are light-gray and light-blue; marble-like limestones in some places are reddish, solid, intensively reacts on salt acid; structure is granoblastic and consists of calcites and quartz cryptocrystalline grains.

Quartzites and quartzy sandstones are gray, light gray, and have solid granoblastic and mosaic structure. They consist of quartz, sericite and biotite grains. Quartzites are originated from sandstones crystallization. Sometimes, quartzy sandstones in quartzites are represented in forms of layers of 10 meter thickness.

Rocks physical-mechanical indicators

	Aspid shales	Marble and marble-like limestones	Quartzites and quartzy sandstones
1. Volume weight	2,300-2,700 kg/m^3	2,682-2,770 kg/m^3	2,230-2,570 kg/m^3
2. Water-absorption	0.39-0.53%	0.20-0.26 %	2.31-3.79%
3. Porosity	0.79-1.8%	-	0.5%
4. Compression strength limit in air-dried state	1212-1995 kg/cm^2	803-1012 kg/cm^2	1894-1995 kg/cm^2
5. Compression strength limit after water absorption	728-993 kg/cm^2	749-845 kg/cm^2	1292-1384 kg/cm^2
6. Softening coefficient	0.33-0.84	0.70-1.05	0.74-0.82
7. Compression strength after freezing 15 times	899-1130 kg/cm^2	662-693 kg/cm^2	-
8. Freezing resistance coefficient	-	0.78-0.89	0.83

The metamorphic formation geological-engineering complex is intensively fractured and dislocated. The whole suite is poorly water-bearing but is abundant in waters in tectonic faults and exogenic fractured zones. Pressureless ground water's intense circulation areas are connected to these zones. These aquafers are mineralized as hydrocarbonate-calcium-sodium or hydrocarboante-sulphate-calcium-sodium. Their overall mineralization amounts to 0.4-0.6 g/liter; overall hardness – equivalent to 3.90-5.30 mg/l. Dry residue is 290-535 mg/liter.

Terrigene and terrigene metamorphic formation

Middle Lias (J^2_1) lithological-genetic complex

The middle Lias shaly suite is wide spread in the Stori River gorge and its tributaries. Lithologically, the shaly suite is represented with the following: clay shales, rarely aspid shales and quartzy sandstones. Clay shales are strongly metamorphic and sometimes don't differ from aspid shales.

The middle Lias shaly suite in the lower part of the geological section is represented with poorly metamorphic clay shales (which are cut with diabase dykes and quartzites) and Leyers of aspid shales. In the middle of the section aspid shales are intensively fractured and dismembered in all three directions. Fracturing dense network is pointing to a layered structure.

Clay shale physical-mechanical indicators are:

volume weight – 2,300-2,410 kg/m^2;

water-absorption 0.18-0.40%;

porosity 0.70-1.96 %;

compression strength limit in air-dried state 890-1600 kg/ cm^2;

compression strength limit after saturation 220-810 kg/ cm^2; (often after water absorption compression strength limit of these rocks decreases to zero and rocks are totally decomposed);

softening coefficient 0.73-0.99;

freezing resistance coefficient 0.83;

These rocks physical-mechanical indicators in weathered rocks decreases 5-6 times.

Water-bearing character of this type lithological-genetical complex is characterized by a complicated system of fractures. Water discharge varies within a range of 0.03-0.8 l/s.

Not-deep circulation underground waters are characterized with hydrocarbonate-calcium-magnesium-sodium composition. Mineralization is within a range of 0.15-0.5 g/l. Water hardness is equivalent to 1.50-5.30 mg/l, dry residues – 134-520 mg/liter.

Terrigene Formation

Upper Lias (J_1^3) sediments lithological-genetical complex

Clay shales and sandstones: this type of complex geological-genetic formation is spread over the left slope of Kakheti Ridge in upper and lower course of the Stori River. Generally, they are represented with alternation of clay shales where solid sandstones are sometimes encountered in the form of interlayers.

Clay shales belong to the semi-rocky group; they are dark gray and black color; they are characterized with different solidity and water resistance.

Sandstones belong to the rocky group, they are light gray and yellowish-gray; fine and medium grained, quite thick, often dissected with quartz and calcite veins.

The rocks physical-mechanical indicators are given below:

Rocks physical-mechanical properties

	Clay shales	Sandstones
1. Volume weight	2,310 kg/m^3	2,620 kg/m^3
2. Water-absorption	0.2-0.5 %	1.10 %
3. Density	78-83 %	-
4. Compression strength limit in air-dried state	698-763 kg/cm^2	1548 kg/cm^2
5. Compression strength limit after water absorption	632-745 kg/cm^2	1233 kg/cm^2
6. Softening coefficient	0.68-0.76	0.80
7. Compression strength after multiple freezing	486-741 kg/cm^2	-
8. Compression strength after freezing 15 times	-	946 kg/cm^2
9. Freezing resistance coefficient	0.59-0.78	0.77
10. Density coefficient	4	6
11. Processing category	V	VII

Sandstones are dismembered with fractures which reach 6-8 m depth: width from 0.5 to 4-5 cm. Fractures in depth are filled with clayey materials that complicate penetration of surface water to deep circulation zone. underground water is circulating in this fracture complex and is characterized by a high discharge rate of 3 l/s.

Ground water from these formations are mineralized as hydrocarbonate-calcium-sodium or hydrocarbonate-calcium-mangnesium. Water mineralization is low – 0.6 g/l; overall hardness is equivalent to 1-6mg. These aquifers are mainly fed by precipitation.

Quaternary Formation

Zones of friable- unconsolidated rocks are generally represented with alluvial, alluvial-proluvial, deluvial, eluvial-deluvial and colluvial formations. Among them alluvial-proluvial sediments attract a great attention because of their wide spread distribution throughout the study area. The distribution of the others is quite limited.

Above-mentioned formations are limitwithin within the study area in the basin of the Stori River at local sites caused by topography.

Clay-soil alluvial sediments, with embedded boulders, cobbles, sands and fillers, are in the Stori riverbed downstream of the study area. They are dominant at the junction with the Alazani River. Boulder-cobble content in the section of the rocks of this complex in sediments overall mass is 5-55%, in clay-soil – 25-35%; in sandstones – 10-15%; in clays – 5%. Boulder-cobble thickness in these sediments is to 0.3-0.5 m, clay-soil thickness – 0.5-3.0 m and sand thickness – up to 1 m. Boulder-cobble is not consolidated in the riverbed of the gorge but in the lower levels of the course of the Stori River, in the terraces originated in the junction with the Alazani River they are poorly consolidated.

Pebble-stones volume weight is 1.90-2.40 tonne/m^3; filtration coefficient – from 1.0 to 15 m/day, water conductivity coefficient varies within a range of 8.2-235 l/m^2/day.

Plasticity data for fillers of pebble-stones such as clay-soils and sand-soil in the upper levels is 19-34%, in the lower levels – 17-31%; plasticity number – 3-17.

Among slope-type sediments within the study area, deluvial, eluvial-deluvial and colluvial formations are rarely observed and they are just connected to local sites caused by topography – old denudation ridges or accumulated on flat surface are primarilly outside the study area. Within the study area, they remain in the form of fragments on the highly inclined slopes. In such conditions their thicknesses don't exceed 1-2m. Even their lithological structure is quite varied and is represented with clay and clay-soils with inclusions of numerous coarse materials. In the middle elevations of the Stori River, on the right slope, fluvioglacial accumulation is observed consisting of big boulders.

Recent geological processes and phenomena within the study area are influenced by:

complicated geological-geomorphological construction,

climate and physical-geographic conditions,

the various rocks' geo-technical properties,

tectonic dislocations,

seismicity and

anthropogenic impacts.

These contribute to forming complicated geotechnical conditions. The following exogenic-geological processes are developed here, namely: weathering, erosion, snow avalanches, landslides, rock avalanches and occasionally mudflows. Weathering processes are developed due to the climatic conditions and existence of easily weathering rocks. In such circumstances weathering products are accumulated which creates the source for mudflows.

Erosion processes, the lateral as well as in depth are associated with almost all rivers and ravines.

Snow avalanches which are quite frequent on the north periphery of the study area are hazardous natural calamities. They are mainly moving along the erosion depression and partly transforming into mudflows.

Landslides, developed outside the limits of study area are large-scale geodynamic processes. Such phenomena are basically encouraged by the following factors: complex geological-geomorphological structure, climatic and hydrological conditions, rocks geotechnical properties and activity of recent geological processes and phenomena. Landslides often have rock-avalanche quality; also observed are plastic and saturated-plastic landslides. According to depth, the landslides have mainly surface-character (5-6m). In the case of deeper complex landslides, the foundation rock also collapses together with the weathered surface rocks; such types of landslides are gravity landslides and the factors that play a significant role in their development, are:

steep slopes of deeply intruded gorges,

local rock lithological composition,

intense disintegration,

tectonic disturbances,

weathering crust dynamic condition and

seismic activity (according to seismic activity the study area is in the zone of magnitude 9). Landslide bodies developed in zones of tectonic disturbances on the study area are stable today. Landslide bodies on slopes as a rule create several steps or have circular forms. Landslide landscapes on the Caucasus left slope are stretched over several kilometers and cover the headwaters of the tributaries of the Stori River.

Mudflow phenomena are spread in local sites. The key elements in their development are first: climate conditions – deep snow cover and fast melting during heavy rain; and second an accumulation of weathering products which provide a large supply of solid material in mudflow gorges.

Besides landslides and mudflows, the study area is characterized with floods. Not only basic rivers but secondary and almost all the rest rivers even minor brooks are characterized with flash flooding which frequently is several times the average flow. Floods mainly are during the spring snow melt period. The water level in the rivers is at a minimum during late autumn and winter.

Conclusions and recommendations

Because of the complexities of the geology conditions the study area belongs to geological-engineering category III (complicated).

Geologically, the study area structural rocks are represented with lower-Jurassic J_1 (Lias) and quaternary – Q formations. Jurassic intrusive, metamorphic, terrigene and terrigene-metamorphic and terrigene formations are lithological-genetical complex rocks belonging to rocky and semi-rocky groups and are distinguished with high solidity character which contribute to favorable conditions for safe construction of small to medium sized Hydro Power Plants, tunnels and auxiliary buildings and their long-term operation.

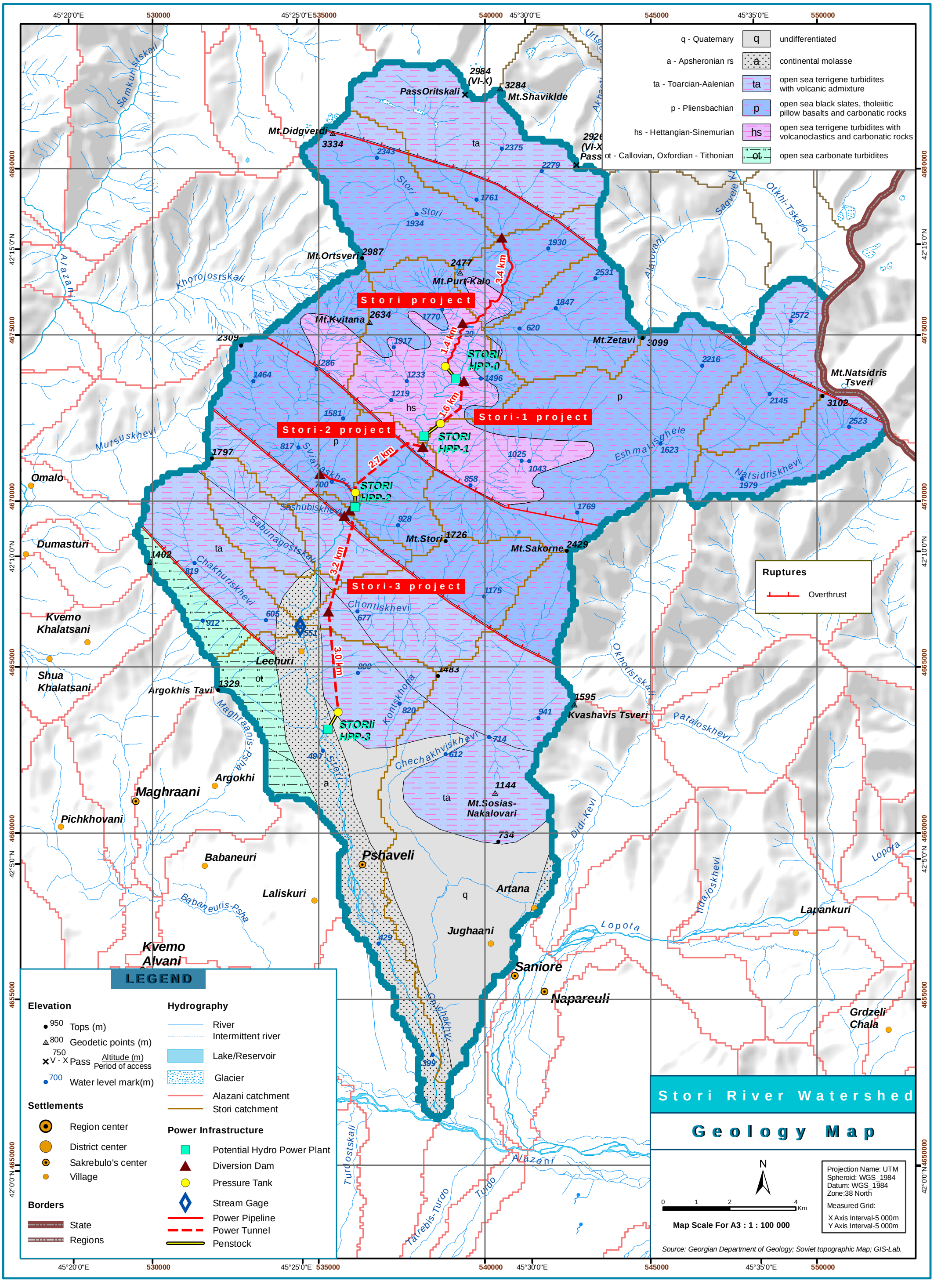
Quaternary formation lithological-genetical complex alluvial-proluvial formations belong to friable-unconsolidated group and consequently are characterized with weak physical - mechanical qualities.

Among exogenic processes, rock avalanches, rockslides, and snow avalanches in winter are basically identified in weathering crust tectonic faulting lines and dislocated zones. Landslides and mudflows are less prevalent. Though in some places, at the crests of the ridges, there are old stable landslide bodies which can become active again during long lasted heavy rain.

Based on above mentioned, designing of tunnels and structures must include taking all protective measures against hazardous geological processes for safe operational condition.

The study area is not rich with building material resources.

According to the active scheme of seismic zoning of Georgia, the study area is located in the area of magnitude 9.0 (the order of Minister of Economic Development of Georgia, No. 1-1/2284, dated with October 7, 2009 "About the statement of building norms and rules" Seismically steady construction» or about approval of 01.01.09).


Stori River Watershed
Geology Map
q - Quaternary
q
undifferentiated
a - Apsheronian rs
a
continental molasse
ta - Toarcian-Aalenian
ta
open sea terrigene turbidites with volcanic admixture
p - Pliensbachian
p
open sea black slates, tholeiitic pillow basalts and carbonatic rocks
hs - Hettangian-Sinemurian
hs
open sea terrigene turbidites with volcanoclastics and carbonatic rocks
ot - Callovian, Oxfordian - Tithonian
ot
open sea carbonate turbidites
Ruptures
Overthrust
Stori project
Stori-1 project
Stori-2 project
Stori-3 project
STORI HPP-0
STORI HPP-1
STORI HPP-2
STORIi HPP-3
1.4 km
1.6 km
2.7 km
3.2 km
3.0 km
3.4 km
Mt.Didgverdi
Mt.Ortsveri
Mt.Purt-Kalo
Mt.Kvitana
Mt.Zetavi
Mt.Natsidris Tsveri
Mt.Shavikide
PassOritskali
Mt.Stori
Mt.Sakorne
Mt.Sosias-Nakalovari
Kvashavis Tsveri
Argokhis Tavi
Omalo
Dumasturi
Kvemo Khalatsani
Shua Khalatsani
Lechuri
Argokhi
Maghraani
Pichkhovani
Babaneuri
Laliskuri
Kvemo Alvani
Pshaveli
Artana
Jughaani
Saniore
Napareuli
Lapankuri
Grdzeli Chala
Stori
Lopota
Alazani
Samkuristskali
Khorojostskali
Mutsuskhevi
Sviatskhevi
Sashubiskhevi
Sabunagostskali
Chakhuriskhevi
Chontiskhevi
Kontskhoha
Chechakhviskhevi
Maghraanis-Psha
Babaneuris-Psha
Turdostskali
Tatrebis-Turdo
Turdo
Didi-Kevi
Hidajoskhevi
Okhotistskali
Pataloskhevi
Natsidriskhevi
Eshmakisghele
Sagveleti
Otkhi-Tskaro
Alatovani
Akhaltsi
Urtsevi
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
Village
Borders
State
Regions
Hydrography
River
Intermittent river
Lake/Reservoir
Glacier
Alazani catchment
Stori catchment
Power Infrastructure
Potential Hydro Power Plant
Diversion Dam
Pressure Tank
Stream Gage
Power Pipeline
Power Tunnel
Penstock
N
0 1 2 4 Km
Map Scale For A3 : 1 : 100 000
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Spheroid: WGS_1984
Datum: WGS_1984
Zone:38 North
Measured Grid:
X Axis Interval-5 000m
Y Axis Interval-5 000m
Source: Georgian Department of Geology; Soviet topographic Map; GIS-Lab.
45°20'0"E
530000
45°25'0"E
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45°30'0"E
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45°35'0"E
550000
4680000
4675000
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4660000
4655000
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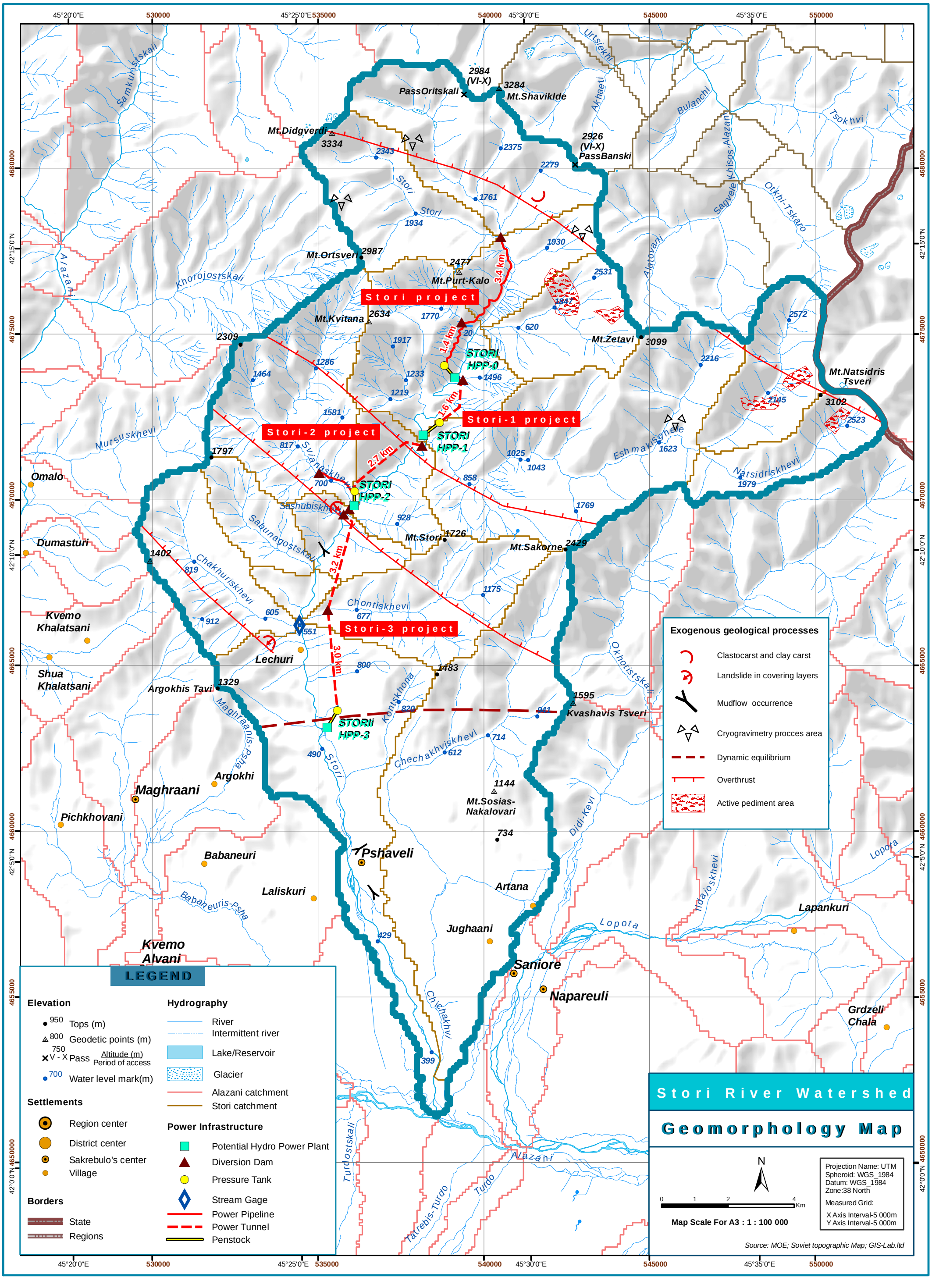
42°15'0"N
42°10'0"N
42°5'0"N
42°0'0"N


Stori River Watershed
Geomorphology Map
Exogenous geological processes
Clastocarst and clay carst
Landslide in covering layers
Mudflow occurrence
Cryogravimetry procces area
Dynamic equilibrium
Overthrust
Active pediment area
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
Village
Borders
State
Regions
Hydrography
River
Intermittent river
Lake/Reservoir
Glacier
Alazani catchment
Stori catchment
Power Infrastructure
Potential Hydro Power Plant
Diversion Dam
Pressure Tank
Stream Gage
Power Pipeline
Power Tunnel
Penstock
Stori project
Stori-1 project
Stori-2 project
Stori-3 project
STORI HPP-0
STORI HPP-1
STORI HPP-2
STORIi HPP-3
Mt.Didgverdi
Mt.Ortsveri
Mt.Purt-Kalo
Mt.Kvitana
Mt.Zetavi
Mt.Natsidris Tsveri
Mt.Stori
Mt.Sakorne
Mt.Sosias-Nakalovari
Kvashavis Tsveri
Argokhis Tavi
Lechuri
Omalo
Dumasturi
Kvemo Khalatsani
Shua Khalatsani
Maghraani
Argokhi
Pichkhovani
Babaneuri
Laliskuri
Kvemo Alvani
Pshaveli
Artana
Jughaani
Saniore
Napareuli
Lapankuri
Grdzeli Chala
Lopota
Alazani
Turdo
Turdostskali
Tavrebis-Turdo
Chichakhvi
Didi-Kevi
Hidajoskhevi
Okhotistskali
Chontiskhevi
Chechakhviskhevi
Kontskhona
Stori
Maghraanis-Psha
Babaneuris-Psha
Sashubiskhevi
Sabunagostskali
Chakhuriskhevi
Svianaskhevi
Mutsuskhevi
Khorojostskali
Alazani
Samkuristskali
Urtsekhi
Akhaeti
Bulanchi
Tsokhvi
Khisos-Alazani
Sagvele
Otkhi-Tskaro
Alatovani
Eshmakisghele
Natsidriskhevi
3.4 km
1.4 km
1.6 km
2.7 km
3.2 km
3.0 km
Source: MOE; Soviet topographic Map; GIS-Lab.ltd
Projection Name: UTM
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Datum: WGS_1984
Zone:38 North
Measured Grid:
X Axis Interval-5 000m
Y Axis Interval-5 000m
Map Scale For A3 : 1 : 100 000
N
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42°10'0"N
42°5'0"N
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4665000
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4655000
4650000

Geological section along Tsageri project HPP tunnel

1:50 000 scale

Legend

Q_{IV} - Recent alluvial sediments

Q_{III} - Upper quaternary alluvial-proluvial sediments

K_2 - Upper Cretaceous sediments. Limestones, marls, glauconitic sandstones, clays

K_1 - Lower Cretaceous sediments. Limestones, dolomitized limestones, marls, quartz-arcosic sandstones

$J_2 S_2$ – Mid-Jurassic Bajocian stage. Khojali suite. Tuffs, tuffogenic sandstones, tuff-breccias, tuff-conglomerates, porphyrites, basalt cover layers

$J_1^3 S_1$ – Mid-Jurassic Aalenian stage. Sori suite. Upper sub-suite. Sandstones, clay shales

$J_1^3 S_1$ – Lower Jurassic Toarcian stage. Sori suite. Lower sub-suite. Clay shales, sandstones

$J_1^3 S_1$ – Lower Jurassic. Middle part. Muashi suite. Aspid and clay shales, quartzy sandstones

$q\delta J_2$ Diorite-porphyrites

βJ_2 Diabases, diabase-porphyrites

Geological boundary between different aged formations

Tectonic contacts

1. Limestones; 2. Marls; 3. Dolomitized limestones; 4. Sandstones

Base composition volcanogenic-sedimentary rocks

1. Aspid and clay shales; 2. Sandstones

Alluvial-proluvial-deluvial sediments

Derivation tunnel

Geological and engineering geological description of the rocks spread over the study region

Table

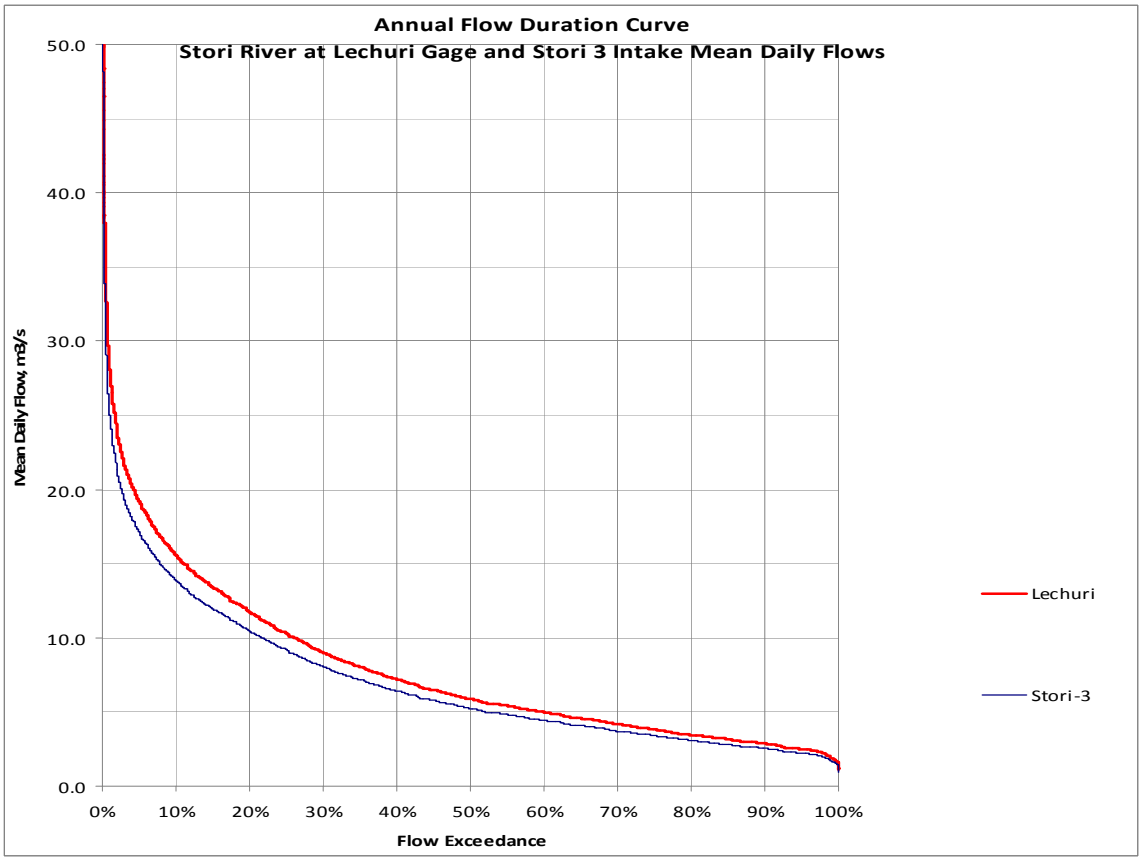
Structural stage	Geotectonic unit	Formation	Rocks geological-genetic complex	Rocks complex geological index	Friable-unconsolidated	Semi-rocky	Rocky	Density in natural condition P g/cm^3	Hardness coefficient according to M.Protodiakonov	Filtration coefficient K m/day	Ground accounting resistance Ro 0.1 M Pa	uniaxial compression strength
Quaternary	Caucasus Folded System I	Continental sedimentary	Fragmented and processed materials, boulder-cobble, gravels, crushed stones and sands with boulder inclusions of beds of alluvial-proluvial rivers and alluvial cones	αpQ_{III-IV}	▭							
Alpine	Caucasus Folded System Kazbegi-Lagodekhi zone I_2	Magmatic intrusive	Diabases	Lower Jurassic Stage			▭	2.77-2.90	15	-	-	2850-2900
		Metamorphic sedimentary	Aspid shales			▭		2.45-2.55	5.0-6.0	-	-	600-1100
			Dark gray, rarely black clay shales			▭		2.52-2.60	4.0-5.0	-	-	50-600
			Quarts sandstones				▭	2.80-2.81	8.0	-	-	1200-2190
			Marble and marble-like limestones				▭	2.70-2.72	6.0	-	-	600-1400

Appendix 2

Monthly and Annual Flow Duration Curves

Note related to this Appendix:

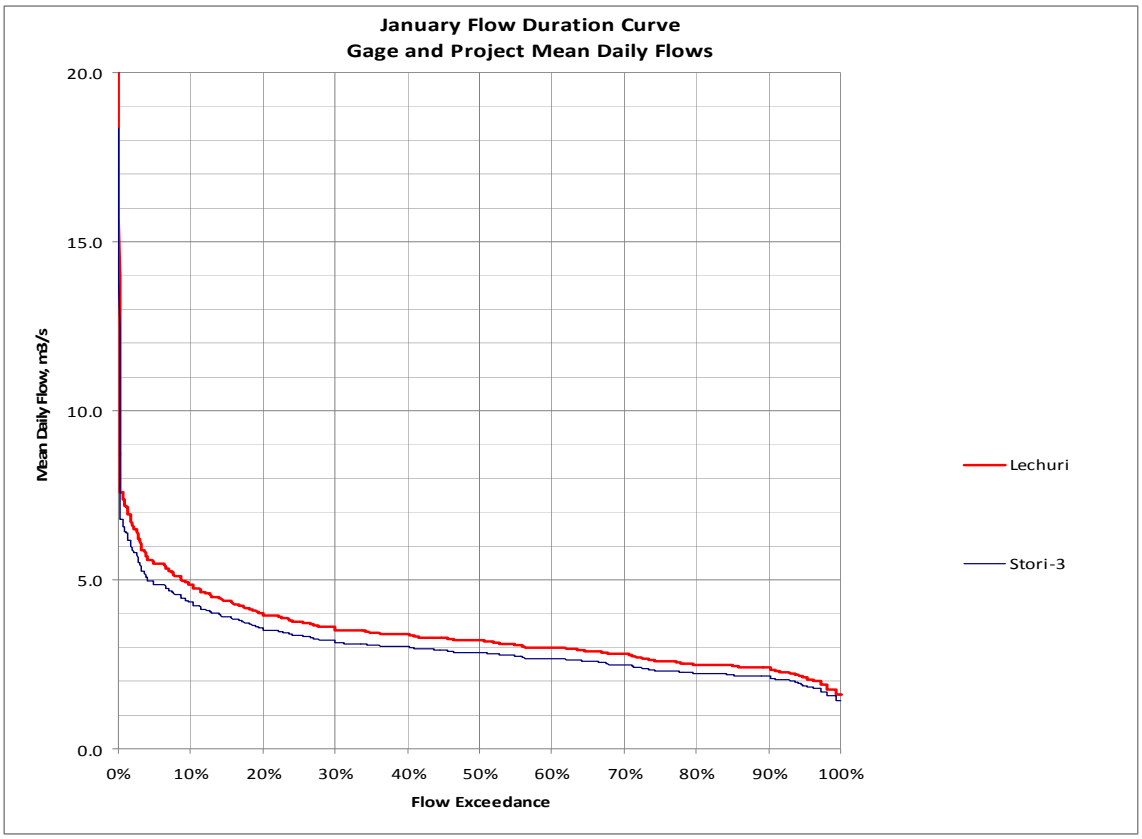
The generation tables following each Flow Duration Curve represent a conservative selection of input data and, therefore, a conservative analysis for monthly and annual HPP generation using this methodology.



Annual.

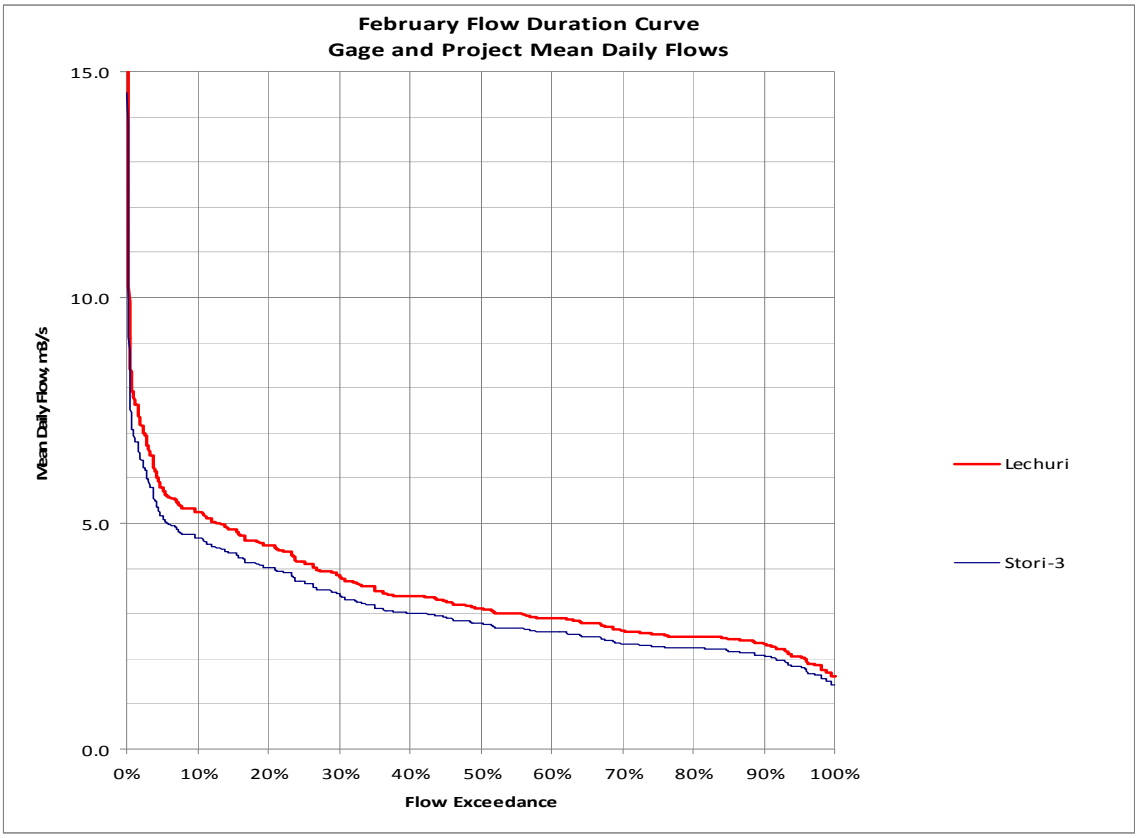
Area under Adjusted Flow Duration Curve in CMS-Hrs	61,837
Select Discharge equal to or exceeded % For HPP	11%
Equivalent Total Turbine Discharge at Selected CF in CMS	13.41
Non useable portion of FDC at selected CF or Exceedance %	5028
Gross Available CMS-HRS for Generation at selected CF	56,810
Annual Average Daily Discharge in CMS	7.06
Select Env/Sanitary Flow as a % of Monthly Avg Dalily Discharge	5%
Environmental/Sanitary Flow in CMS	0.30
Non-useable Environmental/Sanitary CMS-HRS	2,668
Net CMS-HRS Available for Generation	54,142
Estimated Intake Elevation in Meters	623.5
Estimated Discharge Elevation in Meters	500
Gross Head for Generation in Meters	123.5
Length of Penstock/Pipeline/tunnel in Km	6
Head Loss (from daily headloss calculation average) in Meters	1.326
Net Head for Generation in Meters	122.174
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Annual Generation in MWH	55,135

Monthly Summary of FDC Generation based on % Exceedance and Average HPP Unit Efficiency				
Month	Exceedance %	Equivalent Discharge in CMS	Estimated Av Monthly Efficiency	Average Monthly Energy in MWH
Jan	1%	6.42	85%	2,055
Feb	0%	8.10	85%	1,943
Mar	1%	12.92	85%	3,220
Apr	17%	13.41	85%	6,427
May	42%	13.41	85%	8,451
Jun	39%	13.41	85%	7,983
Jul	17%	13.41	85%	6,460
Aug	5%	13.37	85%	4,819
Sep	6%	13.41	85%	4,109
Oct	6%	13.41	85%	4,018
Nov	1%	12.97	85%	3,235
Dec	2%	7.84	85%	2,483
Annual Average Values	11%	11.84	85%	
FDC Summed Annual Average Generation				55,202



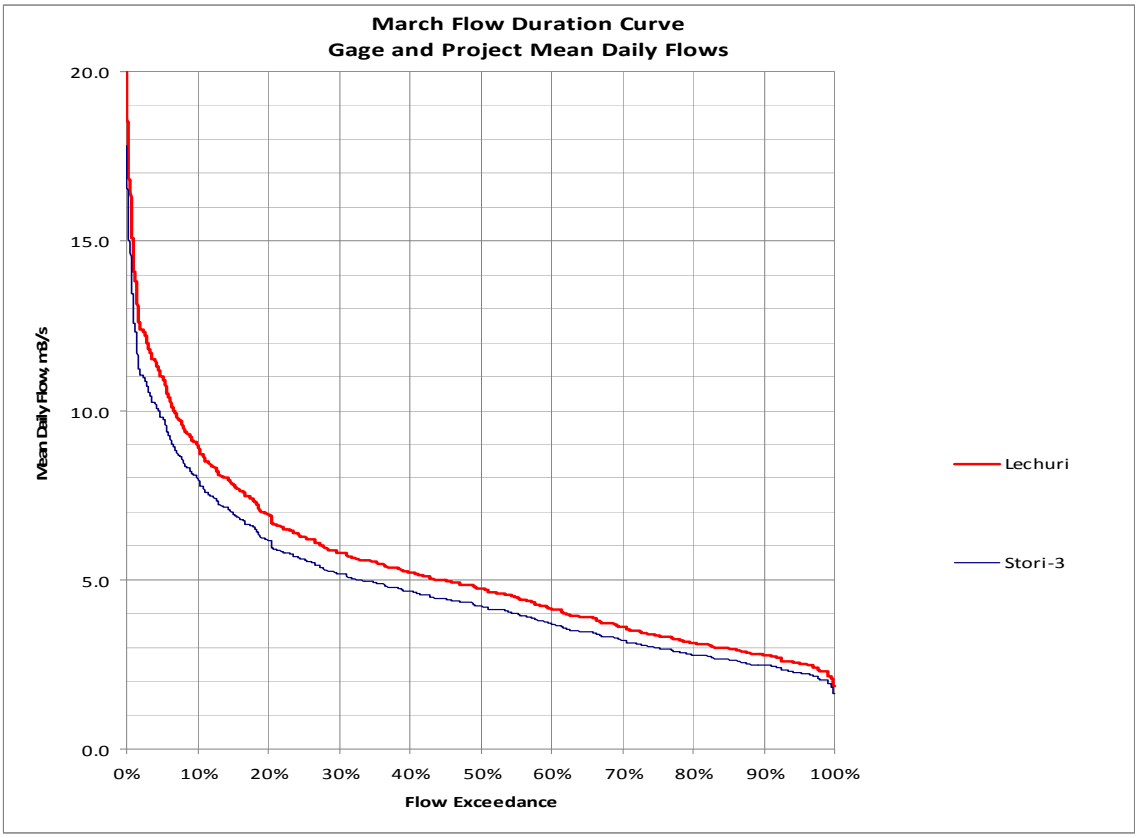
January

Area under Adjusted Flow Duration Curve in CMS-Hrs	2,243
Select Discharge equal to or exceeded % For HPP	1.10%
Equivalent Total Turbine Discharge at Selected CF in CMS	6.42
Non-useable portion of FDC at selected CF or Exceedance %	0
Gross Available CMS-HRS for Generation at selected CF	2,242
Monthly Average Daily Discharge in CMS	3.02
Select Env/Sanitary Flow as a % of Monthly Avg Daily Discharge	10%
Environmental/Sanitary Flow in CMS	0.30
Non-useable Environmental/Sanitary CMS-HRS	225
Net CMS-HRS Available for Generation	2018
Estimated Intake Elevation in Meters	623.5
Estimated Discharge Elevation in Meters	500
Gross Head for Generation in Meters	123.5
Length of Penstock/Pipeline/tunnel in Km	6
Head Loss (from daily head loss calculation average) in Meters	1.326
Net Head for Generation in Meters	122.174
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in kWh	2,054,713
MWh	2,055



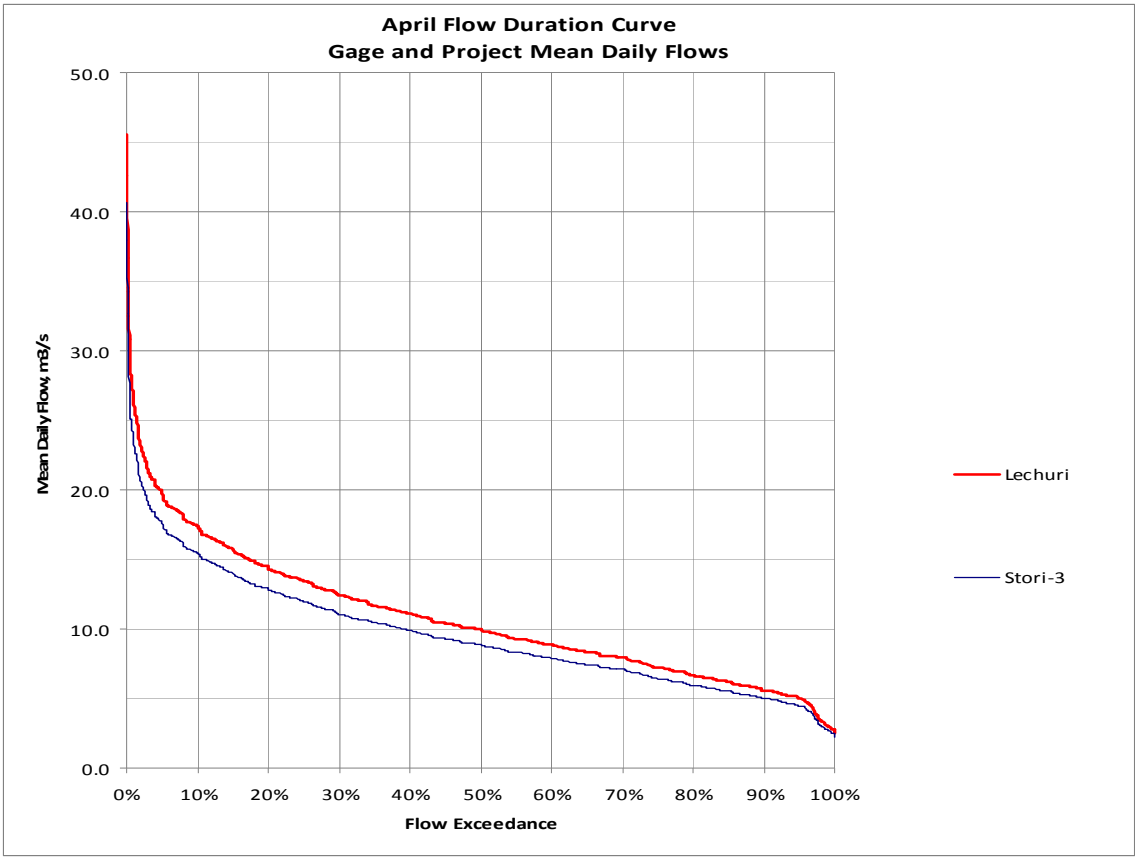
February

Area under Adjusted Flow Duration Curve in CMS-Hrs	2,094
Select Discharge equal to or exceeded % For HPP	0.43%
Equivalent Total Turbine Discharge at Selected CF in CMS	8.10
Non-useable portion of FDC at selected CF or Exceedance %	4
Gross Available CMS-HRS for Generation at selected CF	2,090
Monthly Average Daily Discharge in CMS	2.71
Select Env/Sanitary Flow as a % of Monthly Avg Daily Discharge	10%
Environmental/Sanitary Flow in CMS	0.27
Non-useable Environmental/Sanitary CMS-HRS	182
Net CMS-HRS Available for Generation	1908
Estimated Intake Elevation in Meters	623.5
Estimated Discharge Elevation in Meters	500
Gross Head for Generation in Meters	123.5
Length of Penstock/Pipeline/tunnel in Km	6
Head Loss (from daily head loss calculation average) in Meters	1.326
Net Head for Generation in Meters	122.174
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in kWh	1,942,823
MWh	1,943



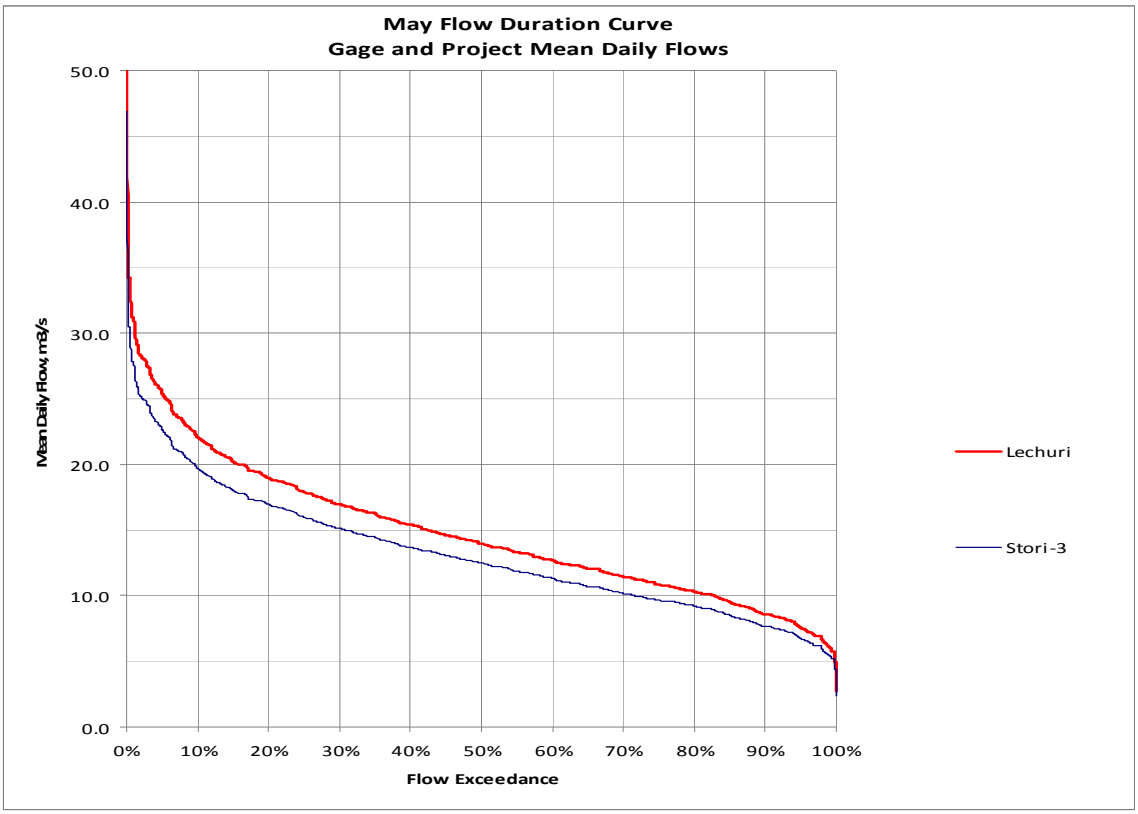
March

Area under Adjusted Flow Duration Curve in CMS-Hrs	3,516
Select Discharge equal to or exceeded % For HPP	1.00%
Equivalent Total Turbine Discharge at Selected CF in CMS	12.92
Non-useable portion of FDC at selected CF or Exceedance %	2
Gross Available CMS-HRS for Generation at selected CF	3,514
Monthly Average Daily Discharge in CMS	4.73
Select Env/Sanitary Flow as a % of Monthly Avg Daily Discharge	10%
Environmental/Sanitary Flow in CMS	0.47
Non-useable Environmental/Sanitary CMS-HRS	352
Net CMS-HRS Available for Generation	3162
Estimated Intake Elevation in Meters	623.5
Estimated Discharge Elevation in Meters	500
Gross Head for Generation in Meters	123.5
Length of Penstock/Pipeline/tunnel in Km	6
Head Loss (from daily head loss calculation average) in Meters	1.326
Net Head for Generation in Meters	122.174
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in kWh	3,219,999
MWh	3,220



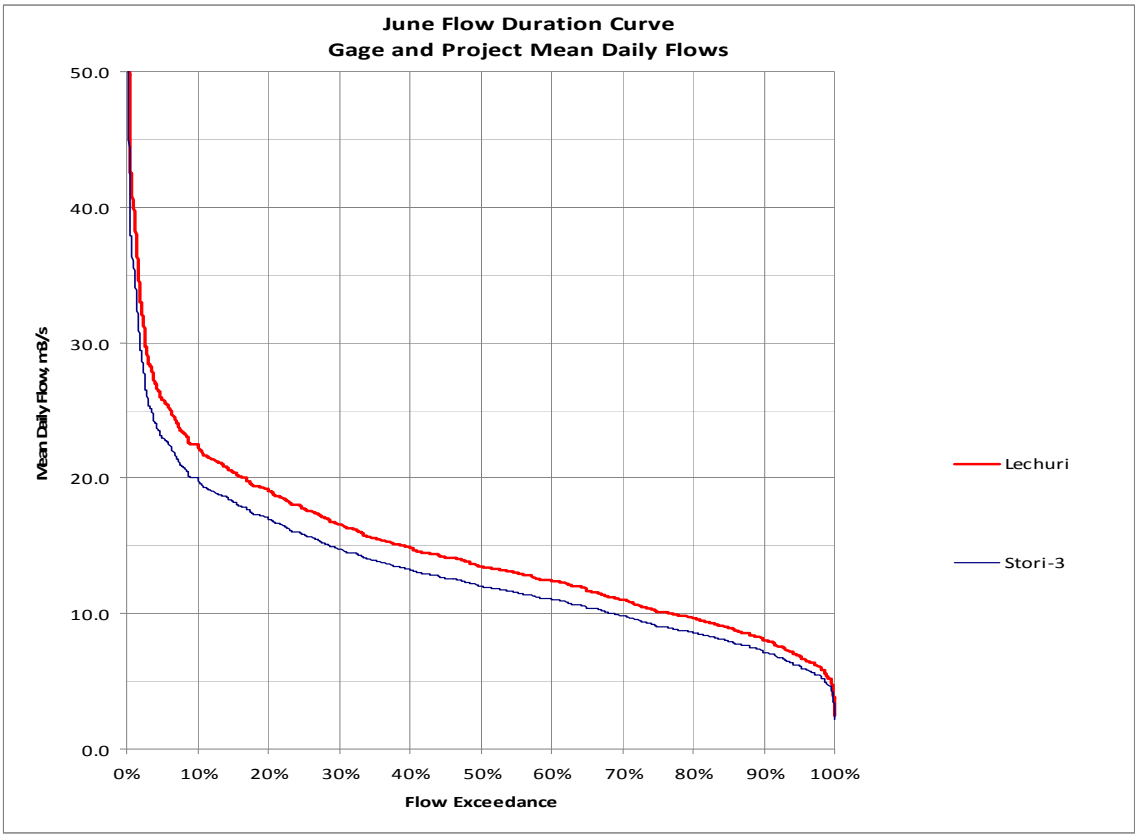
April

Area under Adjusted Flow Duration Curve in CMS-Hrs	6,931
Select Discharge equal to or exceeded % For HPP	17.15%
Equivalent Total Turbine Discharge at Selected CF in CMS	13.41
Non-useable portion of FDC at selected CF or Exceedance %	422
Gross Available CMS-HRS for Generation at selected CF	6,509
Monthly Average Daily Discharge in CMS	9.33
Select Env/Sanitary Flow as a % of Monthly Avg Daily Discharge	3%
Environmental/Sanitary Flow in CMS	0.27
Non-useable Environmental/Sanitary CMS-HRS	198
Net CMS-HRS Available for Generation	6311
Estimated Intake Elevation in Meters	623.5
Estimated Discharge Elevation in Meters	500
Gross Head for Generation in Meters	123.5
Length of Penstock/Pipeline/tunnel in Km	6
Head Loss (from daily head loss calculation average) in Meters	1.326
Net Head for Generation in Meters	122.174
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in kWh	6,426,948
MWh	6,427



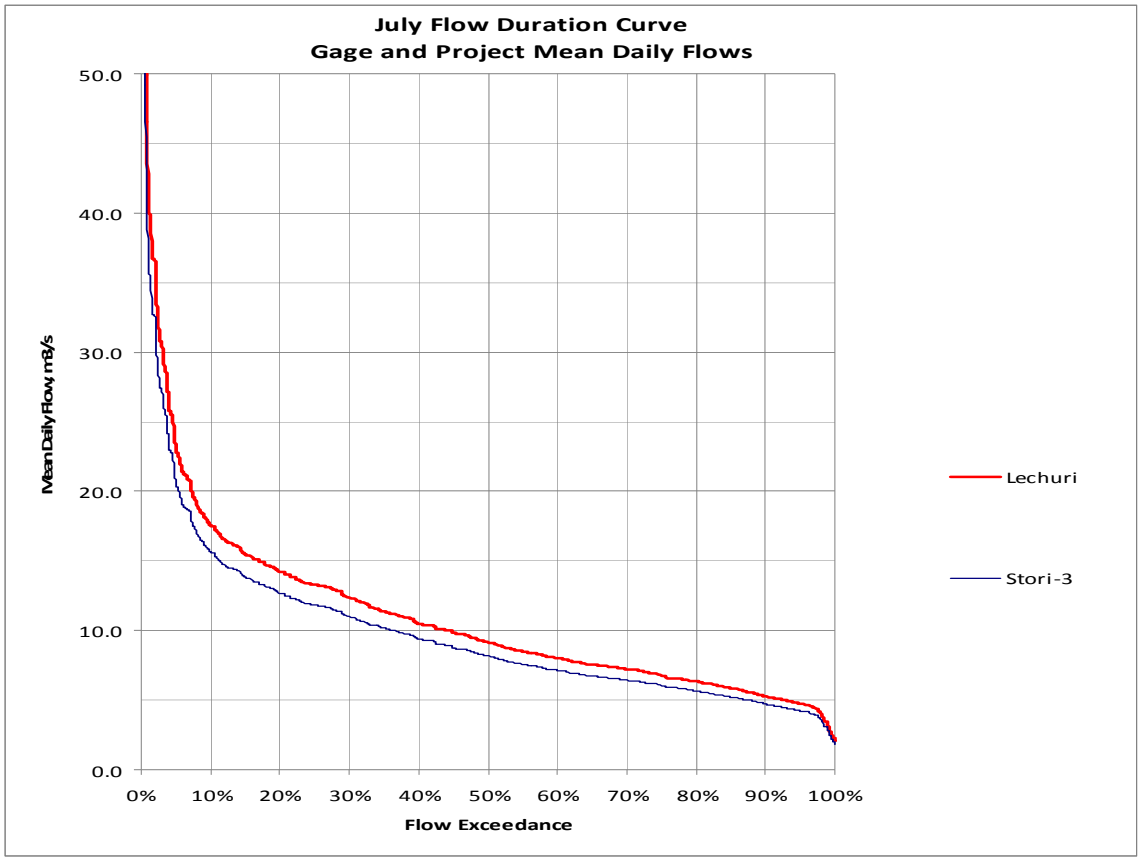
May

Area under Adjusted Flow Duration Curve in CMS-Hrs	9,846
Select Discharge equal to or exceeded % For HPP	42.42%
Equivalent Total Turbine Discharge at Selected CF in CMS	13.41
Non-useable portion of FDC at selected CF or Exceedance %	1349
Gross Available CMS-HRS for Generation at selected CF	8,496
Monthly Average Daily Discharge in CMS	13.25
Select Env/Sanitary Flow as a % of Monthly Avg Daily Discharge	2%
Environmental/Sanitary Flow in CMS	0.26
Non-useable Environmental/Sanitary CMS-HRS	197
Net CMS-HRS Available for Generation	8,299
Estimated Intake Elevation in Meters	624
Estimated Discharge Elevation in Meters	500
Gross Head for Generation in Meters	124
Length of Penstock/Pipeline/tunnel in Km	6
Head Loss (from daily head loss calculation average) in Meters	1.326
Net Head for Generation in Meters	122.174
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in kWh	8,451,297
MWh	8,451



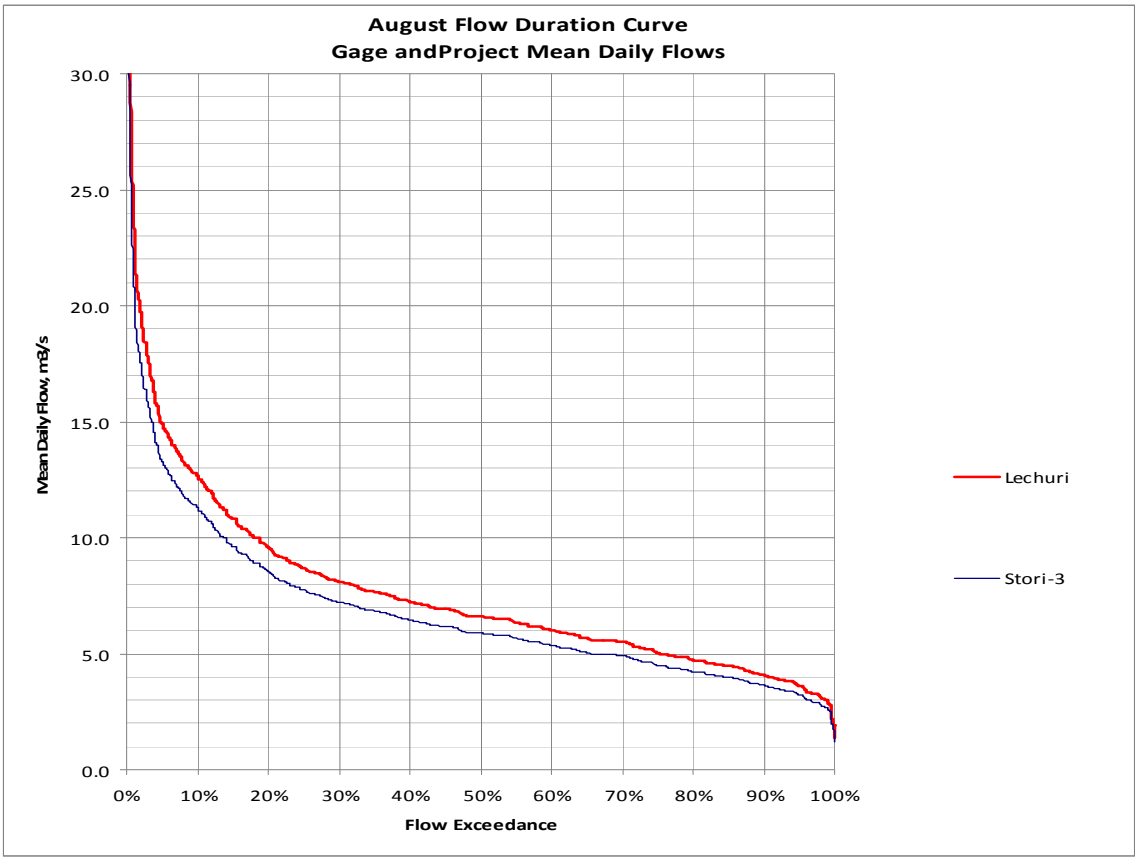
June

Area under Adjusted Flow Duration Curve in CMS-Hrs	9,477
Select Discharge equal to or exceeded % For HPP	38.60%
Equivalent Total Turbine Discharge at Selected CF in CMS	13.41
Non-useable portion of FDC at selected CF or Exceedance %	1452
Gross Available CMS-HRS for Generation at selected CF	8,025
Monthly Average Daily Discharge in CMS	12.94
Select Env/Sanitary Flow as a % of Monthly Avg Daily Discharge	2%
Environmental/Sanitary Flow in CMS	0.26
Non-useable Environmental/Sanitary CMS-HRS	186
Net CMS-HRS Available for Generation	7,839
Estimated Intake Elevation in Meters	624
Estimated Discharge Elevation in Meters	500
Gross Head for Generation in Meters	123.5
Length of Penstock/Pipeline/tunnel in Km	6
Head Loss (from daily head loss calculation average) in Meters	1.326
Net Head for Generation in Meters	122.174
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in kWh	7,982,576
MWh	7,983



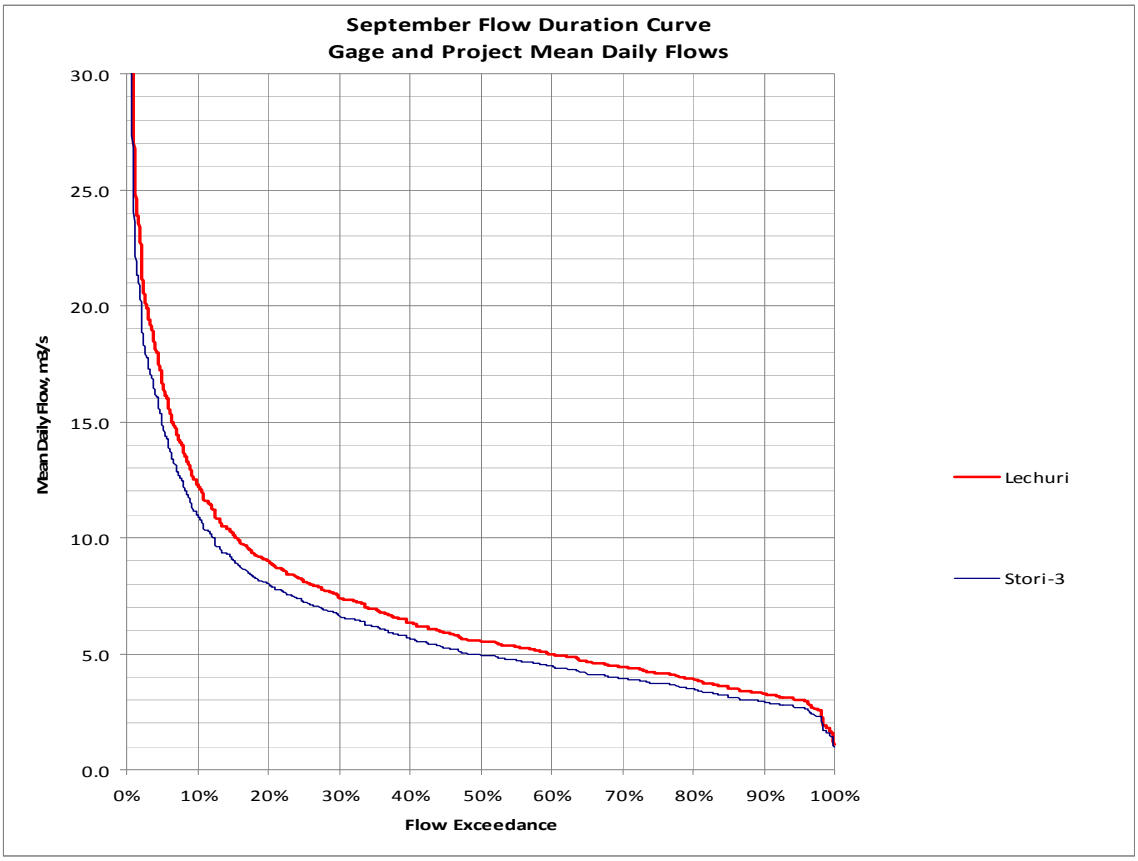
July

Area under Adjusted Flow Duration Curve in CMS-Hrs	7,450
Select Discharge equal to or exceeded % For HPP	17.00%
Equivalent Total Turbine Discharge at Selected CF in CMS	13.41
Non-useable portion of FDC at selected CF or Exceedance %	957
Gross Available CMS-HRS for Generation at selected CF	6,493
Monthly Average Daily Discharge in CMS	10.04
Select Env/Sanitary Flow as a % of Monthly Avg Daily Discharge	2%
Environmental/Sanitary Flow in CMS	0.20
Non-useable Environmental/Sanitary CMS-HRS	149
Net CMS-HRS Available for Generation	6,344
Estimated Intake Elevation in Meters	624
Estimated Discharge Elevation in Meters	500
Gross Head for Generation in Meters	123.5
Length of Penstock/Pipeline/tunnel in Km	6
Head Loss (from daily head loss calculation average) in Meters	1.326
Net Head for Generation in Meters	122.174
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in kWh	6,459,795
MWh	6,460



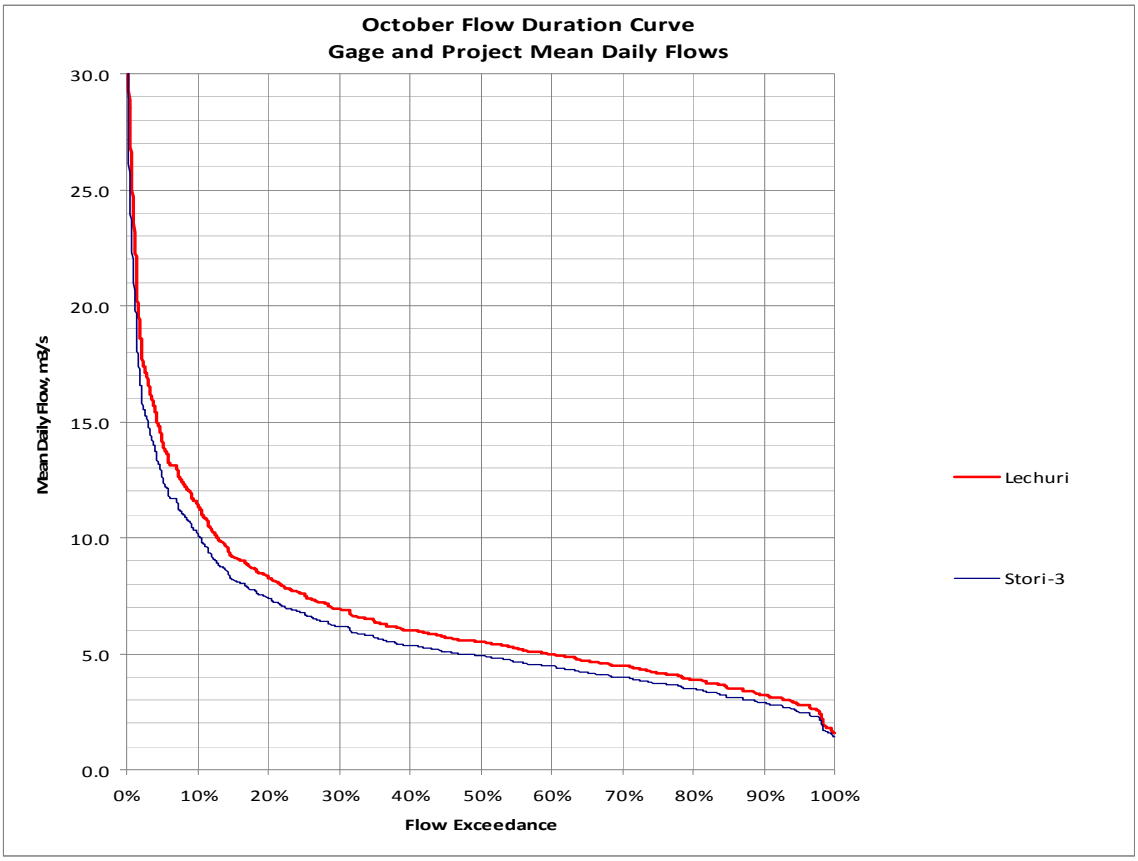
August

Area under Adjusted Flow Duration Curve in CMS-Hrs	5,083
Select Discharge equal to or exceeded % For HPP	4.84%
Equivalent Total Turbine Discharge at Selected CF in CMS	13.37
Non-useable portion of FDC at selected CF or Exceedance %	198
Gross Available CMS-HRS for Generation at selected CF	4,885
Monthly Average Daily Discharge in CMS	6.85
Select Env/Sanitary Flow as a % of Monthly Avg Daily Discharge	3%
Environmental/Sanitary Flow in CMS	0.21
Non-useable Environmental/Sanitary CMS-HRS	153
Net CMS-HRS Available for Generation	4732
Estimated Intake Elevation in Meters	623.5
Estimated Discharge Elevation in Meters	500
Gross Head for Generation in Meters	123.5
Length of Penstock/Pipeline/tunnel in Km	6
Head Loss (from daily head loss calculation average) in Meters	1.326
Net Head for Generation in Meters	122.174
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in kWh	4,819,085
MWh	4,819



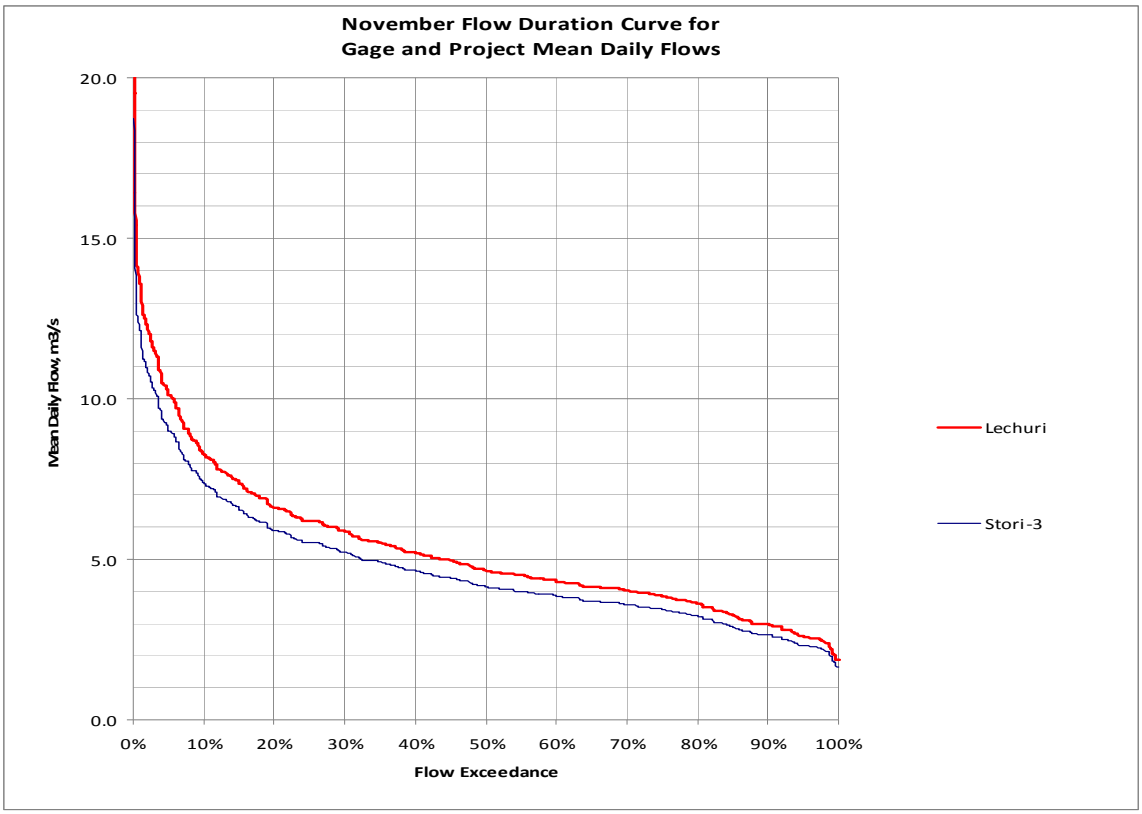
September

Area under Adjusted Flow Duration Curve in CMS-Hrs	4,608
Select Discharge equal to or exceeded % For HPP	6.45%
Equivalent Total Turbine Discharge at Selected CF in CMS	13.41
Non-useable portion of FDC at selected CF or Exceedance %	350
Gross Available CMS-HRS for Generation at selected CF	4,259
Monthly Average Daily Discharge in CMS	6.21
Select Env/Sanitary Flow as a % of Monthly Avg Daily Discharge	5%
Environmental/Sanitary Flow in CMS	0.31
Non-useable Environmental/Sanitary CMS-HRS	224
Net CMS-HRS Available for Generation	4035
Estimated Intake Elevation in Meters	623.5
Estimated Discharge Elevation in Meters	500
Gross Head for Generation in Meters	123.5
Length of Penstock/Pipeline/tunnel in Km	6
Head Loss (from daily head loss calculation average) in Meters	1.326
Net Head for Generation in Meters	122.174
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in kWh	4,109,114
MWh	4,109



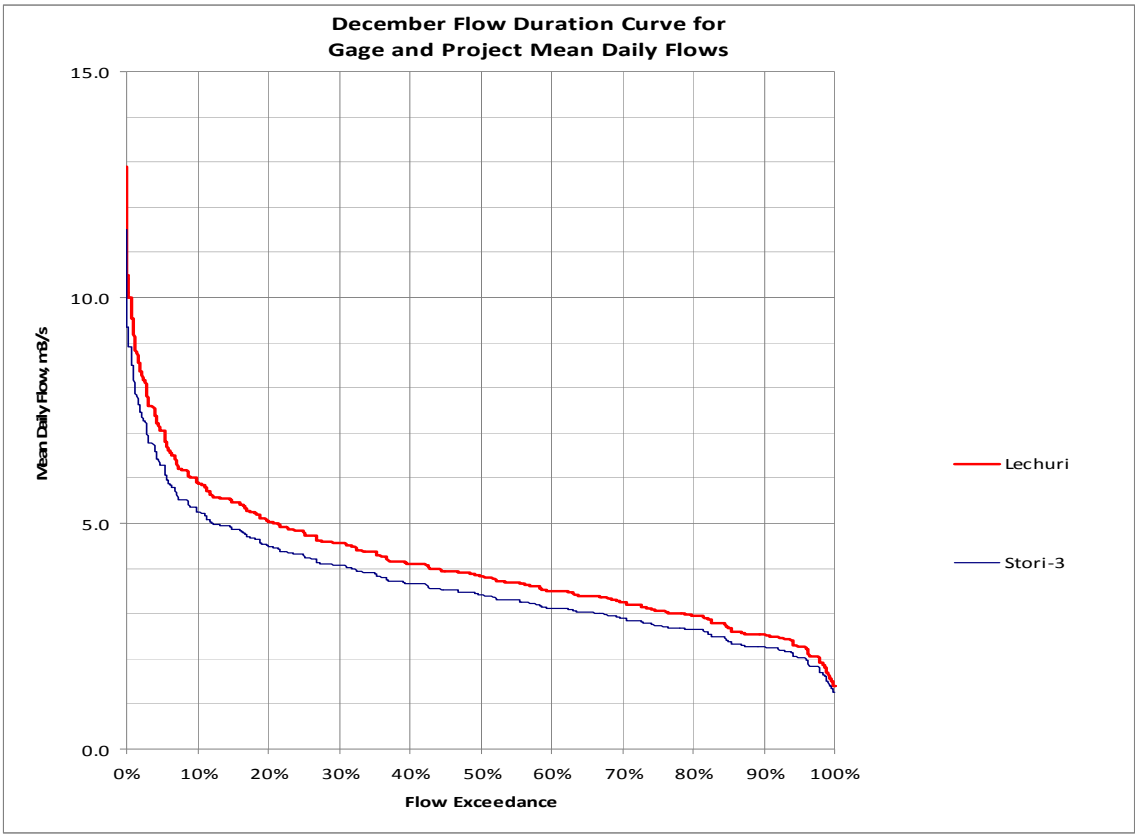
October

Area under Adjusted Flow Duration Curve in CMS-Hrs	4,373
Select Discharge equal to or exceeded % For HPP	4.30%
Equivalent Total Turbine Discharge at Selected CF in CMS	13.41
Non-useable portion of FDC at selected CF or Exceedance %	163
Gross Available CMS-HRS for Generation at selected CF	4,209
Monthly Average Daily Discharge in CMS	5.91
Select Env/Sanitary Flow as a % of Monthly Avg Daily Discharge	6%
Environmental/Sanitary Flow in CMS	0.35
Non-useable Environmental/Sanitary CMS-HRS	264
Net CMS-HRS Available for Generation	3946
Estimated Intake Elevation in Meters	623.5
Estimated Discharge Elevation in Meters	500
Gross Head for Generation in Meters	123.5
Length of Penstock/Pipeline/tunnel in Km	6
Head Loss (from daily head loss calculation average) in Meters	1.326
Net Head for Generation in Meters	122.174
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in kWh	4,018,103
MWh	4,018



November

Area under Adjusted Flow Duration Curve in CMS-Hrs	3,406
Select Discharge equal to or exceeded % For HPP	0.52%
Equivalent Total Turbine Discharge at Selected CF in CMS	12.97
Non-useable portion of FDC at selected CF or Exceedance %	3
Gross Available CMS-HRS for Generation at selected CF	3,403
Monthly Average Daily Discharge in CMS	4.51
Select Env/Sanitary Flow as a % of Monthly Avg Daily Discharge	7%
Environmental/Sanitary Flow in CMS	0.32
Non-useable Environmental/Sanitary CMS-HRS	227
Net CMS-HRS Available for Generation	3176
Estimated Intake Elevation in Meters	623.5
Estimated Discharge Elevation in Meters	500
Gross Head for Generation in Meters	123.5
Length of Penstock/Pipeline/tunnel in Km	6
Head Loss (from daily head loss calculation average) in Meters	1.326
Net Head for Generation in Meters	122.174
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in kWh	3,234,592
MWh	3,235

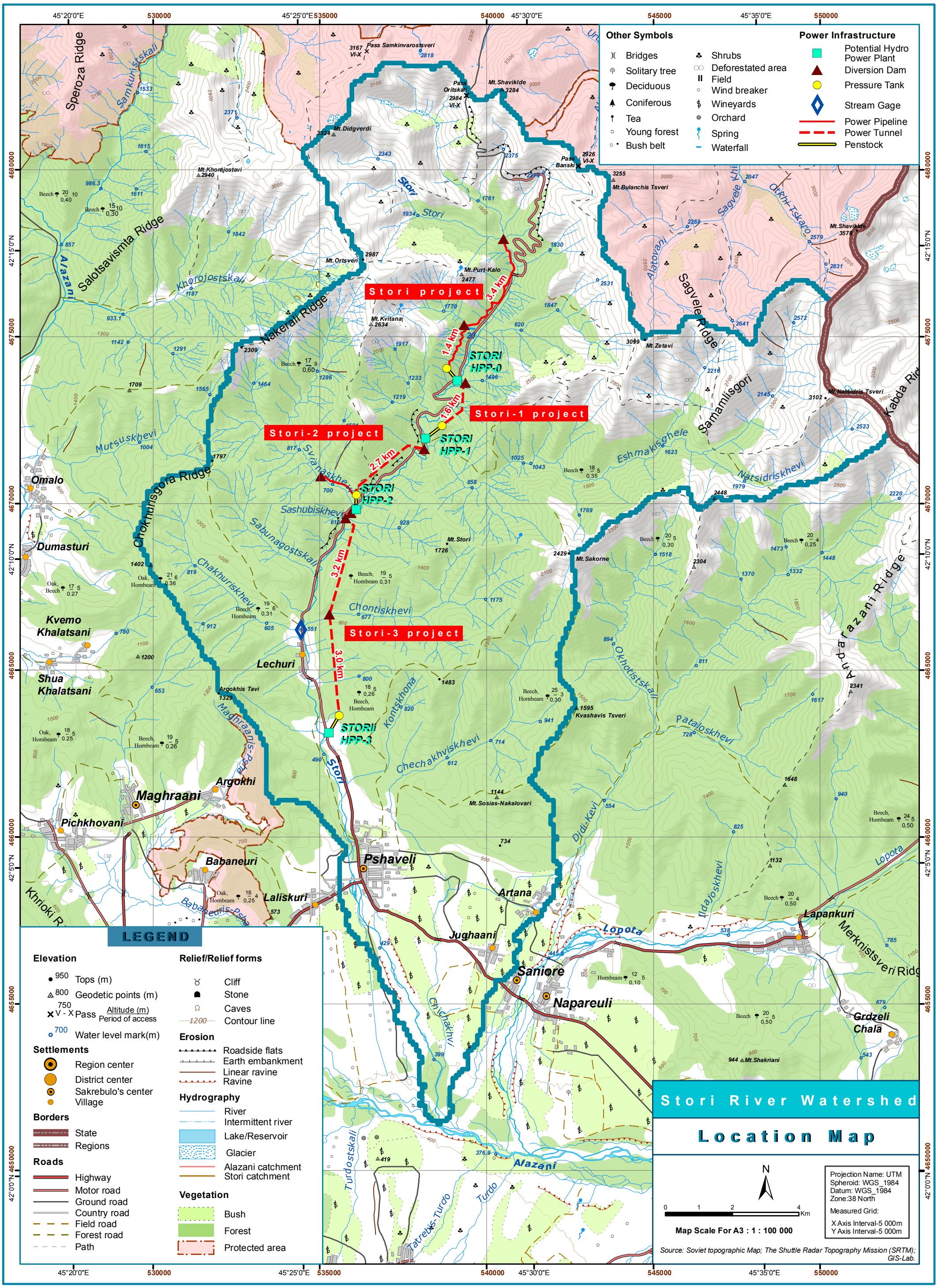


December

Area under Adjusted Flow Duration Curve in CMS-Hrs	2,712
Select Discharge equal to or exceeded % For HPP	1.50%
Equivalent Total Turbine Discharge at Selected CF in CMS	7.84
Non-useable portion of FDC at selected CF or Exceedance %	2
Gross Available CMS-HRS for Generation at selected CF	2,710
Monthly Average Daily Discharge in CMS	3.65
Select Env/Sanitary Flow as a % of Monthly Avg Daily Discharge	10%
Environmental/Sanitary Flow in CMS	0.36
Non-useable Environmental/Sanitary CMS-HRS	271
Net CMS-HRS Available for Generation	2439
Estimated Intake Elevation in Meters	623.5
Estimated Discharge Elevation in Meters	500
Gross Head for Generation in Meters	123.5
Length of Penstock/Pipeline/tunnel in Km	6
Head Loss (from daily head loss calculation average) in Meters	1.326
Net Head for Generation in Meters	122.174
Input Estimated Average Unit Efficiency in %	85%
Estimated Average Monthly Generation in kWh	2,483,316
MWh	2,483

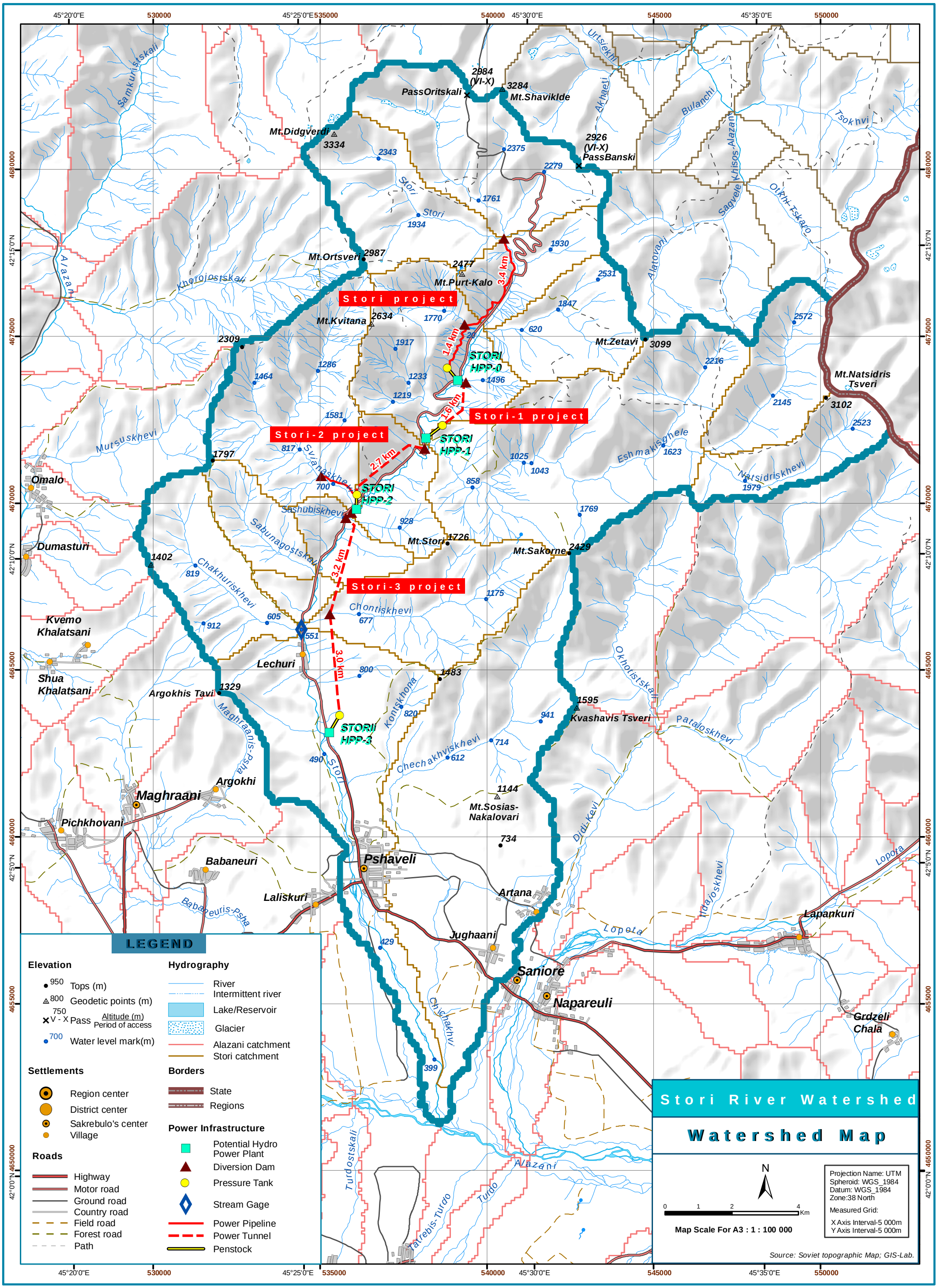
Appendix 3

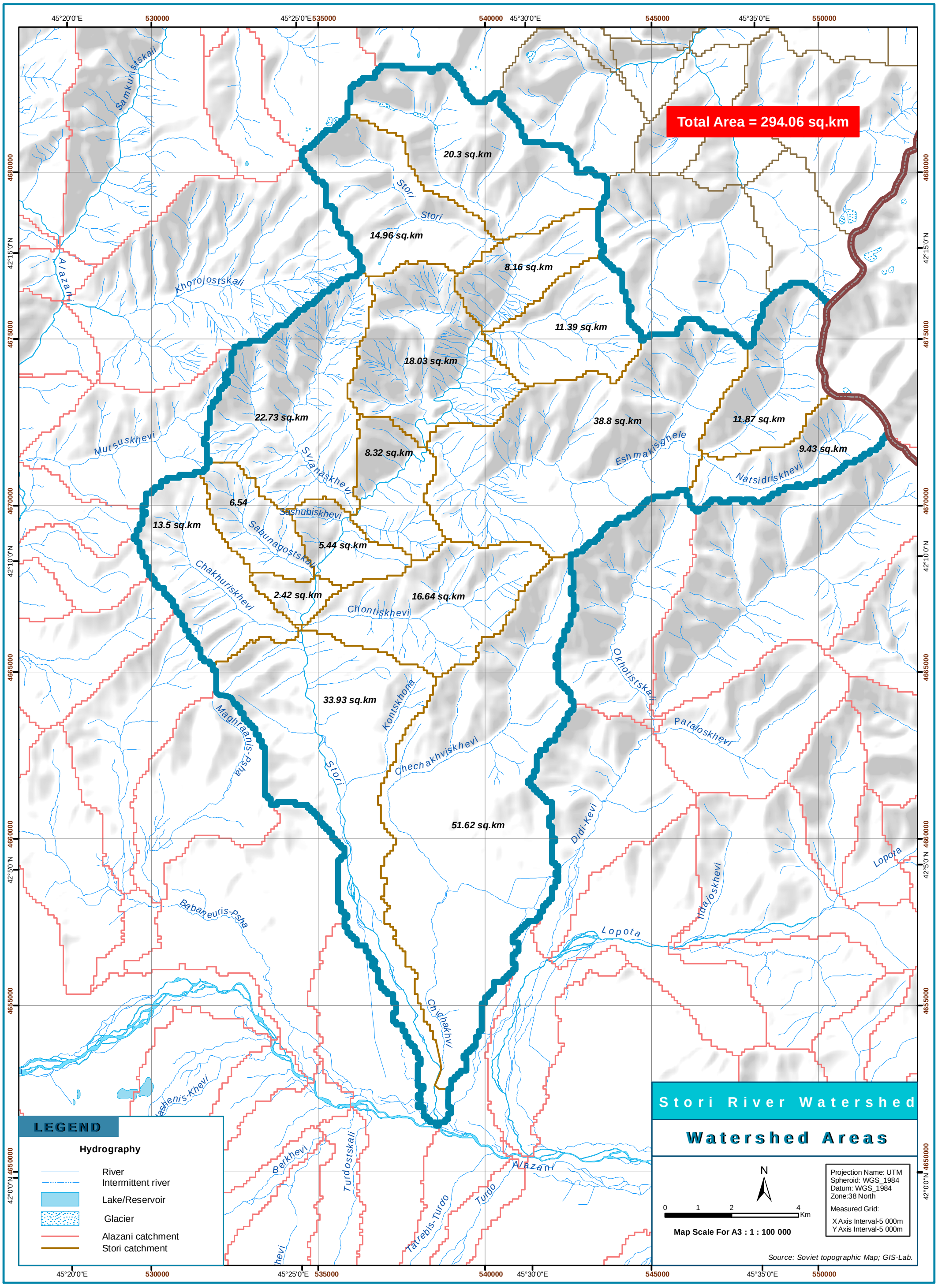
Location Map


Other Symbols
Bridges
Solitary tree
Deciduous
Coniferous
Tea
Young forest
Bush belt
Shrubs
Deforestated area
Field
Wind breaker
Wineyards
Orchard
Spring
Waterfall
Power Infrastructure
Potential Hydro Power Plant
Diversion Dam
Pressure Tank
Stream Gage
Power Pipeline
Power Tunnel
Penstock
Stori project
Stori-1 project
Stori-2 project
Stori-3 project
STORI HPP-0
STORI HPP-1
STORI HPP-2
STORI HPP-3
3.4 km
1.4 km
1.6 km
2.7 km
3.2 km
3.0 km
Omalo
Dumasturi
Kvemo Khalatsani
Shua Khalatsani
Lechuri
Maghraani
Argokhi
Pichkhovani
Babaneuri
Laliskuri
Pshaveli
Artana
Jughaani
Saniore
Napareuli
Lapankuri
Grdzeli Chala
Speroza Ridge
Salotsavismta Ridge
Nakerali Ridge
Chokhurisgora Ridge
Sagvele Ridge
Samamlisgori
Kabda Ridge
Merknistsveri Ridge
Stori River Watershed
Location Map
LEGEND
Elevation
Tops (m)
Geodetic points (m)
Pass
Water level mark(m)
Settlements
Region center
District center
Sakrebulo's center
Village
Borders
State
Regions
Roads
Highway
Motor road
Ground road
Country road
Field road
Forest road
Path
Relief/Relief forms
Cliff
Stone
Caves
Contour line
Erosion
Roadside flats
Earth embankment
Linear ravine
Ravine
Hydrography
River
Intermittent river
Lake/Reservoir
Glacier
Alazani catchment
Stori catchment
Vegetation
Bush
Forest
Protected area
N
Km
Map Scale For A3 : 1 : 100 000
Projection Name: UTM
Spheroid: WGS_1984
Datum: WGS_1984
Zone:38 North
Measured Grid:
X Axis Interval-5 000m
Y Axis Interval-5 000m
Source: Soviet topographic Map; The Shuttle Radar Topography Mission (SRTM); GIS-Lab.

Appendix 4

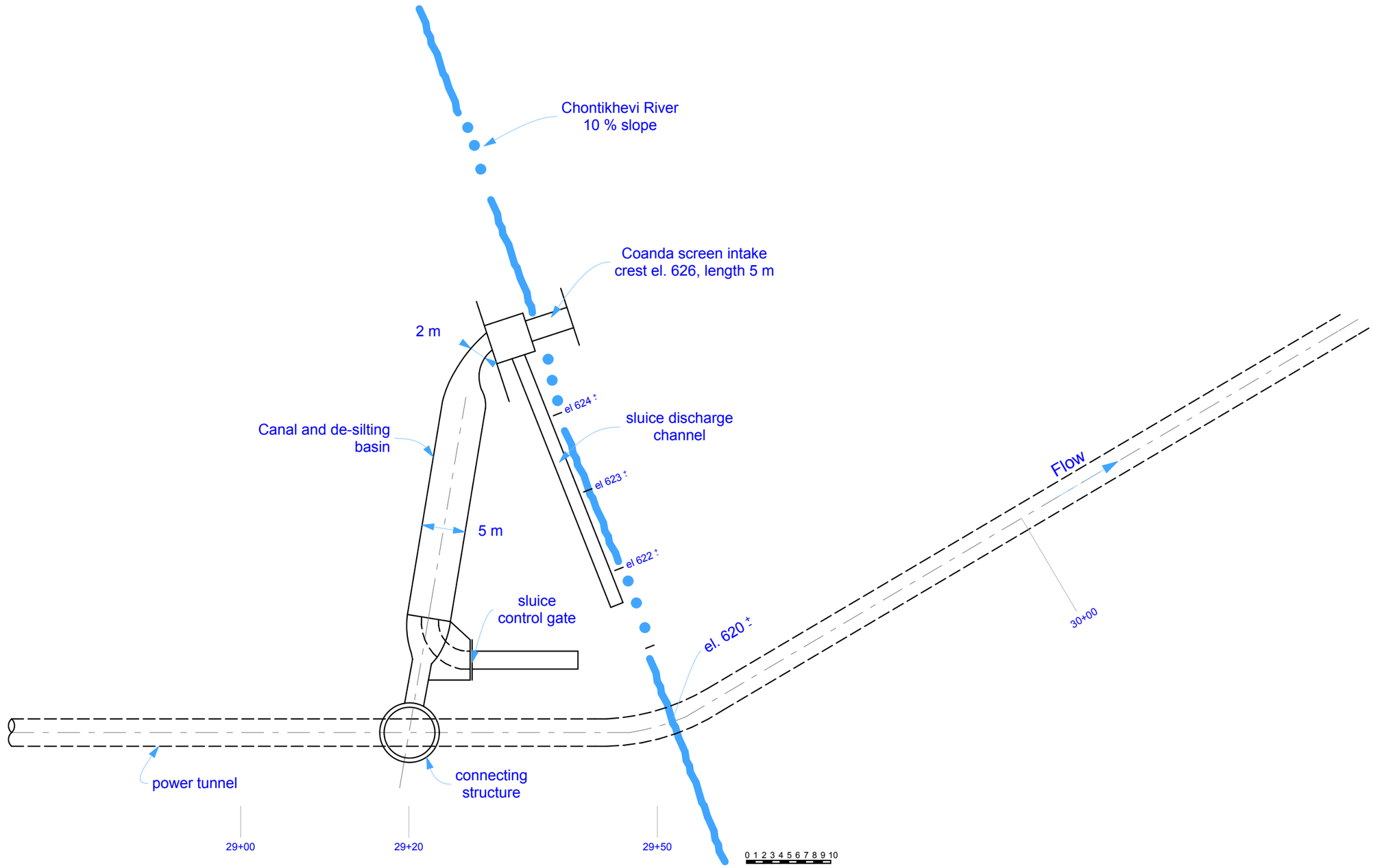
Watershed Map


Stori River Watershed
Watershed Map
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
Village
Roads
Highway
Motor road
Ground road
Country road
Field road
Forest road
Path
Hydrography
River
Intermittent river
Lake/Reservoir
Glacier
Alazani catchment
Stori catchment
Borders
State
Regions
Power Infrastructure
Potential Hydro Power Plant
Diversion Dam
Pressure Tank
Stream Gage
Power Pipeline
Power Tunnel
Penstock
Stori project
Stori-1 project
Stori-2 project
Stori-3 project
STORI HPP-0
STORI HPP-1
STORI HPP-2
STORI HPP-3
1.4 km
1.6 km
2.7 km
3.2 km
3.0 km
3.4 km
PassOritskali
Mt.ShavikIde
Mt.Didgverdi
PassBanski
Mt.Ortsveri
Mt.Purt-Kalo
Mt.Kvitana
Mt.Zetavi
Mt.Natsidris Tsveri
Mt.Stori
Mt.Sakorne
Kvashavis Tsveri
Mt.Sosias-Nakalovari
Omalo
Dumasturi
Kvemo Khalatsani
Shua Khalatsani
Lechuri
Argokhis Tavi
Maghraani
Argokhi
Pichkhovani
Babaneuri
Pshaveli
Laliskuri
Artana
Jughaani
Lapankuri
Saniore
Napareuli
Grdzeli Chala
Stori
Alazani
Lopota
Turdo
Turdostskali
Tatrebis-Turdo
Chichakhvi
Didi-Kevi
Okhotistskali
Pataloskhevi
Chechakhviskhevi
Chontiskhevi
Kontskhona
Chakhuriskhevi
Sabunagostskali
Sashubiskhevi
Svianaskhevi
Mutsuskhevi
Maghraanis-Psha
Babaneuris-Psha
Khorojostskali
Samkuristskali
Urtsekhi
Akhaeti
Bulanchi
Tsokhvi
Khisos-Alazani
Sagvele
Otkhi-Tskaro
Alatovani
Eshmakisghele
Narsidriskhevi
Idajoskhevi
2984 (VI-X)
3284
2926 (VI-X)
2343
2375
2279
1761
1934
1930
2531
1847
2572
2987
2477
2634
1770
620
2309
1917
1286
1464
1233
1496
1219
1581
2216
3099
2145
3102
2523
1623
1797
817
700
1025
1043
858
1979
1769
928
1726
2429
1402
819
1175
605
677
912
551
800
1483
1329
820
941
1595
714
612
490
1144
734
429
399


Total Area = 294.06 sq.km
20.3 sq.km
14.96 sq.km
8.16 sq.km
11.39 sq.km
18.03 sq.km
22.73 sq.km
38.8 sq.km
11.87 sq.km
9.43 sq.km
8.32 sq.km
6.54
13.5 sq.km
5.44 sq.km
2.42 sq.km
16.64 sq.km
33.93 sq.km
51.62 sq.km
Stori
Samkuristskali
Alazani
Khorojostskali
Mutsuskhevi
Svanaskhevi
Eshmakisghele
Natsidriskhevi
Sashubiskhevi
Sabunagostskali
Chakhuriskhevi
Chontiskhevi
Okhotistskali
Kontskhona
Maghraanis-psha
Pataloskhevi
Chechakhviskhevi
Didi-Kevi
Lopota
Ildajoskhevi
Babaneuris-Psha
Chiehakhvi
Berkhevi
Turdostskali
Tatrebis-Turdo
Turdo
Stori River Watershed
Watershed Areas
LEGEND
Hydrography
River
Intermittent river
Lake/Reservoir
Glacier
Alazani catchment
Stori catchment
N
0 1 2 4 Km
Map Scale For A3 : 1 : 100 000
Projection Name: UTM
Spheroid: WGS_1984
Datum: WGS_1984
Zone:38 North
Measured Grid:
X Axis Interval-5 000m
Y Axis Interval-5 000m
Source: Soviet topographic Map; GIS-Lab.
45°20'0"E
530000
45°25'0"E
535000
540000
45°30'0"E
545000
45°35'0"E
550000
4680000
42°15'0"N
4675000
4670000
42°10'0"N
4665000
4660000
42°5'0"N
4655000
4650000
42°0'0"N

Appendix 5

Site HPP Figure



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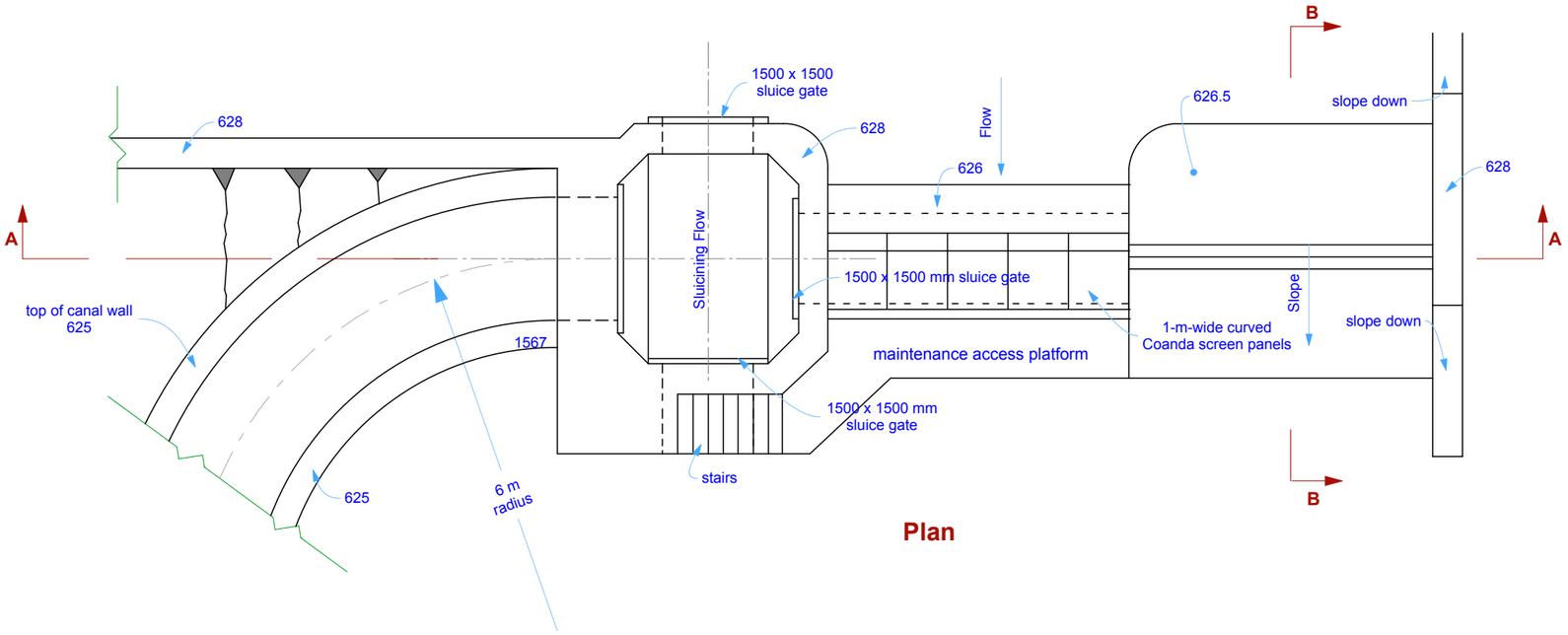
Building a world of difference.

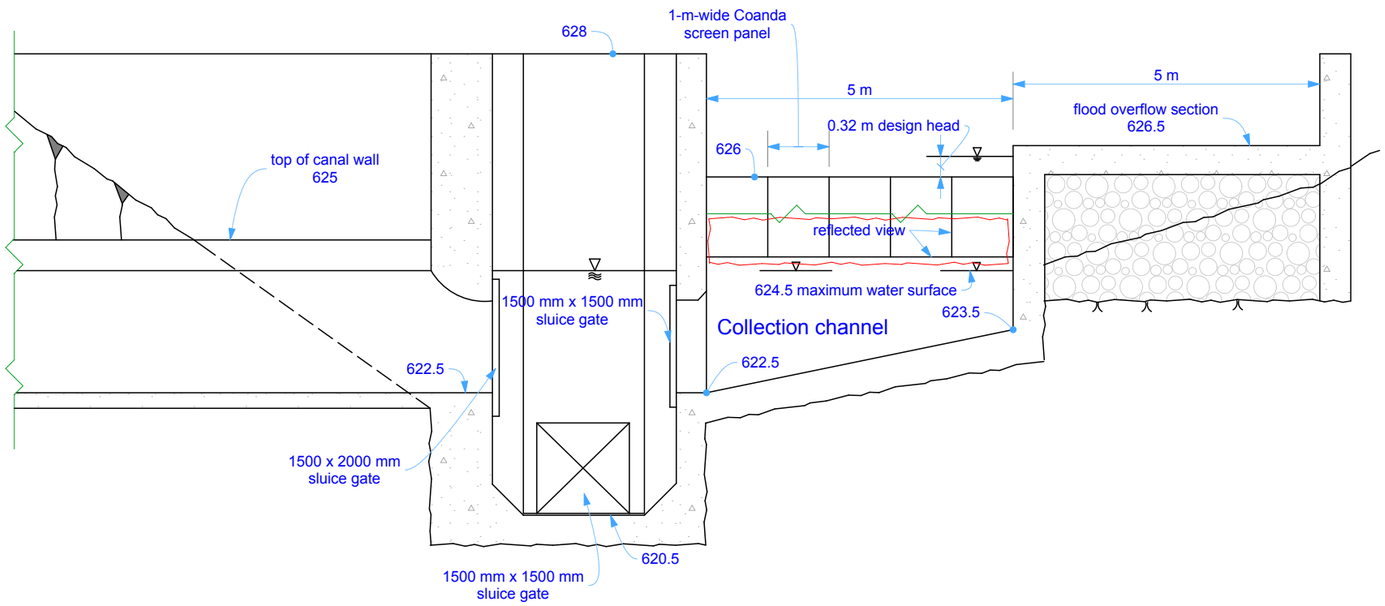
Pre-Feasibility Study
Stori 3

Chontiskhevi Diversion and Connecting Structure, Plan

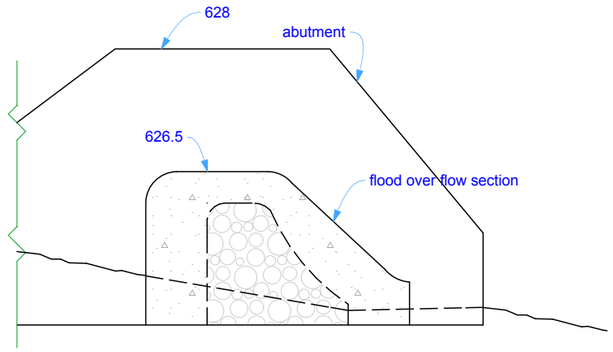
Drawing Scale	
1:500	July 2011



Plan



Section A-A



Section B-B

0 1 2 3 4 5 m

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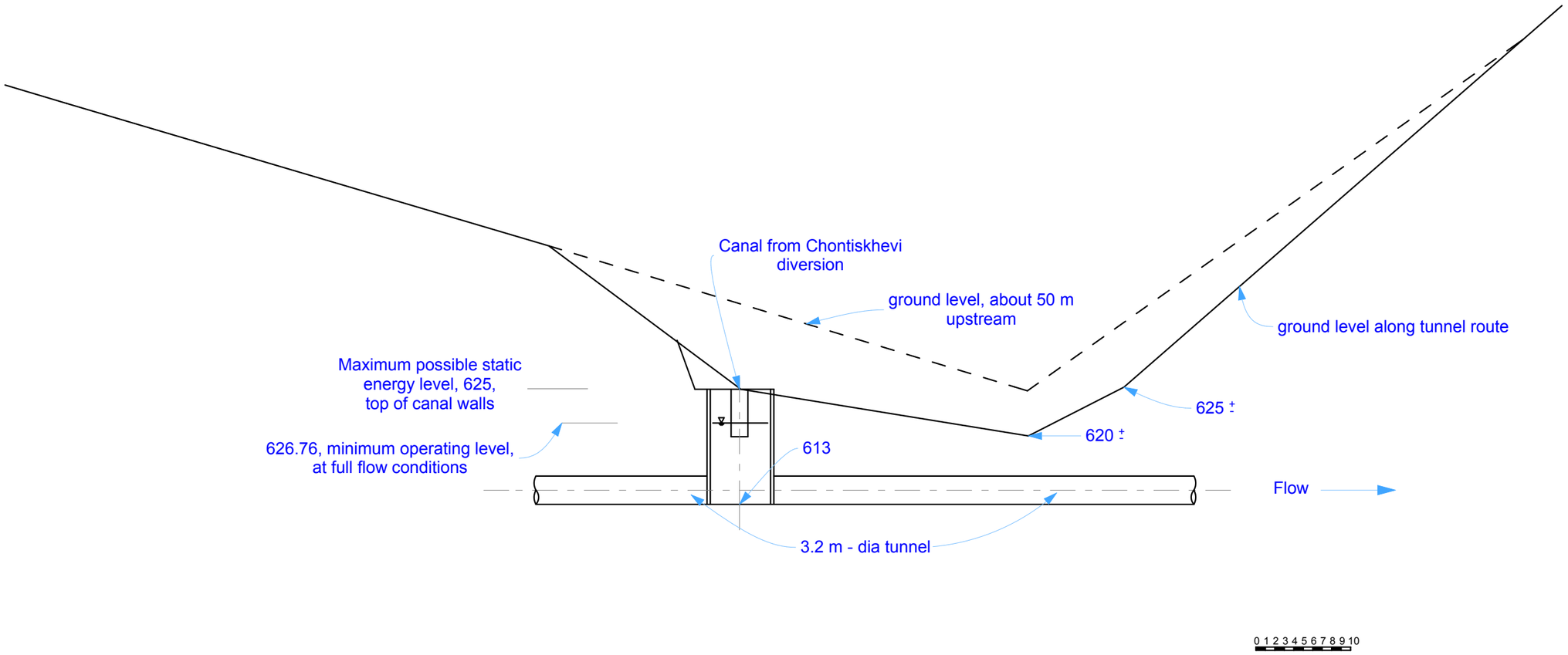
Pre-Feasibility Study
Stori 3

Chontiskhevi Diversion Plan and Sections

Drawing Scale	
1:100	**July 2011**



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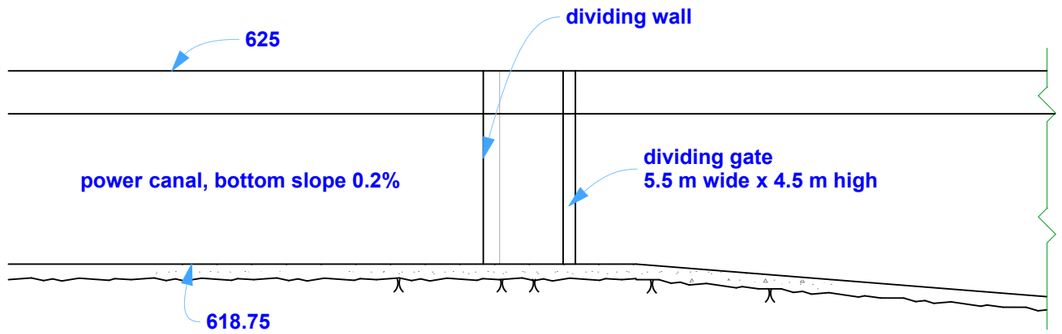
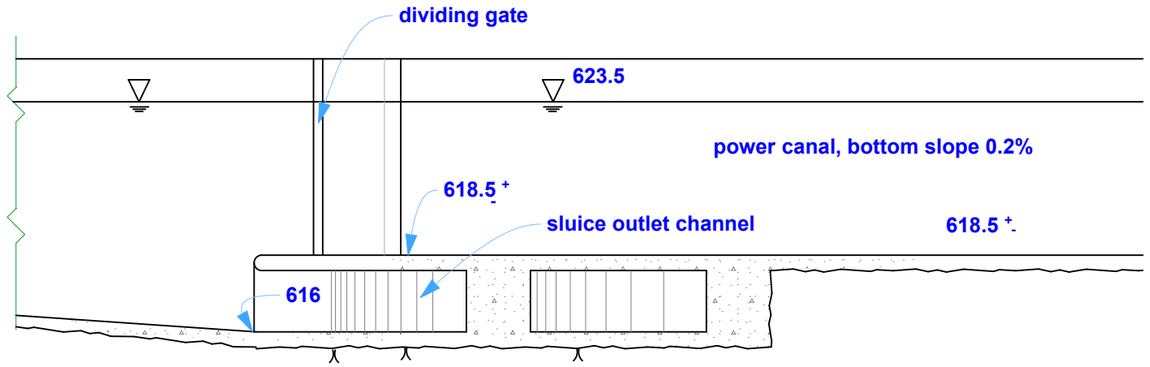
Pre-Feasibility Study
Stori 3

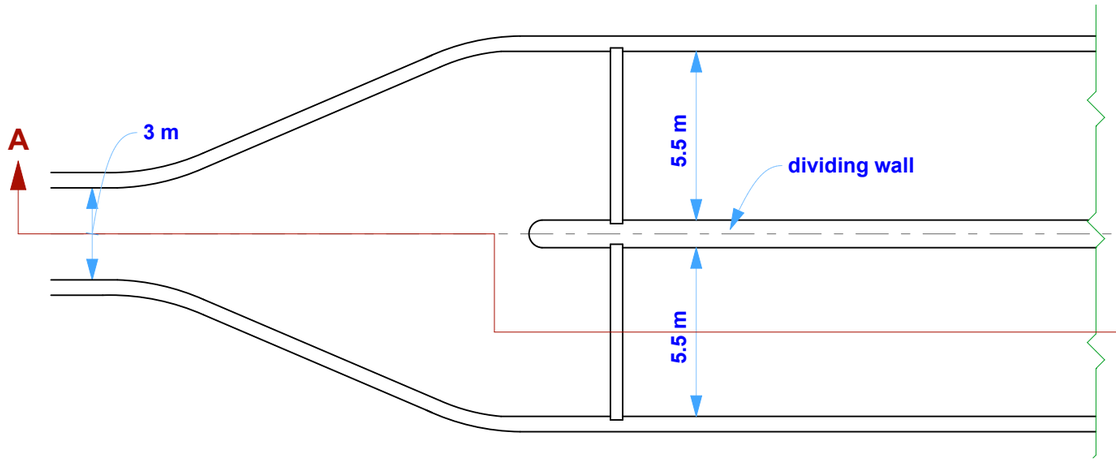
Connecting Structure and Tunnel Profile

Drawing Scale **1:500** | **July 2011**

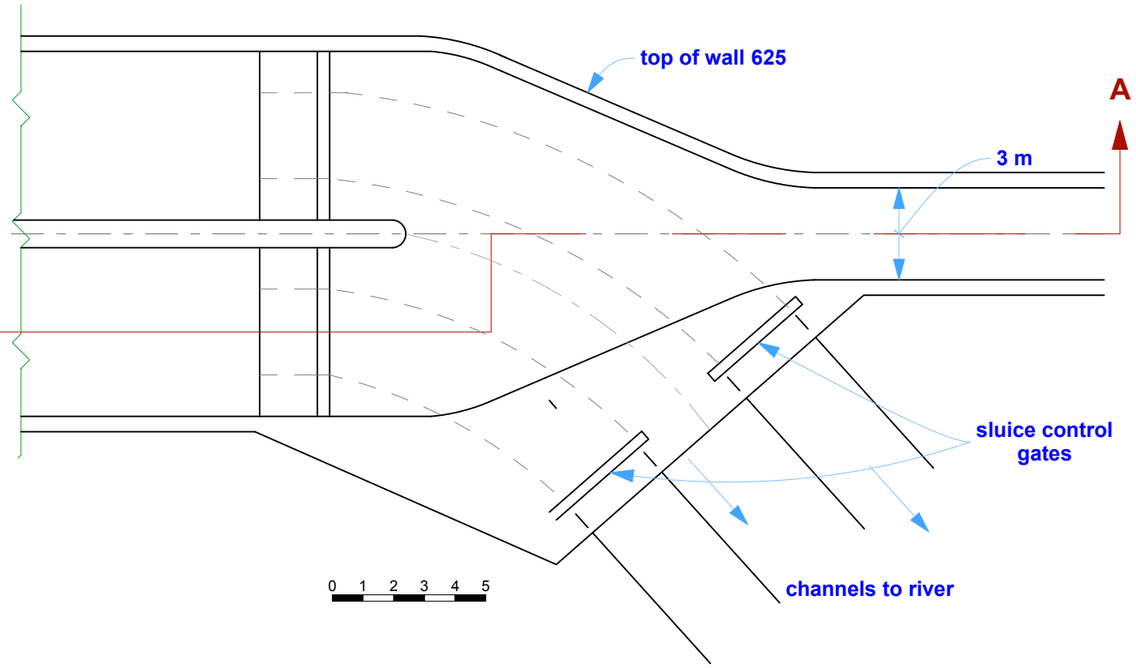


Section A-A





Plan



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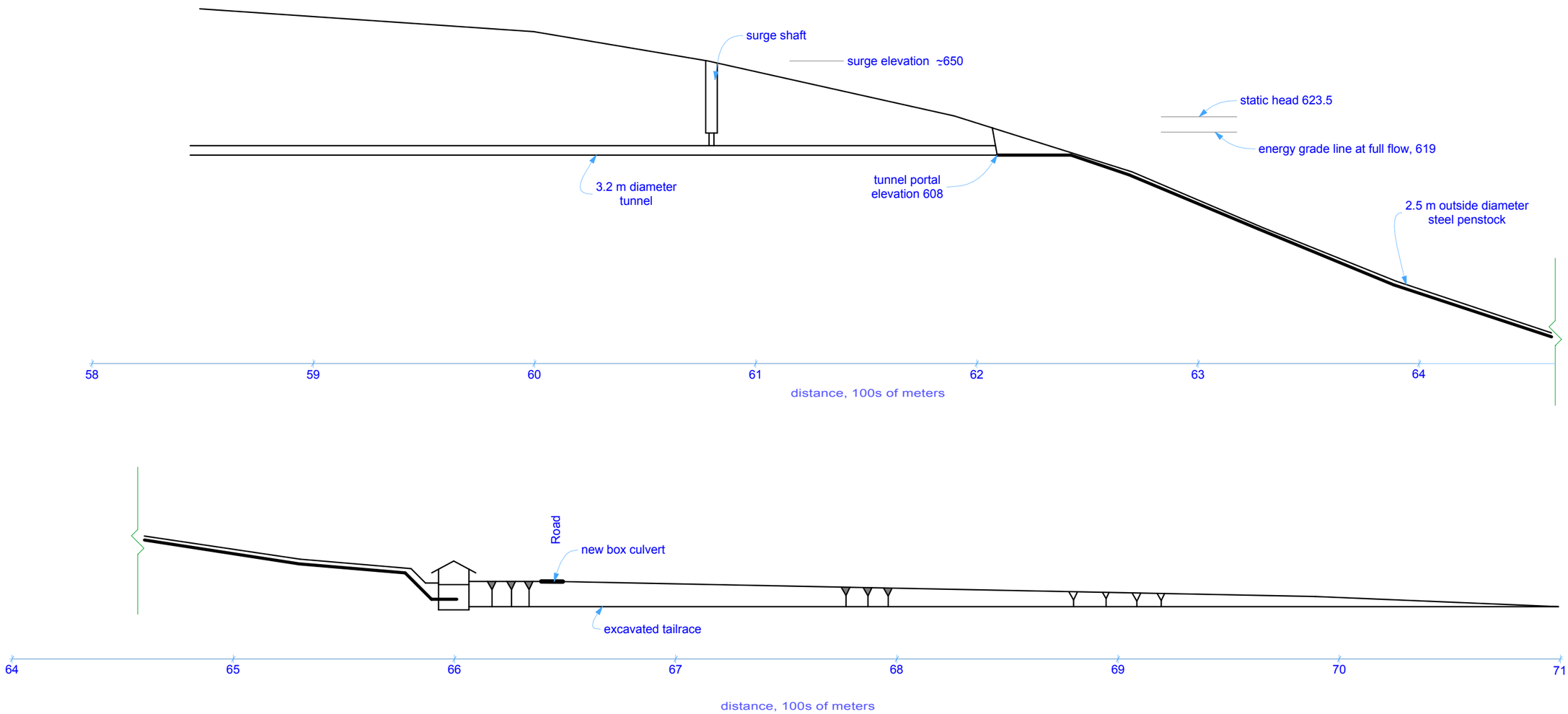
Pre-Feasibility Study
Stori 3

De-Silting Basin, Plan and Section

Drawing Scale	1:200	July 2011



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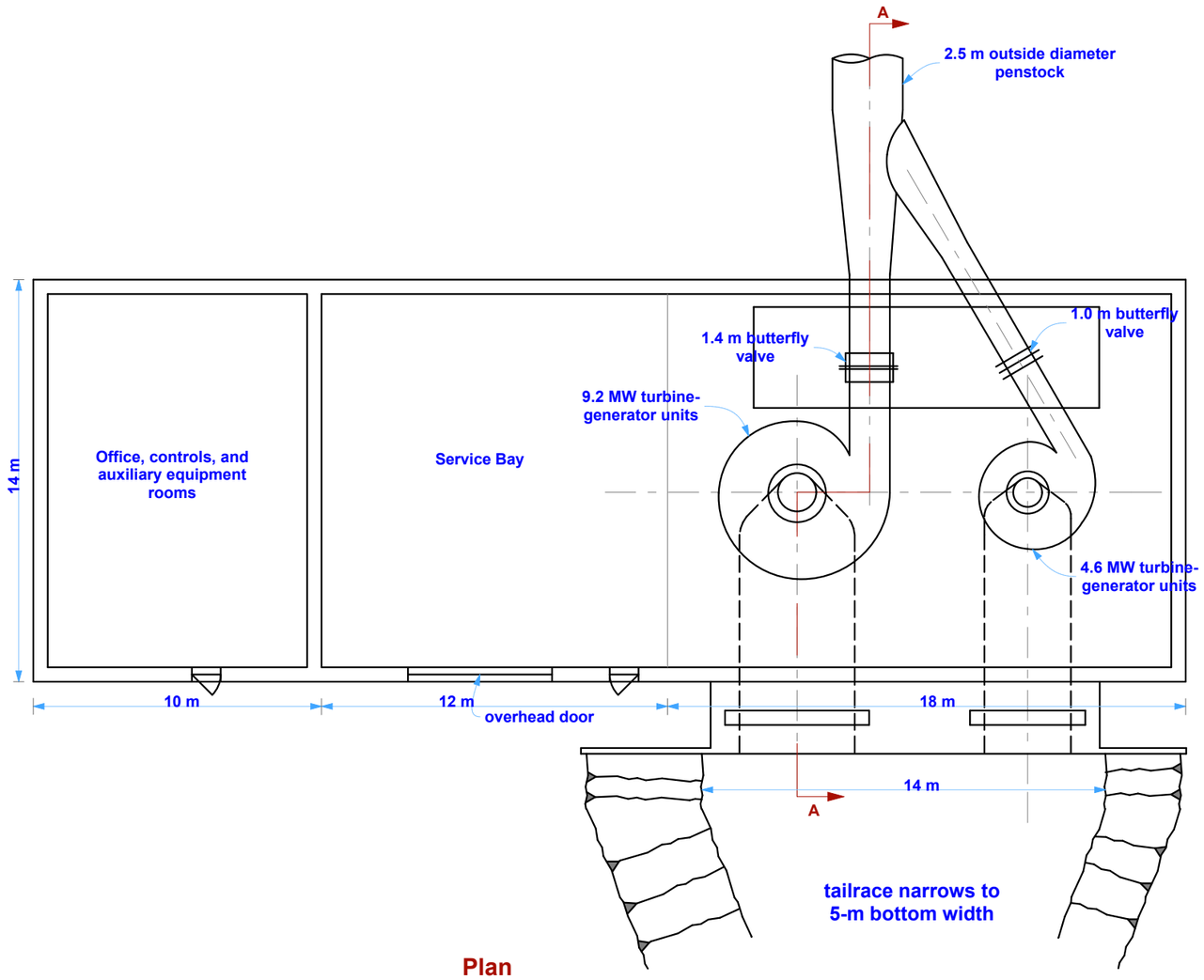
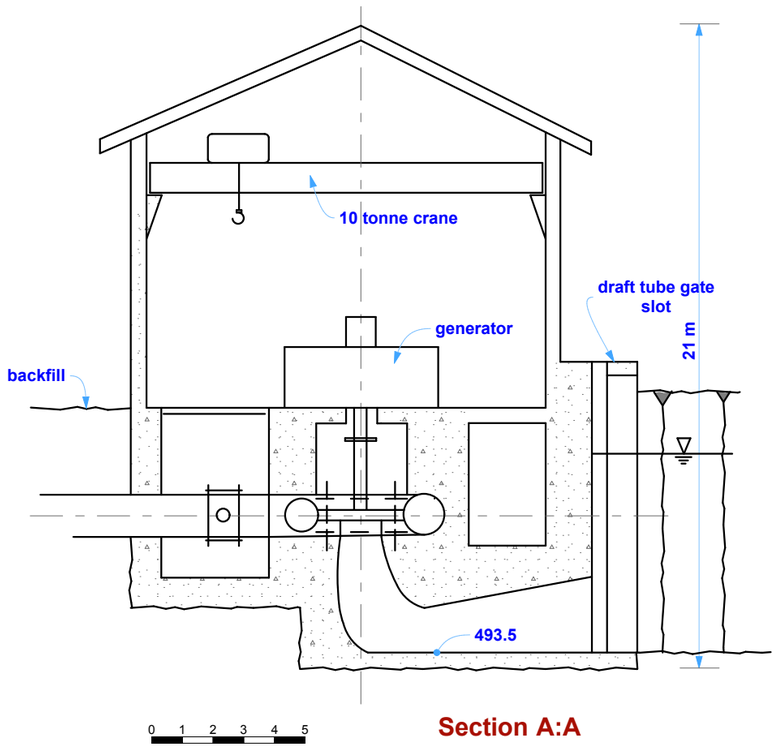
Pre-Feasibility Study
Stori 3

Powerhouse Area Profile

Drawing Scale	1:2,000	July 2011



Plan



Section A:A

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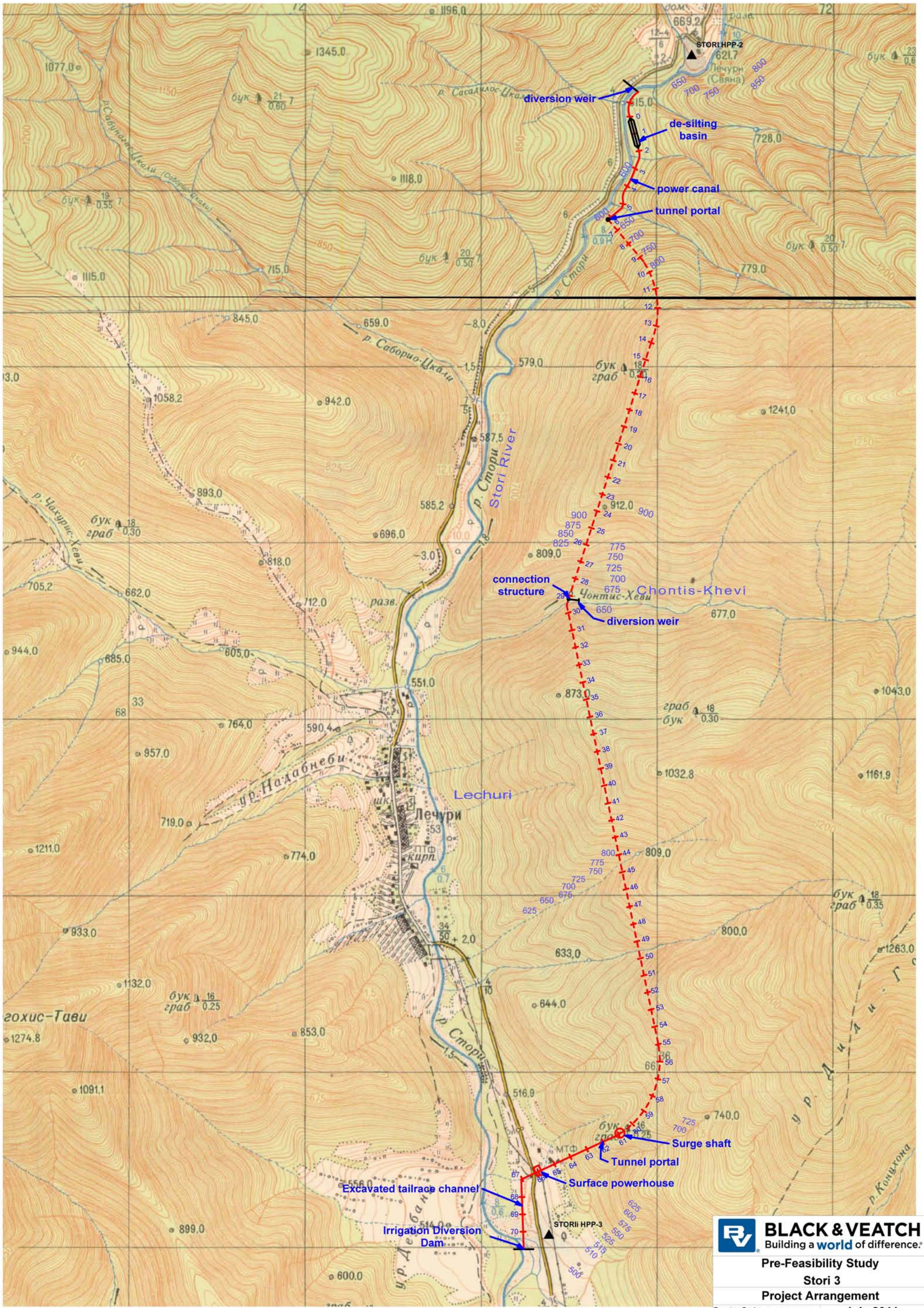
Pre-Feasibility Study
Stori 3

Powerhouse Plan and Section

Drawing Scale	1:200	July 2011



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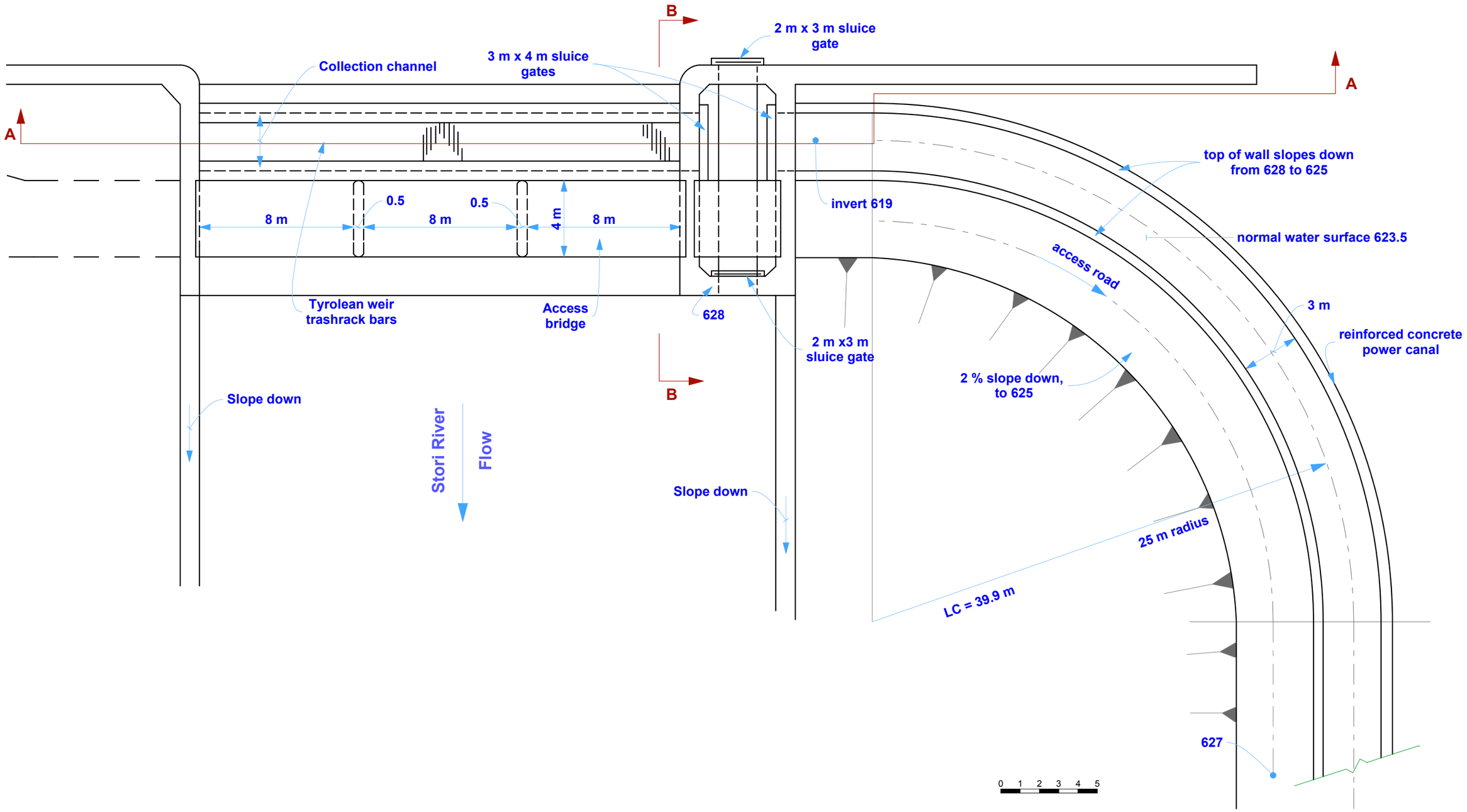
Pre-Feasibility Study
Stori 3
Project Arrangement

Drawing Scale 1:20,000 July 2011



BLACK & VEATCH
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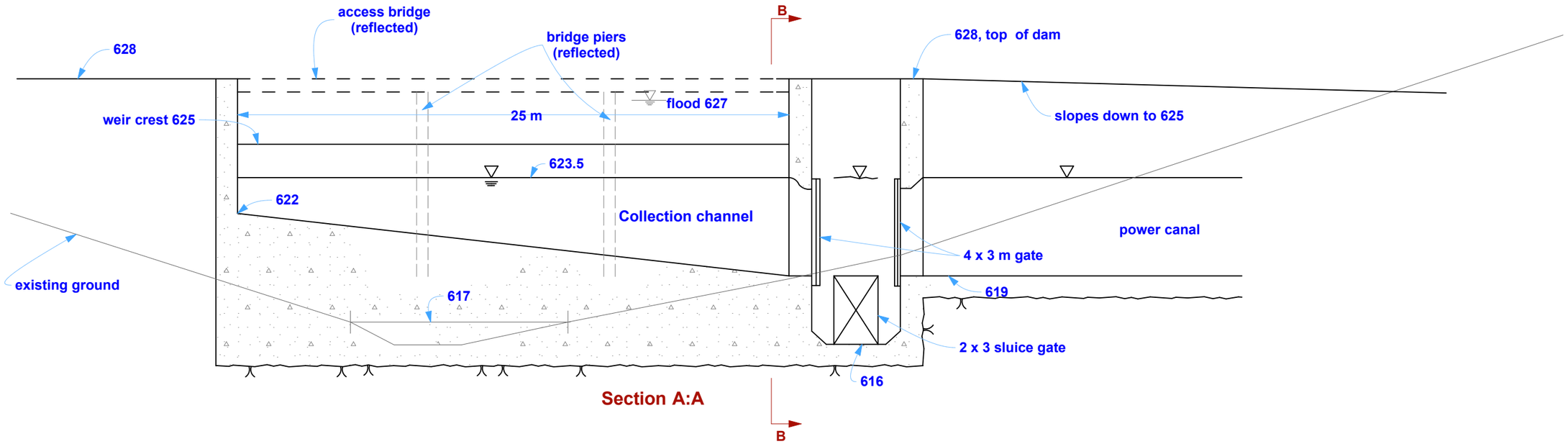
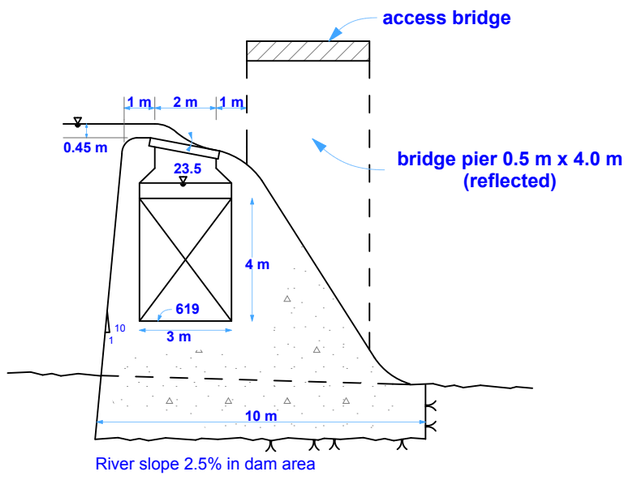
Pre-Feasibility Study
Stori 3

Stori River Diversion, Plan

Drawing Scale	1:200	July 2011



Section A:A



Section B:B

0 1 2 3 4 5

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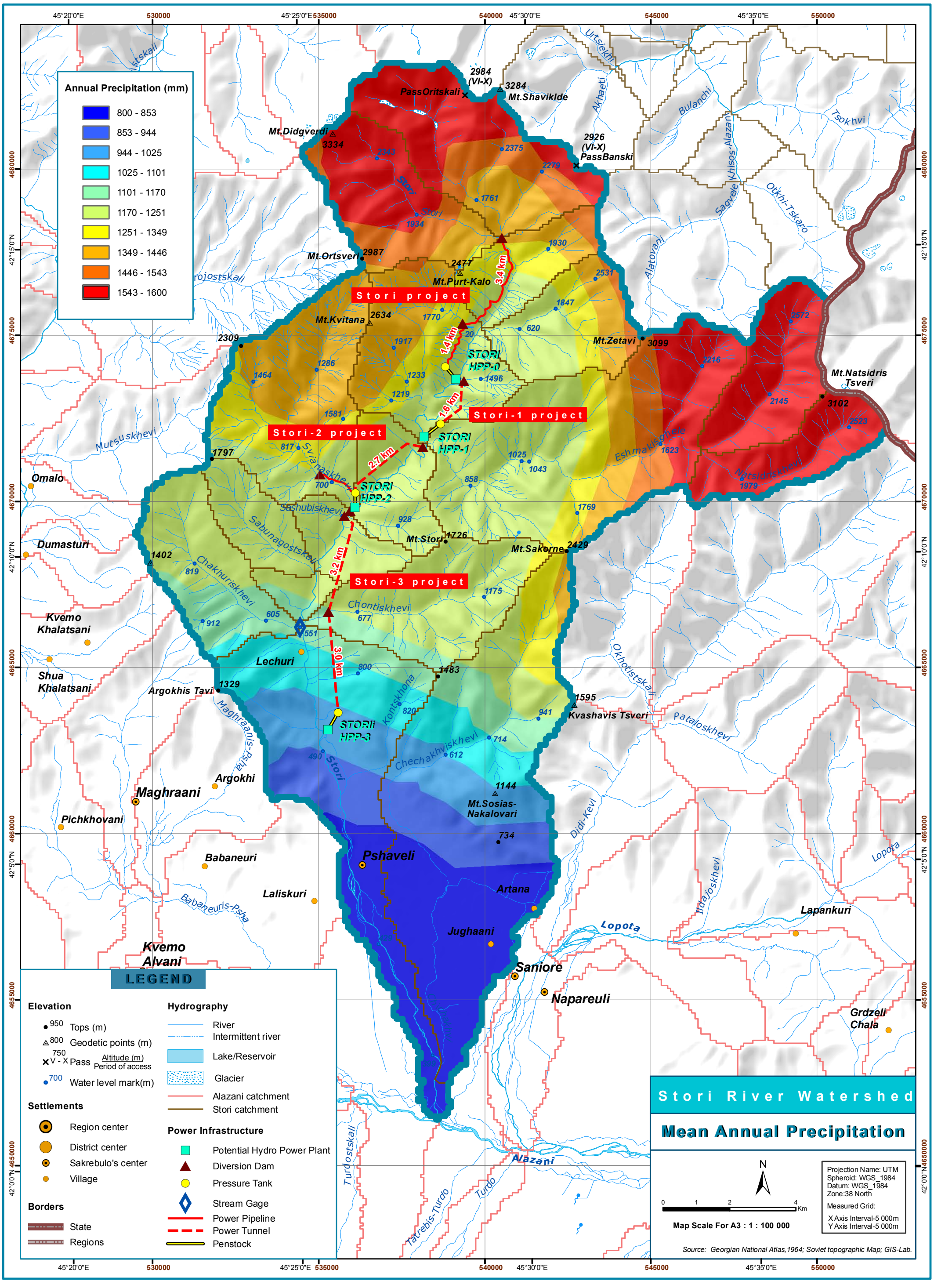
Pre-Feasibility Study
Stori 3

Stori River Diversion, Sections

Drawing Scale	1:200	July 2011

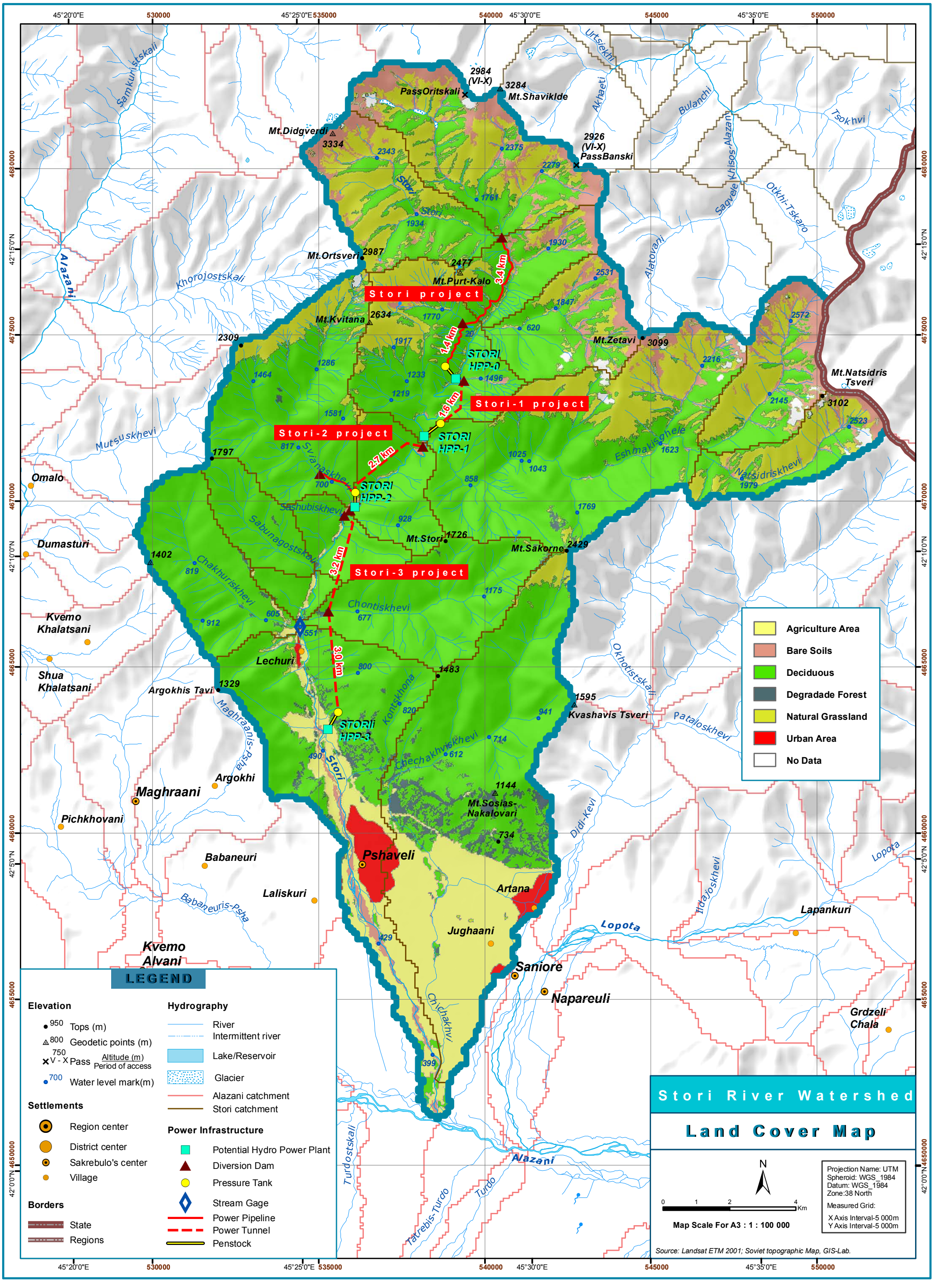
Appendix 6

Annual Precipitation Map


Annual Precipitation (mm)
800 - 853
853 - 944
944 - 1025
1025 - 1101
1101 - 1170
1170 - 1251
1251 - 1349
1349 - 1446
1446 - 1543
1543 - 1600
Stori project
Stori-1 project
Stori-2 project
Stori-3 project
STORI HPP-0
STORI HPP-1
STORI HPP-2
STORI HPP-3
1.4 km
1.6 km
2.7 km
3.2 km
3.0 km
3.4 km
PassOritskali
Mt.Shavikide
Mt.Didgverdi
PassBanski
Mt.Ortsveri
Mt.Purt-Kalo
Mt.Kvitana
Mt.Zetavi
Mt.Natsidris Tsveri
Mt.Stori
Mt.Sakorne
Argokhis Tavi
Kvashavis Tsveri
Mt.Sosias-Nakalovari
Omalo
Dumasturi
Kvemo Khalatsani
Shua Khalatsani
Lechuri
Argokhi
Maghraani
Pichkhovani
Babaneuri
Laliskuri
Kvemo Alvani
Pshaveli
Artana
Jughaani
Saniore
Napareuli
Lapankuri
Grdzeli Chala
Stori
Alazani
Lopota
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
Village
Borders
State
Regions
Hydrography
River
Intermittent river
Lake/Reservoir
Glacier
Alazani catchment
Stori catchment
Power Infrastructure
Potential Hydro Power Plant
Diversion Dam
Pressure Tank
Stream Gage
Power Pipeline
Power Tunnel
Penstock
Stori River Watershed
Mean Annual Precipitation
Map Scale For A3 : 1 : 100 000
Projection Name: UTM
Spheroid: WGS_1984
Datum: WGS_1984
Zone:38 North
Measured Grid:
X Axis Interval-5 000m
Y Axis Interval-5 000m
Source: Georgian National Atlas,1964; Soviet topographic Map; GIS-Lab.

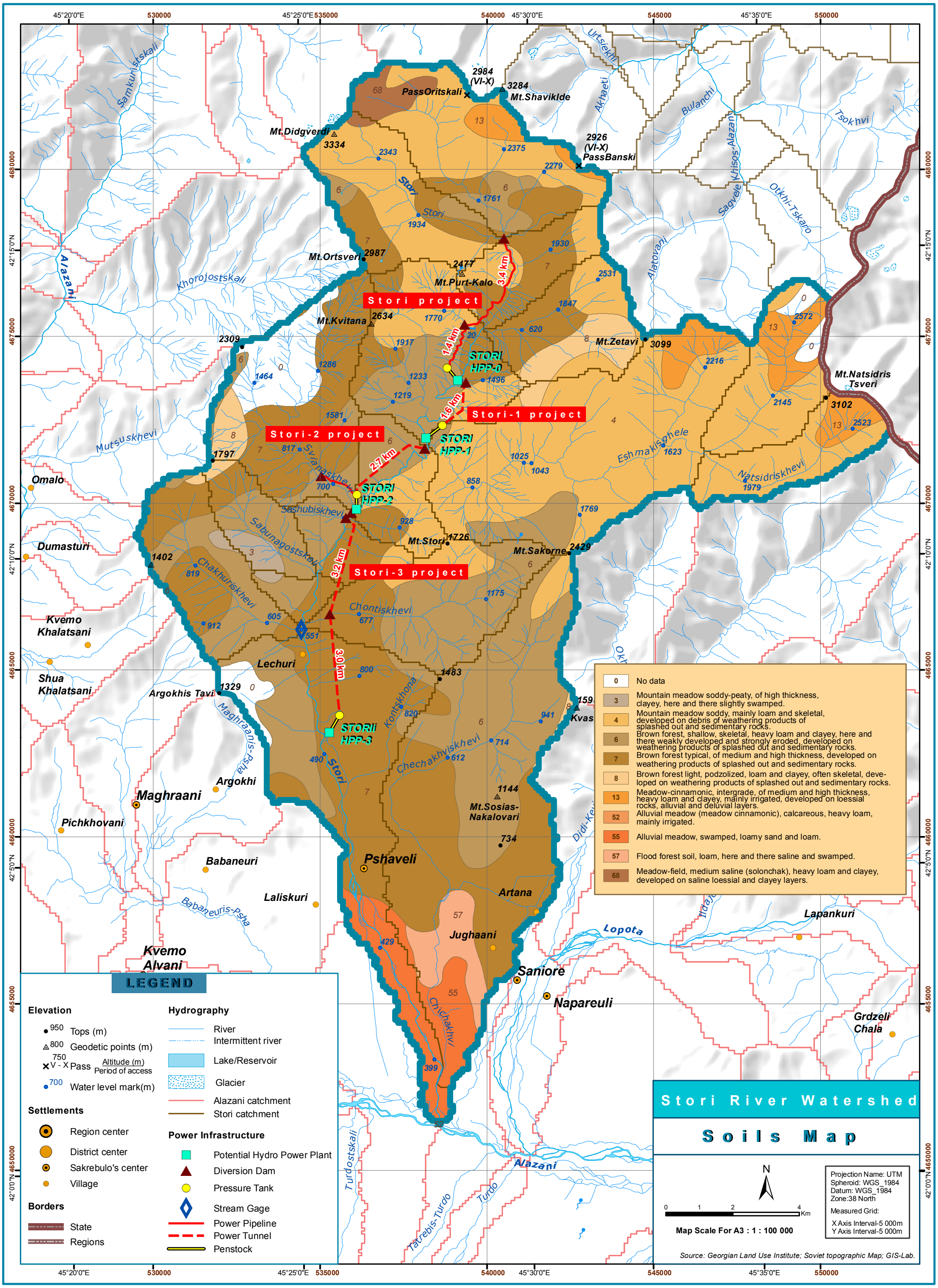
Appendix 7

Land Cover Map


Stori River Watershed
Land Cover Map
Stori project
Stori-1 project
Stori-2 project
Stori-3 project
STORI HPP-0
STORI HPP-1
STORI HPP-2
STORI HPP-3
3.4 km
1.4 km
1.6 km
2.7 km
3.2 km
3.0 km
Agriculture Area
Bare Soils
Deciduous
Degradade Forest
Natural Grassland
Urban Area
No Data
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
Village
Borders
State
Regions
Hydrography
River
Intermittent river
Lake/Reservoir
Glacier
Alazani catchment
Stori catchment
Power Infrastructure
Potential Hydro Power Plant
Diversion Dam
Pressure Tank
Stream Gage
Power Pipeline
Power Tunnel
Penstock
Projection Name: UTM
Spheroid: WGS_1984
Datum: WGS_1984
Zone:38 North
Measured Grid:
X Axis Interval-5 000m
Y Axis Interval-5 000m
Map Scale For A3 : 1 : 100 000
Source: Landsat ETM 2001; Soviet topographic Map, GIS-Lab.
Mt.Shavikide
PassOritskali
Mt.Didgverdi
PassBanski
Mt.Ortsveri
Mt.Purt-Kalo
Mt.Kvitana
Mt.Zetavi
Mt.Natsidris Tsveri
Mt.Stori
Mt.Sakorne
Mt.Sosias-Nakalovari
Omalo
Dumasturi
Kvemo Khalatsani
Shua Khalatsani
Argokhis Tavi
Lechuri
Kvashavis Tsveri
Maghraani
Argokhi
Pichkhovani
Babaneuri
Laliskuri
Pshaveli
Artana
Jughaani
Lapankuri
Kvemo Alvani
Saniore
Napareuli
Grdzeli Chala
Alazani
Lopota
Stori
Samkuristskali
Urtsiekhi
Akhaeti
Bulanchi
Tsokhvi
Khisos-Alazani
Sagvele
Otkhi-Tskalo
Alatovani
Khorojostskali
Mutsuskhevi
Svianaskhevi
Sashubiskhevi
Sabunagostskali
Chakhuriskhevi
Chontiskhevi
Kontskhona
Chechakhviskhevi
Maghraanis-psha
Okhotistskali
Pataloskhevi
Didi-Kevi
Tidajoskhevi
Eshmakighele
Natsidriskhevi
Babaneuris-Psha
Chichakhvi
Turdostskali
Tatrebis-Turdo
Turdo
45°20'0"E
530000
45°25'0"E
535000
540000
45°30'0"E
545000
45°35'0"E
550000
4680000
4675000
4670000
4665000
4660000
4655000
4650000
42°15'0"N
42°10'0"N
42°5'0"N
42°0'0"N

Appendix 8

Soils Map

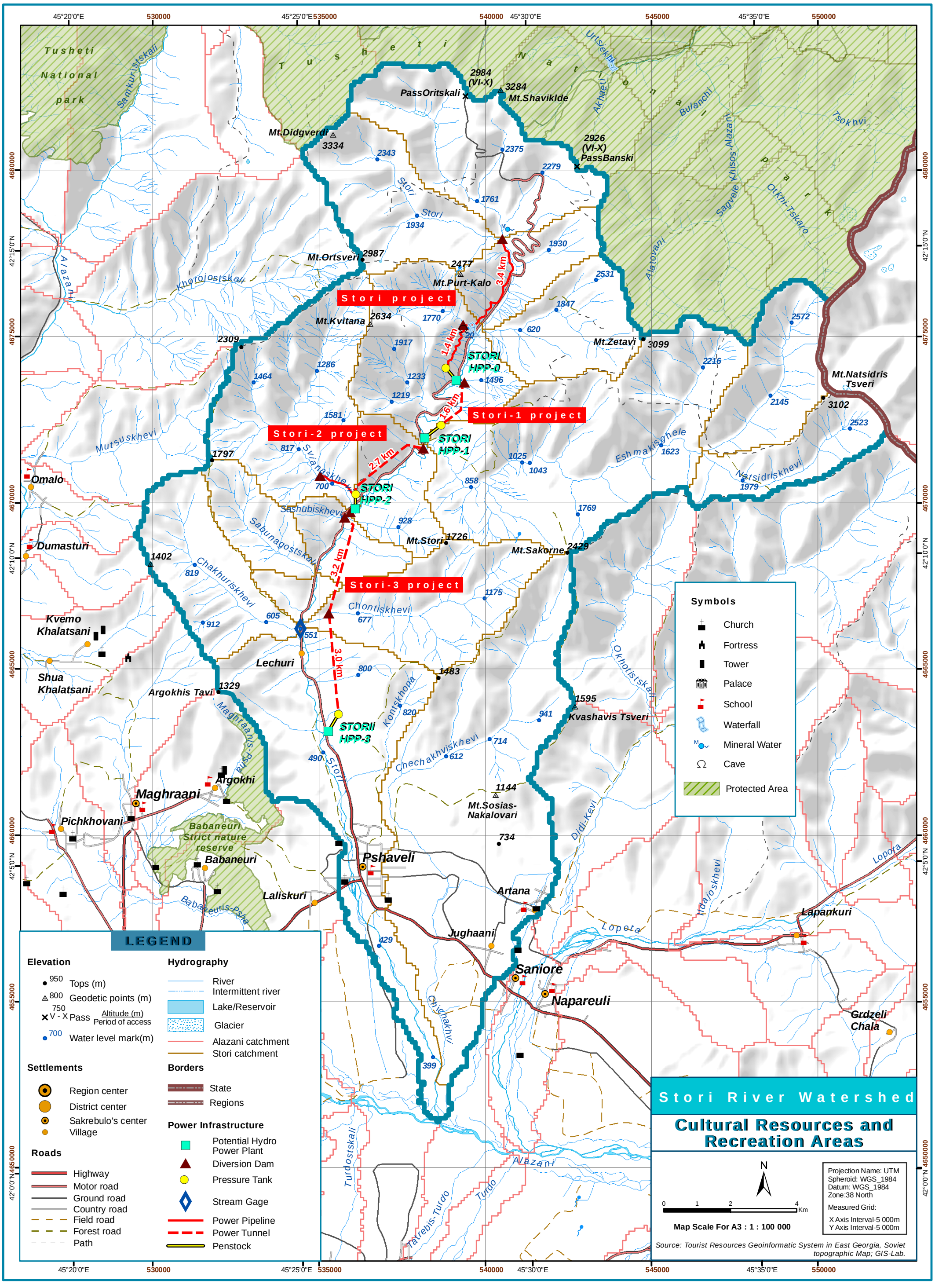

Stori project
Stori-1 project
Stori-2 project
Stori-3 project
STORI HPP-0
STORI HPP-1
STORI HPP-2
STORIi HPP-3
1.4 km
1.6 km
2.7 km
3.2 km
3.0 km
3.4 km
PassOritskali
Mt.Shavikide
Mt.Didgverdi
PassBanski
Mt.Ortsveri
Mt.Purt-Kalo
Mt.Kvitana
Mt.Zetavi
Mt.Natsidris Tsveri
Mt.Stori
Mt.Sakorne
Mt.Sosias-Nakalovari
Omalo
Dumasturi
Kvemo Khalatsani
Shua Khalatsani
Lechuri
Argokhis Tavi
Kvas
Argokhi
Maghraani
Pichkhovani
Babaneuri
Laliskuri
Pshaveli
Artana
Jughaani
Saniore
Napareuli
Lapankuri
Grdzeli Chala
Kvemo Alvani
Stori
Alazani
Lopota
Samkurtskali
Urtsekhi
Akhaeti
Bulanchi
Tsokhvi
Khisos-Alazani
Sagvele
Otkhi-Tskalo
Alatovani
Khorojostskali
Mutsuskhevi
Svanaskhevi
Sashubiskhevi
Sabunagostskali
Chakhuriskhevi
Chontiskhevi
Kontskhona
Chechakhviskhevi
Maghraanis-Psha
Babaneuris-Psha
Eshmakisghele
Natsidriskhevi
Chichakhvi
Turdostskali
Tatrebis-Turdo
Turdo
Djidi-Kevi
Ildaji
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
Village
Borders
State
Regions
Hydrography
River
Intermittent river
Lake/Reservoir
Glacier
Alazani catchment
Stori catchment
Power Infrastructure
Potential Hydro Power Plant
Diversion Dam
Pressure Tank
Stream Gage
Power Pipeline
Power Tunnel
Penstock
0 No data
3 Mountain meadow soddy-peaty, of high thickness, clayey, here and there slightly swamped.
4 Mountain meadow soddy, mainly loam and skeletal, developed on debris of weathering products of splashed out and sedimentary 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.
13 Meadow-cinnamonic, intergrade, of medium and high thickness, heavy loam and clayey, mainly irrigated, developed on loessial rocks, alluvial and deluvial layers.
52 Alluvial meadow (meadow cinnamonic), calcareous, heavy loam, mainly irrigated.
55 Alluvial meadow, swamped, loamy sand and loam.
57 Flood forest soil, loam, here and there saline and swamped.
68 Meadow-field, medium saline (solonchak), heavy loam and clayey, developed on saline loessial and clayey layers.
Stori River Watershed
Soils Map
N
0 1 2 4 Km
Map Scale For A3 : 1 : 100 000
Projection Name: UTM
Spheroid: WGS_1984
Datum: WGS_1984
Zone:38 North
Measured Grid:
X Axis Interval-5 000m
Y Axis Interval-5 000m
Source: Georgian Land Use Institute; Soviet topographic Map; GIS-Lab.

Appendix 9

Cultural Resources & Recreation Areas

Historical, cultural and archeological resources of the Telavi municipality

#	Name	Location	Dated
1	Akura Monastery	Village Akuri	IX century
2	Gvtismshobeli Church	Village Kiskiskhevi	VI-VII century
3	Ikalto Monastery	Village Ikalto	VI century
4	Shuamta Monastery	Village Shuamta	XVI century
5	Old Shuamta Monastery	Village Shuamta	V-VII
6	Napareuli Church	Village Napareuli	


Stori River Watershed
Cultural Resources and Recreation Areas
Stori project
Stori-1 project
Stori-2 project
Stori-3 project
STORI HPP-0
STORI HPP-1
STORI HPP-2
STORI HPP-3
Tusheti National park
Tushetian Nature Park
Alazani Nature Park
Babaneuri Strict nature reserve
Mt.Didgverdi 3334
Mt.Shavikide 3284
PassOritskali 2984 (VI-X)
PassBanski 2926 (VI-X)
Mt.Ortsveri 2987
Mt.Purt-Kalo 2477
Mt.Kvitana 2634
Mt.Zetavi 3099
Mt.Natsidris Tsveri 3102
Mt.Stori 1726
Mt.Sakorne 2429
Mt.Sosias-Nakalovari 1144
Kvashavis Tsveri 1595
Omalo
Dumasturi
Kvemo Khalatsani
Shua Khalatsani
Argokhis Tavi 1329
Lechuri
Maghraani
Argokhi
Pichkhovani
Babaneuri
Laliskuri
Pshaveli
Artana
Jughaani
Saniore
Napareuli
Lapankuri
Grdzeli Chala
Symbols
Church
Fortress
Tower
Palace
School
Waterfall
Mineral Water
Cave
Protected Area
LEGEND
Elevation
Tops (m)
Geodetic points (m)
Pass
Water level mark(m)
Settlements
Region center
District center
Sakrebulo's center
Village
Roads
Highway
Motor road
Ground road
Country road
Field road
Forest road
Path
Hydrography
River
Intermittent river
Lake/Reservoir
Glacier
Alazani catchment
Stori catchment
Borders
State
Regions
Power Infrastructure
Potential Hydro Power Plant
Diversion Dam
Pressure Tank
Stream Gage
Power Pipeline
Power Tunnel
Penstock
Projection Name: UTM
Spheroid: WGS_1984
Datum: WGS_1984
Zone:38 North
Measured Grid:
X Axis Interval-5 000m
Y Axis Interval-5 000m
Map Scale For A3 : 1 : 100 000
Source: Tourist Resources Geoinformatic System in East Georgia, Soviet topographic Map; GIS-Lab.

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 Stori River basin. 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, and/or 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 ----------	**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 • Construction of the dam will create a small permanent reservoir changing natural river conditions. ----------	SH SH SH LG ----------	VL/R/T VL/R/T L/IR/P ----------	Very high sediment and bed load transport by upper Stori 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. ----------
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.
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	SH SH	VL/R/T VL/R/T	Very high sediment and bed load transport by upper Stori 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

---------- M/L	• Temporary Diversion of River away from Dam and intake structure ---------- **Operation Phase:** effects on surface water resources during facility operations	---------- LG	---------- L/R/T	controls and spill prevention plans and monitoring are included during construction. ---------- 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 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. Early Warning Monitoring to include Weather and

---------- H/L	---------- **Operation Phase:** Minimize increasing the impacts from this natural occurrence from HPP operations	---------- SH	---------- L/R/T	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** ----------	**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.
L/L				

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 in-stream 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 _____ L/H	**Construction Phase HPP and Transmission Facility)**: Based on available information, only a closed archaeological site in the vicinity of construction area is ruins of Abano castle. Construction activities (e.g. blasting) could cause negative impact on the cultural/archaeological resources in the vicinity of construction area. Archaeological objects should be protected from damage. ---------- **Operation Phase:** No damage on archaeological/cultural resources is expected from operational phase. Small reservoir behind dam may provide new opportunities for recreational activities	VSH ---------- VSH	H/IR/T ---------- VL/R/P	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 ---------- 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 in-stream 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

TURBNPRO Version 3 - PELTON TURBINE SOLUTION SUMMARY

Solution File Name: No File Name

TURBINE SIZING CRITERIA

Rated Discharge:	236.6	cfs	/	6.70	m3/s
Net Head at Rated Discharge:	390.4	feet	/	119.0	meters
Gross Head:	405.2	feet	/	123.5	meters
Efficiency Priority:			5		
System Frequency:			50 Hz		
Minimum Net Head:	390.4	feet	/	119.0	meters
Maximum Net Head:	398.3	feet	/	121.4	meters

PELTON TURBINE SOLUTION DATA

Arrangement:	HORIZONTAL WITH RUNNER ON TURBINE SHAFT				
Intake Type:	2 - JET				
Runner Pitch Diameter:	115.1	inches	/	2922	mm
Unit Speed:	150.0	rpm			
Multiplier Efficiency Modifier:	1.000				
Flow Squared Efficiency Modifier:	0.0000				

Specific Speed at Rated Net Head (turbine) -	(US Cust.)	(SI Units)
At 100% Turbine Output:	8.4	31.9
At Peak Efficiency Condition:	7.6	29.1

Specific Speed at Rated Net Head (per jet) -	(US Cust.)	(SI Units)
At 100% Turbine Output:	5.9	22.6
At Peak Efficiency Condition:	5.4	20.6

SOLUTION PERFORMANCE DATA

At Rated Net Head of: 390.4 feet / 119.0 meters

% of Rated Discharge	Output (KW)	Efficiency (%)	cfs	m3/s
** 116.6	8092	88.7	276.0	7.82
100	6985	89.3	236.6	6.70
* 83.3	5831	89.5	197.1	5.58
75	7004	89.9	177.4	5.03
50	4608	88.7	118.3	3.35
25	2235	87.3	59.1	1.68

** - Overcapacity

* - Peak Efficiency Condition

At Maximum Net Head of: 398.3 feet / 121.4 meters

Max. Output (KW)	Efficiency (%)	cfs	m3/s
8336	88.7	278.7	7.89

At Minimum Net Head of: 390.4 feet / 119.0 meters

Max. Output (KW)	Efficiency (%)	cfs	m3/s
8094	88.7	276.0	7.82

Solution File Name: No File Name

MISCELLANEOUS DATA

Maximum Runaway Speed (at Max. Net Head):	264 rpm		
D/B Ratio (Runner Pitch Dia./Bucket Width):	2.81		
Maximum Hydraulic Thrust (at Max. Net Head):	33018 lbs	/	15008 kg
Hydraulic Thrust per Jet (at Max. Net Head):	19309 lbs	/	8777 kg
Estimated Axial Hydraulic Thrust:	3632 lbs	/	1651 kg
Approximate Runner and Shaft Weight:	81559 lbs	/	37072 kg

DIMENSIONAL DATA

Intake Type: 2 - JET

	inches	/	mm
Inlet Diameter:	47.8		1213
Nozzle Diameter:	40.0		1015
Jet Orifice Diameter:	12.8		324
Needle Stroke:	12.1		308
Centerline to Inlet:	494.7		12565
Jet to Jet Included Angle:	70 to 90		Degrees

Housing/Discharge Geometry:

	inches	/	mm
Centerline to Housing Top:	83.9		2130
Housing Width:	167.7		4259
Discharge Width:	167.7		4259
Tailwater Depth:	41.3		1049
Discharge Ceiling to T.W.:	69.0		1753
Centerline to Tailwater:	228.8		5811
Downstream Length:	184.1		4675

Shafting Arrangement: HORIZONTAL WITH RUNNER ON TURBINE SHAFT

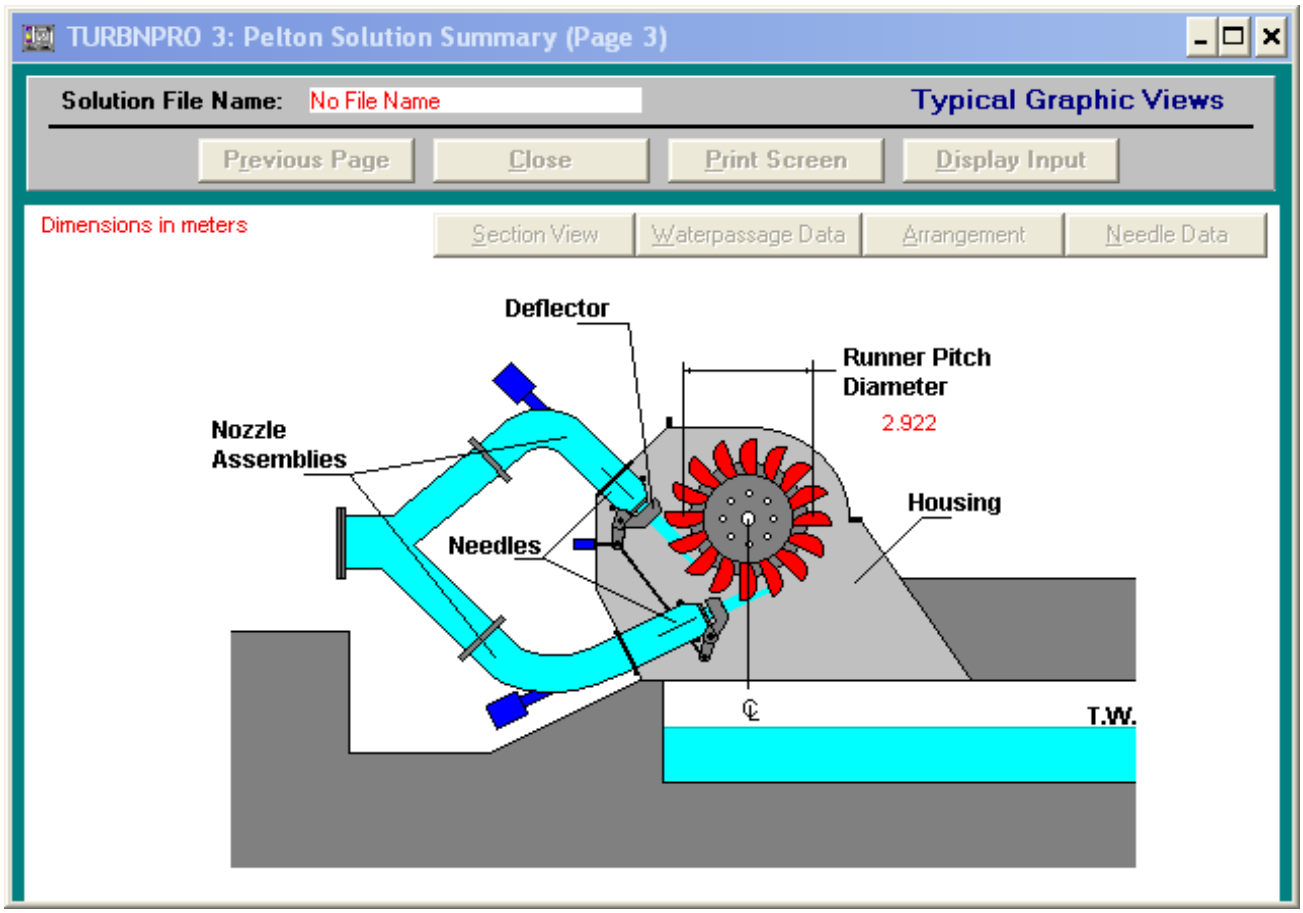
	inches	/	mm
Overall Shaft Length:	252.8		6421
Turbine Shaft Diameter:	17.9		455

Miscellaneous:

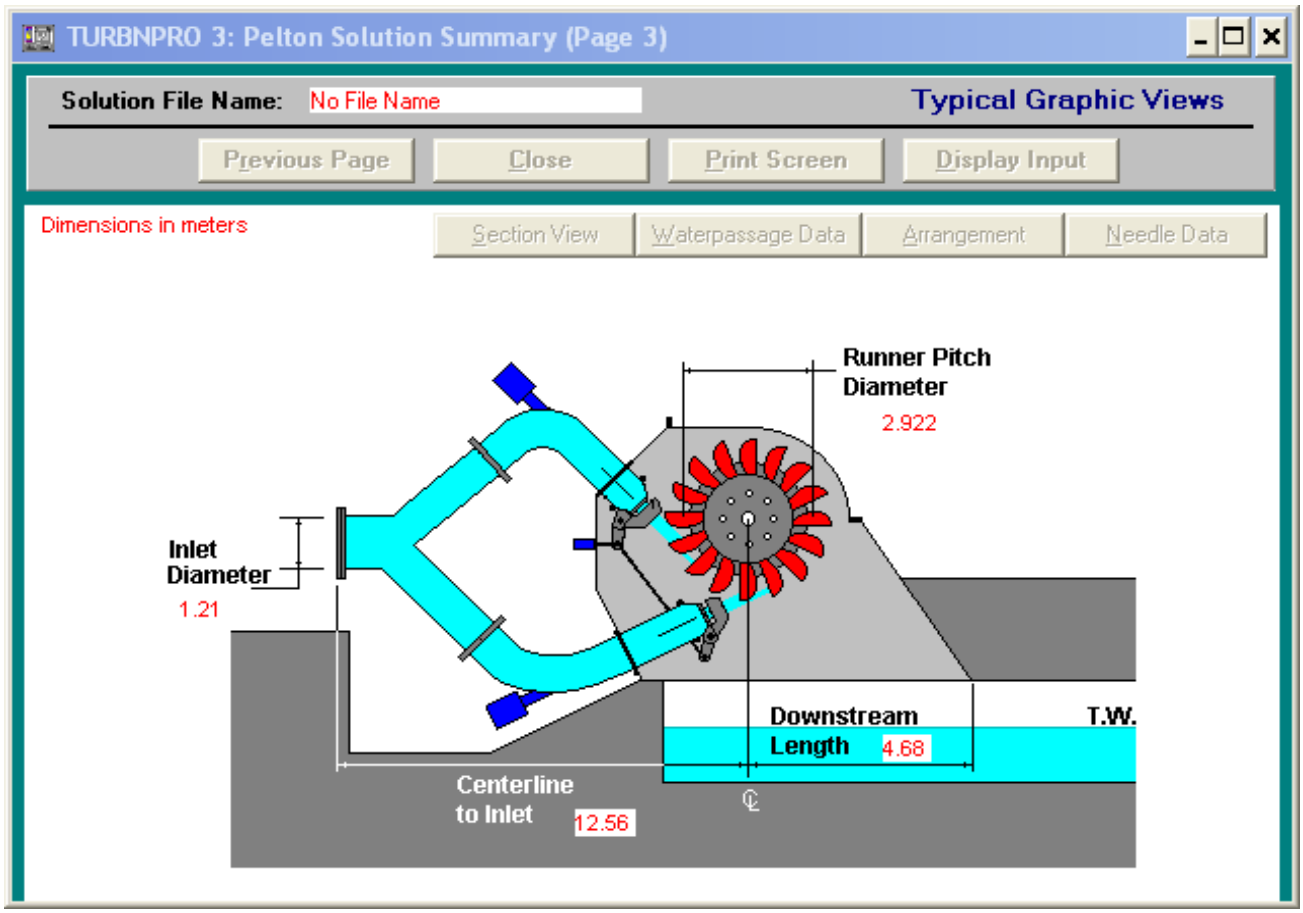
	inches	/	mm
Runner Outside Diameter:	155.9		3961
Runner Bucket Width:	40.9		1039

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

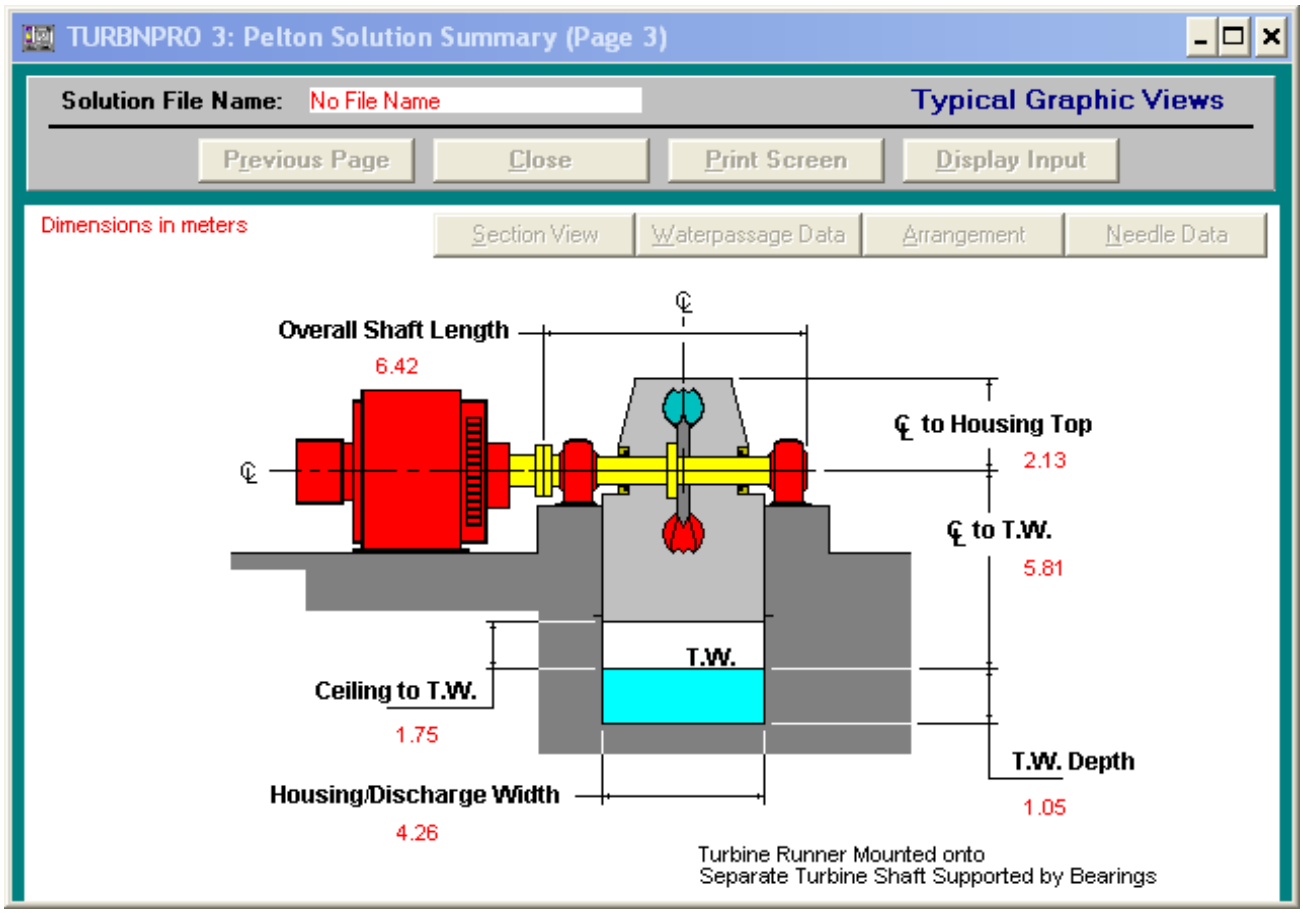
Solution File Name: No File Name
Intake Type: 2 - JET
Runner Diameter: 2922 mm
Net Head at Rated Discharge: 119.00 meters
Unit Speed: 150.0 rpm



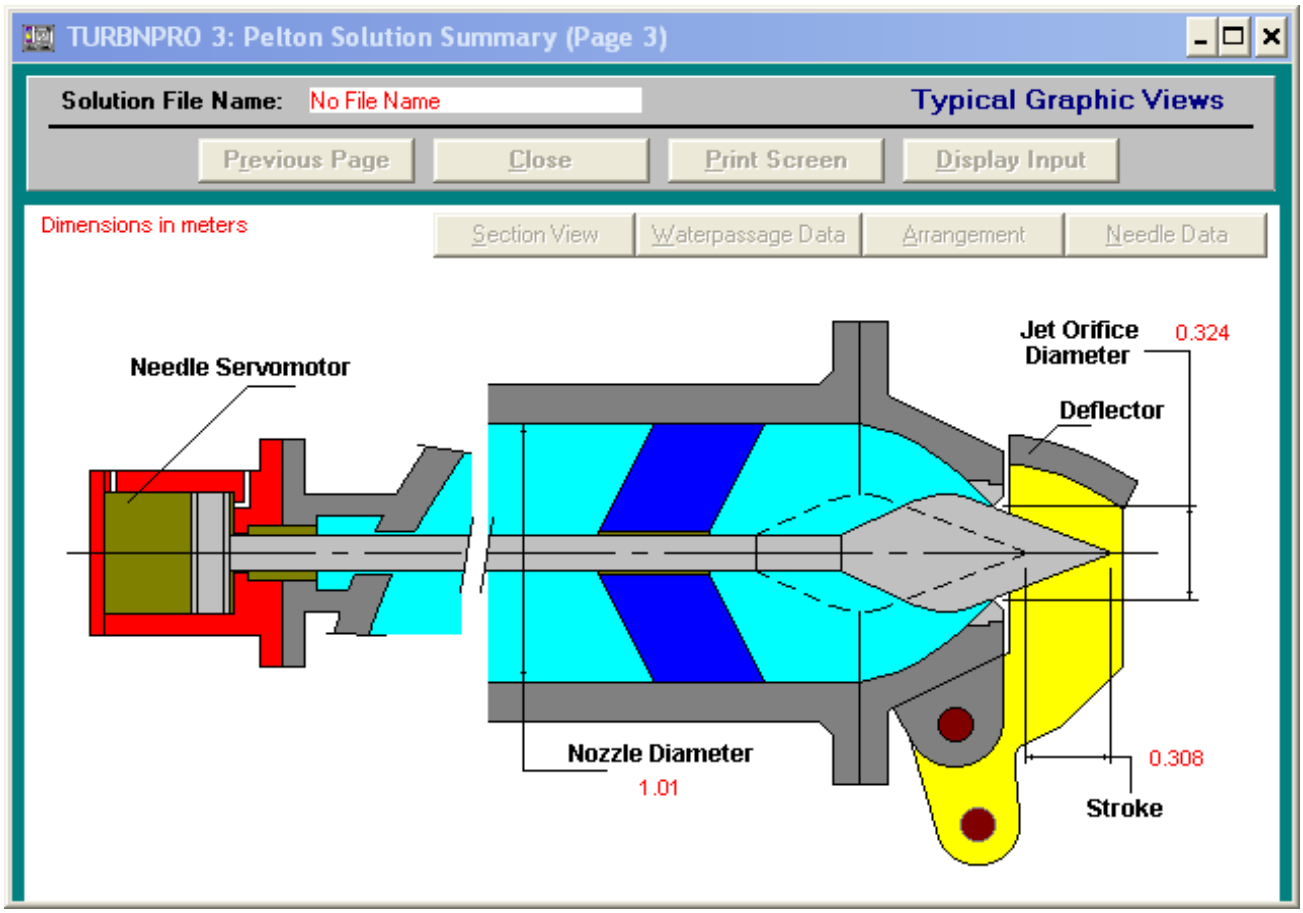
Solution File Name: No File Name
Intake Type: 2 - JET
Runner Diameter: 2922 mm
Net Head at Rated Discharge: 119.00 meters
Unit Speed: 150.0 rpm



Solution File Name: No File Name
Intake Type: 2 - JET
Runner Diameter: 2922 mm
Net Head at Rated Discharge: 119.00 meters
Unit Speed: 150.0 rpm

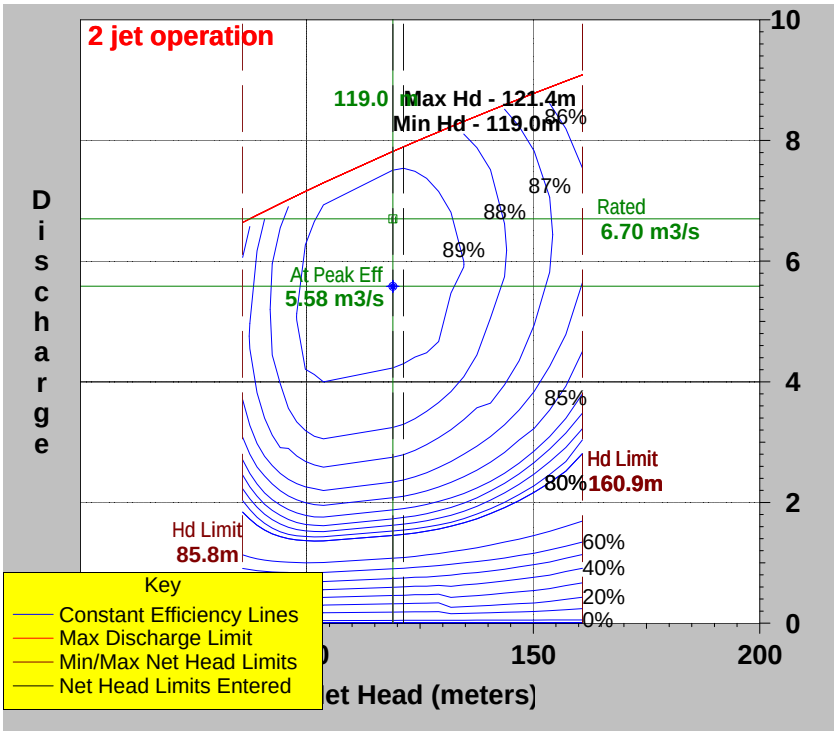


Solution File Name: No File Name
Intake Type: 2 - JET
Runner Diameter: 2922 mm
Net Head at Rated Discharge: 119.00 meters
Unit Speed: 150.0 rpm



Solution File Name: No File Name

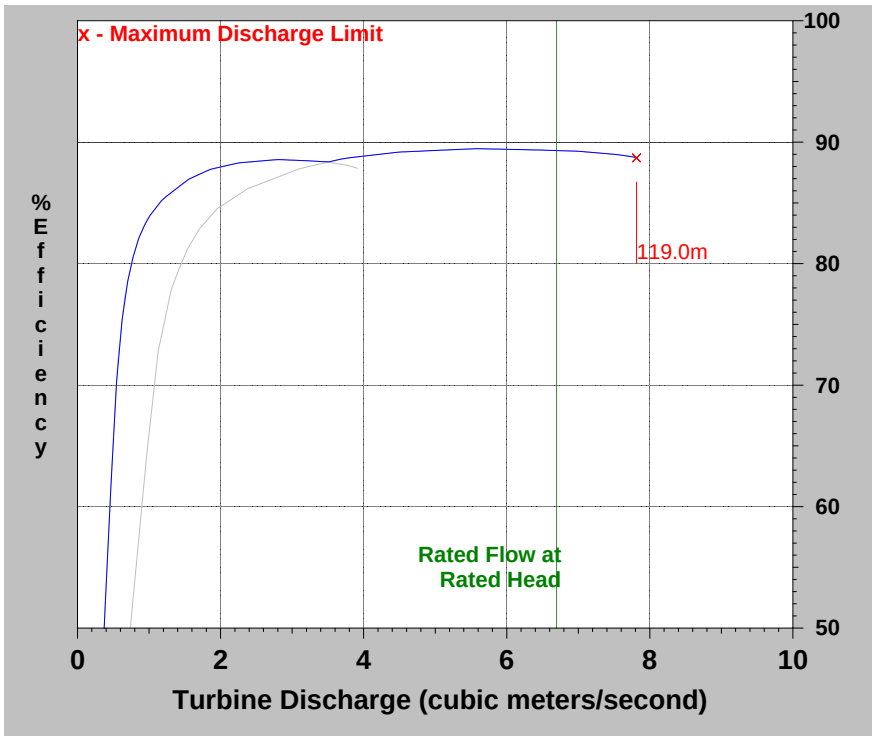
Intake Type:	2 - JET
Runner Pitch Diameter:	2922 mm
Net Head at Rated Discharge:	119.00 meters
Unit Speed:	150.0 rpm
Peak Efficiency:	89.5 %
Multiplier Efficiency Modifier:	1.000
Flow Squared Efficiency Modifier:	0.0000



NOTE: Discharge is in cubic meters per second

```
Solution File Name: No File Name
Intake Type:                        2 - JET
Runner Pitch Diameter:              2922  mm
Net Head at Rated Discharge:        119.00  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: 119



TURBNPRO Version 3 - FRANCIS TURBINE SOLUTION SUMMARY

Solution File Name: c:\georgi~1\hipphy~1\storip~1\stori3~1\sto3-2xf.dat

TURBINE SIZING CRITERIA

Rated Discharge:	236.6	cfs	/	6.7	m3/s
Net Head at Rated Discharge:	390.4	feet	/	119.0	meters
Gross Head:	405.2	feet	/	123.5	meters
Site Elevation:	1969	feet	/	600	meters
Water Temperature:	68	Degrees F	/	20	Degrees C
Setting to Tailwater:	-6.6	feet	/	-2.0	meters
Efficiency Priority:			5		
System Frequency:			50	Hz	
Minimum Net Head:	390.4	feet	/	119.0	meters
Maximum Net Head:	405.2	feet	/	123.5	meters

FRANCIS TURBINE SOLUTION DATA

Arrangement: VERTICAL WITH RUNNER ON TURBINE SHAFT
Intake Type: SPIRAL CASE
Draft Tube Type: ELBOW

Runner Diameter:	41.4	inches	/	1051	mm
Unit Speed:	500.0	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:	28.3	108.0
At Peak Efficiency Condition:	27.1	103.3

SOLUTION PERFORMANCE DATA

At Rated Net Head of: 390.4 feet / 119.0 meters

% of Rated Discharge	Output (KW)	Efficiency (%)	cfs	m3/s
** 109.1	7752	90.8	258.1	7.3
100	7214	92.2	236.6	6.7
* 90.9	6591	92.7	215.1	6.1
75	5377	91.7	177.4	5.0
50	3300	84.4	118.3	3.4
25	1253	64.1	59.1	1.7
+ 48.8	3193	83.7	115.4	3.3

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

At Maximum Net Head of: 405.2 feet / 123.5 meters

Sigma Allowable	Max. Output (KW)	Efficiency (%)	cfs	m3/s
0.060	8126	90.8	260.7	7.4

At Minimum Net Head of: 390.4 feet / 119.0 meters

Sigma Allowable	Max. Output (KW)	Efficiency (%)	cfs	m3/s
0.060	7752	90.8	258.1	7.3

Solution File Name: c:\georgi~1\hipphy~1\storip~1\stori3~1\sto3-2xf.dat

MISCELLANEOUS DATA

Maximum Runaway Speed (at Max. Net Head):	834 rpm		
Turbine Discharge at:			
Runaway Speed (at Rated Net Head & 100% gate):	111 cfs	/	3.1 m3/s
Synchronous Speed-No-Load (at Rated Net Head):	19 cfs	/	0.5 m3/s
Site's Atmospheric Pressure minus Vapor Pressure:	30.8 feet	/	9.4 meters
Sigma Allowable (at 100% Output & Rated Net Head):	0.045		
Sigma Plant (at 100% Output & Rated Net Head):	0.096		
Maximum Hydraulic Thrust (at Max. Net Head):	35106 lbs	/	15957 kg
Approximate Runner and Shaft Weight:	5793 lbs	/	2633 kg
Vel. at Draft Tube Exit (at Rated Head & Discharge):	3.7 fps	/	1.1 m/s

DIMENSIONAL DATA

Intake Type: SPIRAL CASE

	inches	/	mm
Inlet Diameter:	42.0		1067
Inlet Offset:	66.2		1682
Centerline to Inlet:	70.9		1801
Outside Radius A:	87.2		2216
Outside Radius B:	82.7		2100
Outside Radius C:	76.5		1944
Outside Radius D:	69.9		1774

Draft Tube Type: ELBOW

	inches	/	mm
Centerline to Invert:	132.4		3363
Shaft Axis to Exit Length:	198.6		5045
Exit Width:	124.1		3153
Exit Height:	74.5		1892

Shafting Arrangement: VERTICAL WITH RUNNER ON TURBINE SHAFT

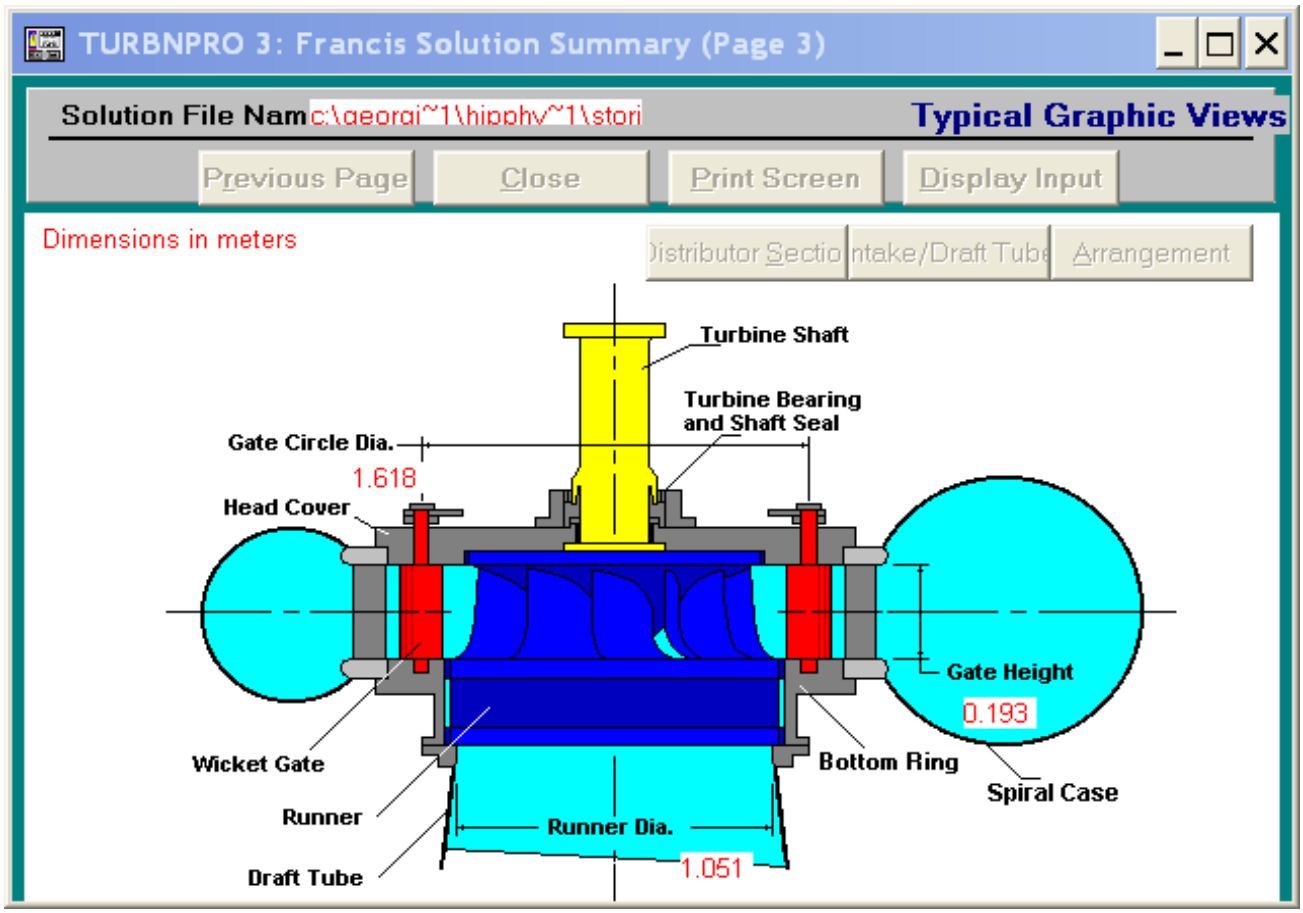
	inches	/	mm
Centerline to Shaft Coupling:	96.0		2438
Turbine Shaft Diameter:	11.7		298

Miscellaneous:

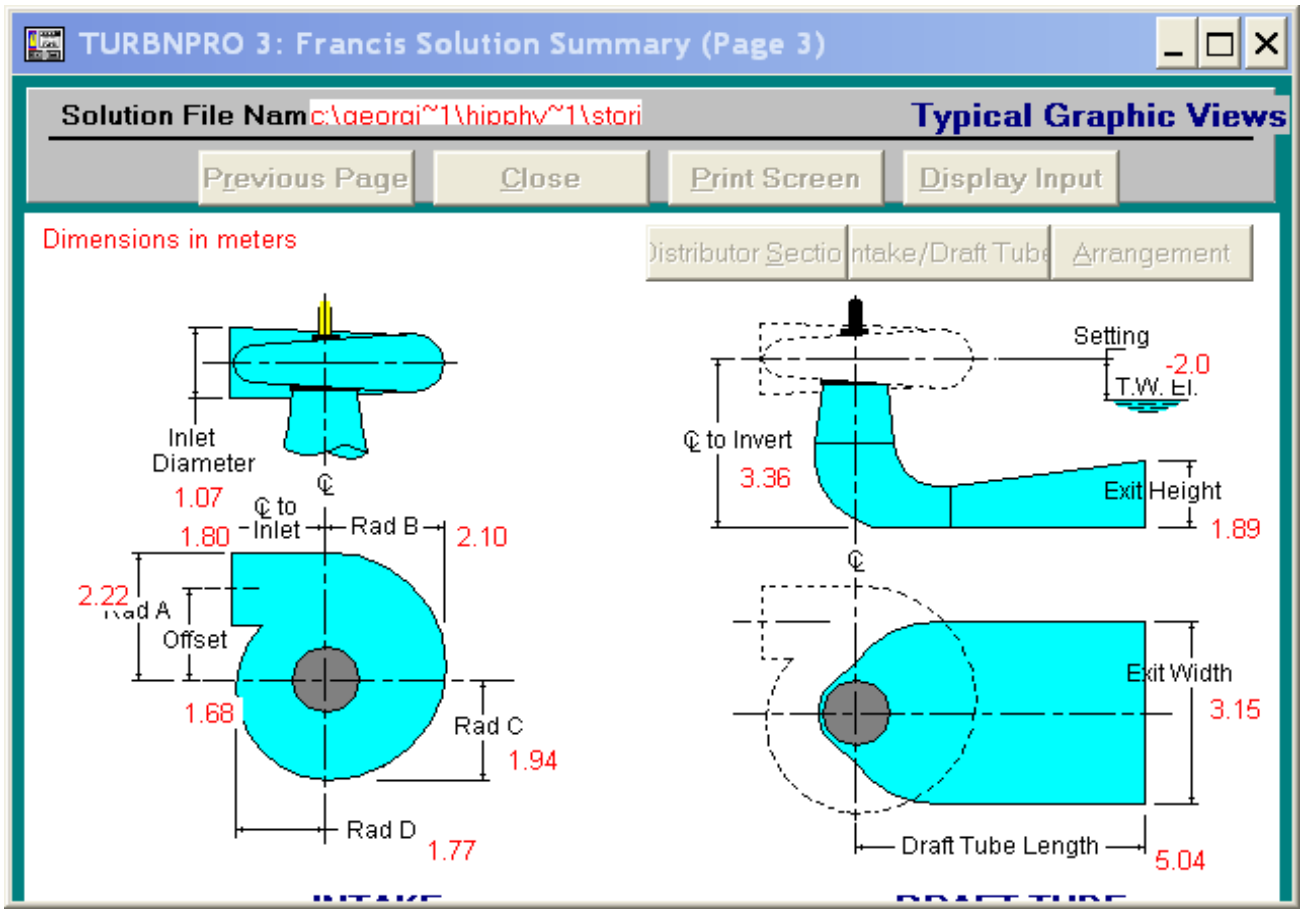
	inches	/	mm
Wicket Gate Height:	7.6		193
Wicket Gate Circle Diameter:	63.7		1618

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

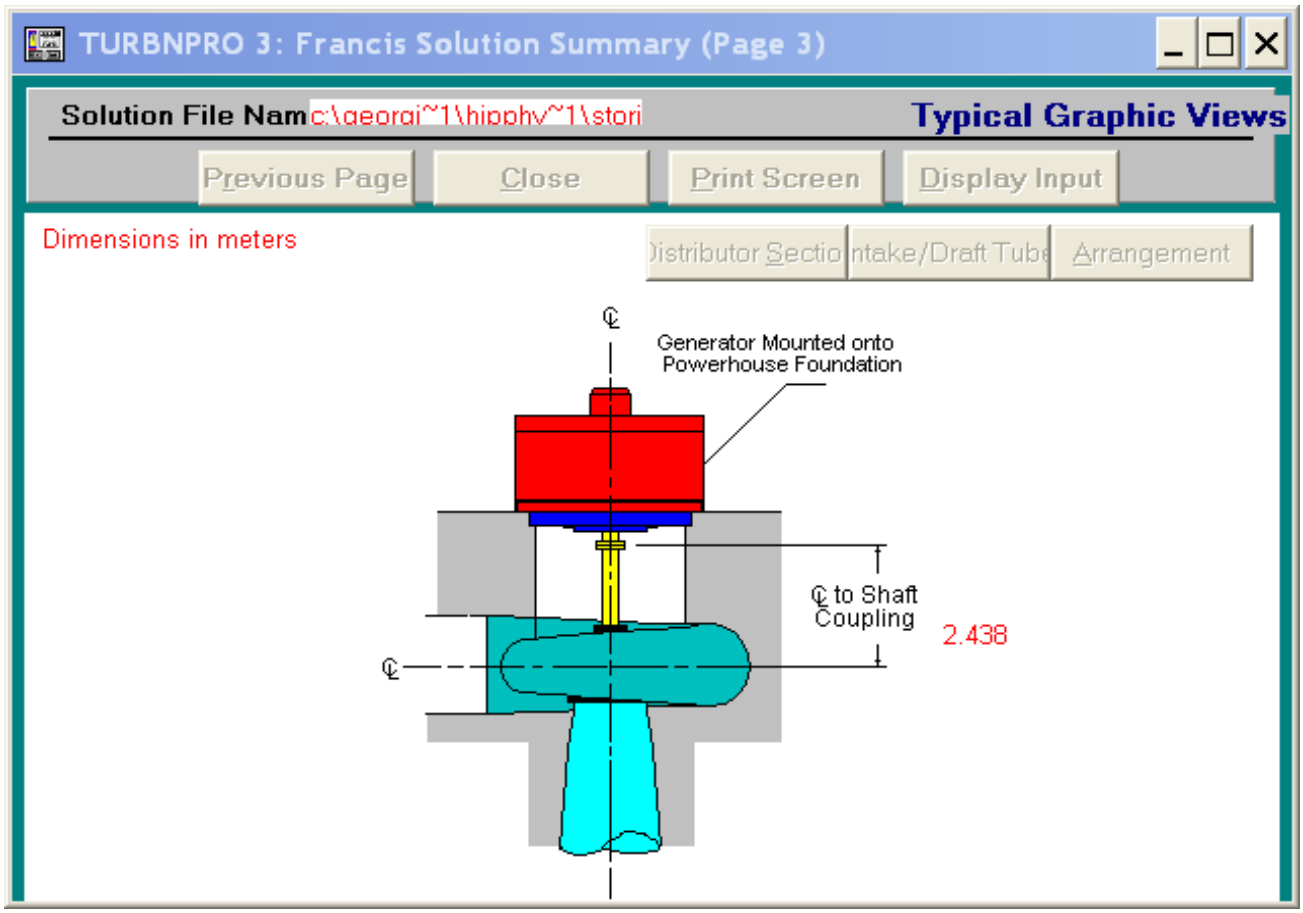
Solution File Name: c:\georgi~1\hipphy~1\storip~1\stori3~1\sto3-2xf.dat
Runner Diameter: 1051 mm
Net Head at Rated Discharge: 119.00 meters
Unit Speed: 500.0 rpm



Solution File Name: c:\georgi~1\hipphy~1\storip~1\stori3~1\sto3-2xf.dat
Runner Diameter: 1051 mm
Net Head at Rated Discharge: 119.00 meters
Unit Speed: 500.0 rpm

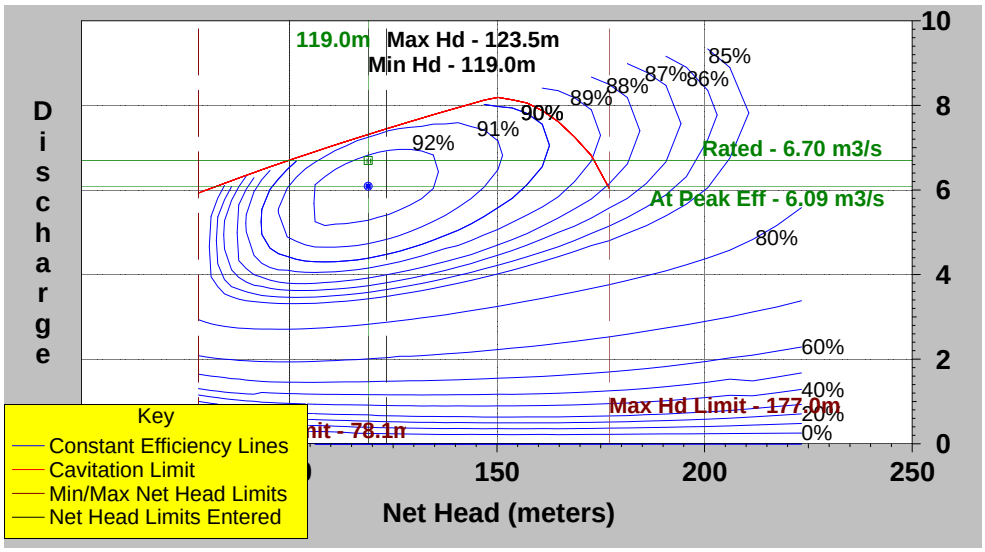


Solution File Name: c:\georgi~1\hipphy~1\storip~1\stori3~1\sto3-2xf.dat
Runner Diameter: 1051 mm
Net Head at Rated Discharge: 119.00 meters
Unit Speed: 500.0 rpm



Solution File Name: c:\georgi~1\hipphy~1\storip~1\stori3~1\sto3-2xf.dat

Runner Diameter:	1051	mm
Net Head at Rated Discharge:	119.00	meters
Unit Speed:	500.0	rpm
Peak Efficiency:	92.7	%
Multiplier Efficiency Modifier:	1.000	
Flow Squared Efficiency Modifier:	0.0000	

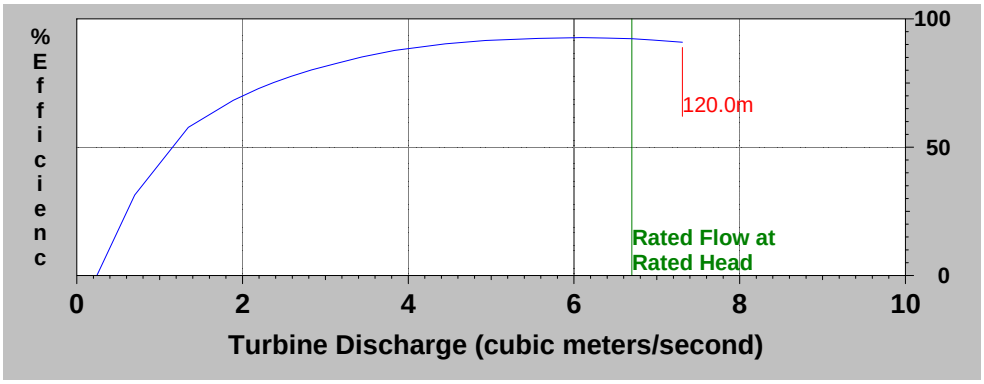


NOTE: Discharge is in cubic meters per second

Solution File Name: c:\georgi~1\hipphy~1\storip~1\stori3~1\sto3-2xf.dat
Runner Diameter: 1051 mm
Net Head at Rated Discharge: 119.00 meters
Unit Speed: 500.0 rpm
Multiplier Efficiency Modifier: 1.000
Flow Squared Efficiency Modifier: 0.0000

Performance Data Shown is for a Net Head of: 120

Power (KW)	Efficiency (%)	Discharge (m3/s)	Notes
7817	90.8	7.31	-
7502	91.8	6.94	-
7150	92.3	6.58	-
6773	92.6	6.21	-
6647	92.7	6.09	Best Efficiency Condition
6371	92.5	5.85	-
5955	92.3	5.48	-
5529	91.8	5.12	-
5093	91.1	4.75	-
4647	90.0	4.39	-
4186	88.4	4.02	-
3722	86.5	3.66	-
3249	83.9	3.29	-
2783	80.9	2.92	-
2327	77.3	2.56	-
1879	72.8	2.19	-
1443	67.1	1.83	-
1032	60.0	1.46	Low efficiency; not used in energy calculation
613	47.5	1.10	Low efficiency; not used in energy calculation
280	32.5	0.73	Low efficiency; not used in energy calculation
36	8.3	0.37	Low efficiency; not used in energy calculation



TURBNPRO Version 3 - FRANCIS TURBINE SOLUTION SUMMARY

Solution File Name: c:\georgi~1\hipphy~1\storip~1\stori3~1\sto3-lgf.dat

TURBINE SIZING CRITERIA

Rated Discharge:	314.3	cfs	/	8.9	m3/s
Net Head at Rated Discharge:	390.4	feet	/	119.0	meters
Gross Head:	405.2	feet	/	123.5	meters
Site Elevation:	1969	feet	/	600	meters
Water Temperature:	68	Degrees F	/	20	Degrees C
Setting to Tailwater:	-6.6	feet	/	-2.0	meters
Efficiency Priority:			5		
System Frequency:			50 Hz		
Minimum Net Head:	390.4	feet	/	119.0	meters
Maximum Net Head:	405.2	feet	/	123.5	meters

FRANCIS TURBINE SOLUTION DATA

Arrangement:	VERTICAL WITH RUNNER ON TURBINE SHAFT			
Intake Type:	SPIRAL CASE			
Draft Tube Type:	ELBOW			
Runner Diameter:	50.1	inches	/	1273 mm
Unit Speed:	375.0	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:	24.4	93.2
At Peak Efficiency Condition:	23.4	89.1

SOLUTION PERFORMANCE DATA

At Rated Net Head of: 390.4 feet / 119.0 meters

% of Rated Discharge	Output (KW)	Efficiency (%)	cfs	m3/s
** 109.1	10255	90.4	342.9	9.7
100	9541	91.8	314.3	8.9
* 90.9	8717	92.3	285.7	8.1
75	7116	91.3	235.7	6.7
50	4395	84.6	157.1	4.5
25	1702	65.5	78.6	2.2
+ 47.2	4075	83.2	148.2	4.2

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

At Maximum Net Head of: 405.2 feet / 123.5 meters

Sigma Allowable	Max. Output (KW)	Efficiency (%)	cfs	m3/s
0.052	10750	90.4	346.4	9.8

At Minimum Net Head of: 390.4 feet / 119.0 meters

Sigma Allowable	Max. Output (KW)	Efficiency (%)	cfs	m3/s
0.052	10255	90.4	342.9	9.7

Solution File Name: c:\georgi~1\hipphy~1\storip~1\stori3~1\sto3-lgf.dat

MISCELLANEOUS DATA

Maximum Runaway Speed (at Max. Net Head):	616 rpm		
Turbine Discharge at:			
Runaway Speed (at Rated Net Head & 100% gate):	139 cfs	/	3.9 m3/s
Synchronous Speed-No-Load (at Rated Net Head):	24 cfs	/	0.7 m3/s
Site's Atmospheric Pressure minus Vapor Pressure:	30.8 feet	/	9.4 meters
Sigma Allowable (at 100% Output & Rated Net Head):	0.039		
Sigma Plant (at 100% Output & Rated Net Head):	0.096		
Maximum Hydraulic Thrust (at Max. Net Head):	46132 lbs	/	20969 kg
Approximate Runner and Shaft Weight:	9026 lbs	/	4103 kg
Vel. at Draft Tube Exit (at Rated Head & Discharge):	3.3 fps	/	1.0 m/s

DIMENSIONAL DATA

Intake Type: SPIRAL CASE

	inches	/	mm
Inlet Diameter:	54.0		1372
Inlet Offset:	83.3		2116
Centerline to Inlet:	105.3		2674
Outside Radius A:	110.3		2802
Outside Radius B:	105.5		2679
Outside Radius C:	98.4		2500
Outside Radius D:	89.8		2282

Draft Tube Type: ELBOW

	inches	/	mm
Centerline to Invert:	161.7		4107
Shaft Axis to Exit Length:	240.6		6110
Exit Width:	150.4		3819
Exit Height:	90.2		2291

Shafting Arrangement: VERTICAL WITH RUNNER ON TURBINE SHAFT

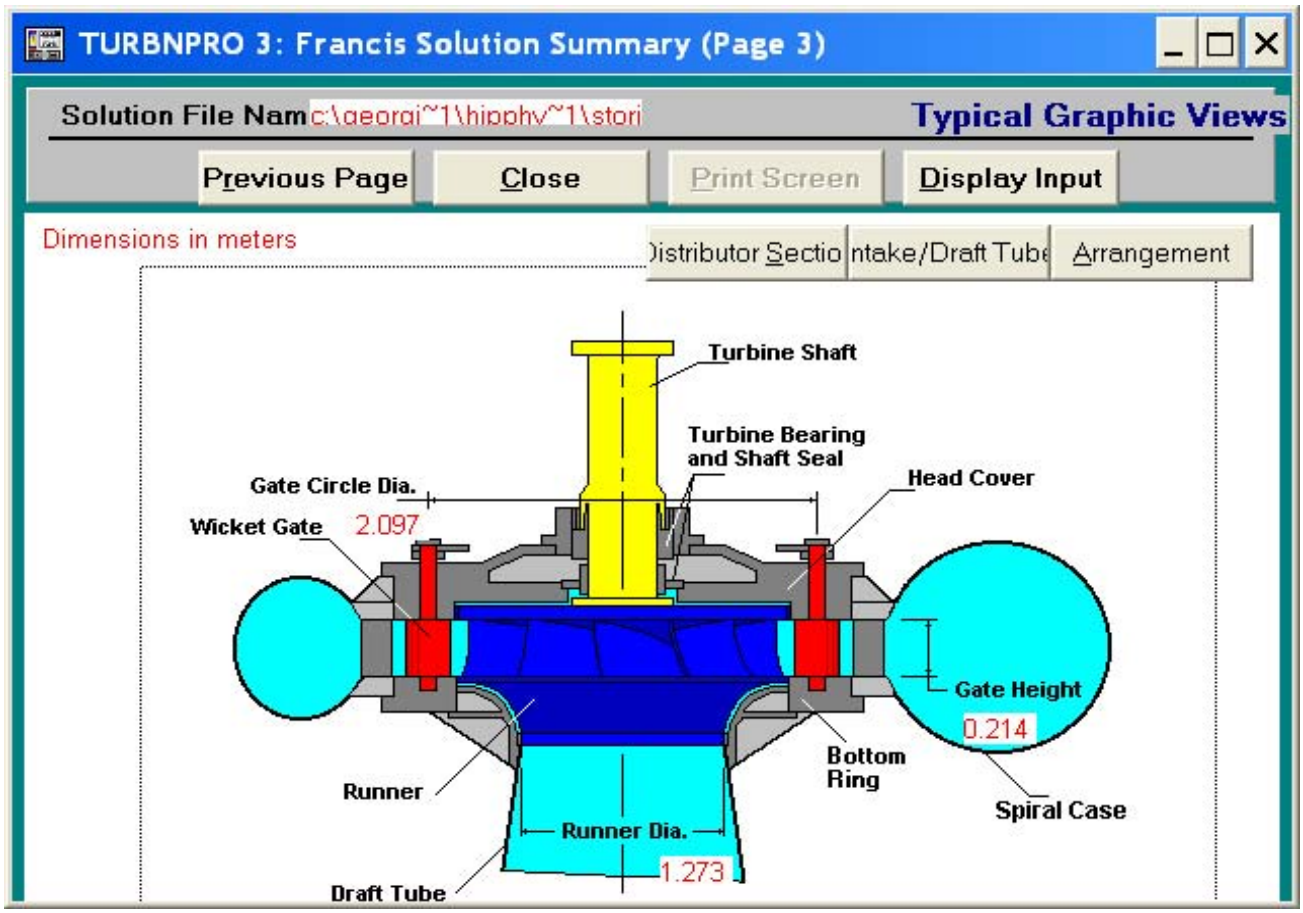
	inches	/	mm
Centerline to Shaft Coupling:	96.0		2438
Turbine Shaft Diameter:	14.2		360

Miscellaneous:

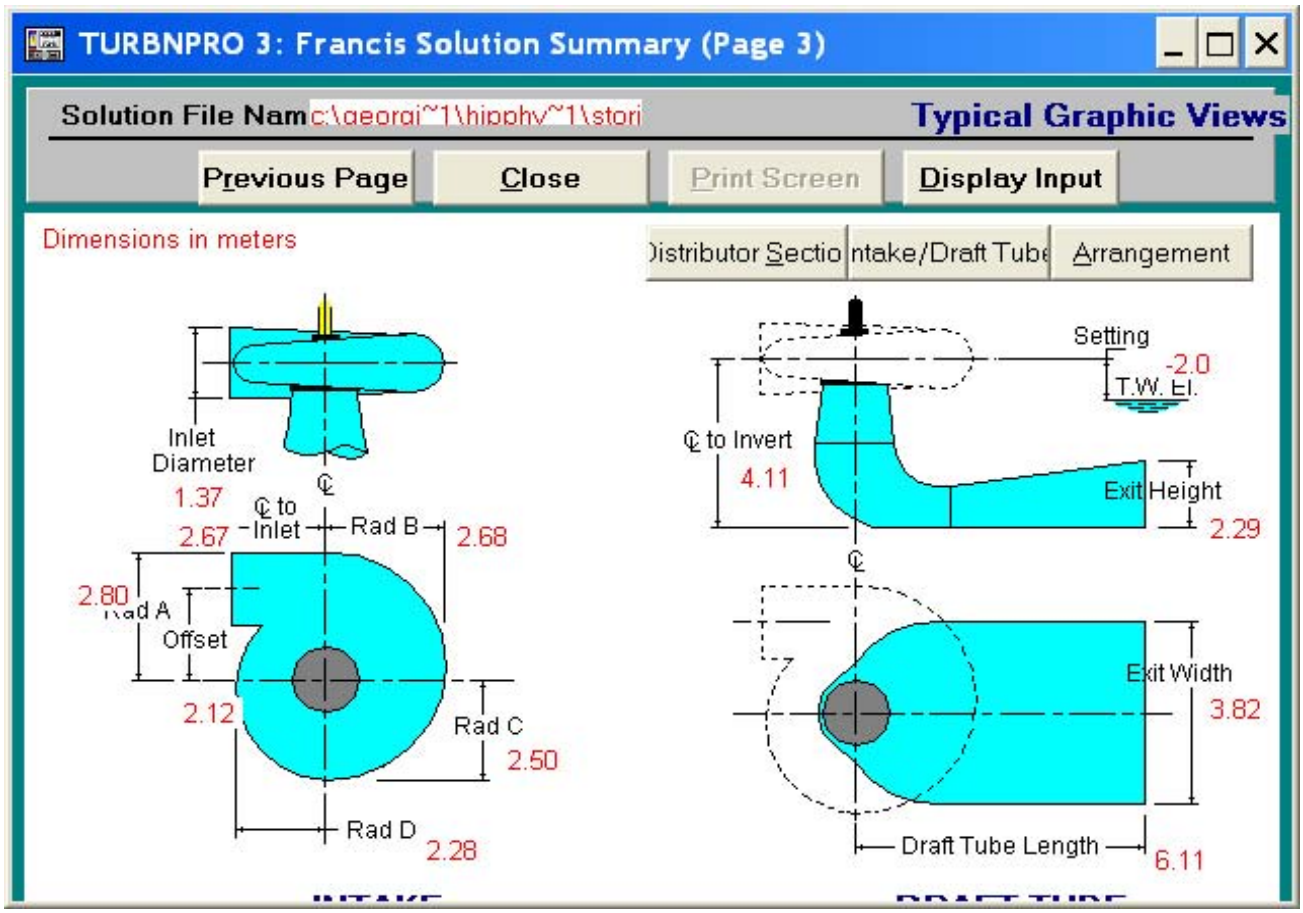
	inches	/	mm
Wicket Gate Height:	8.4		214
Wicket Gate Circle Diameter:	82.6		2097

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

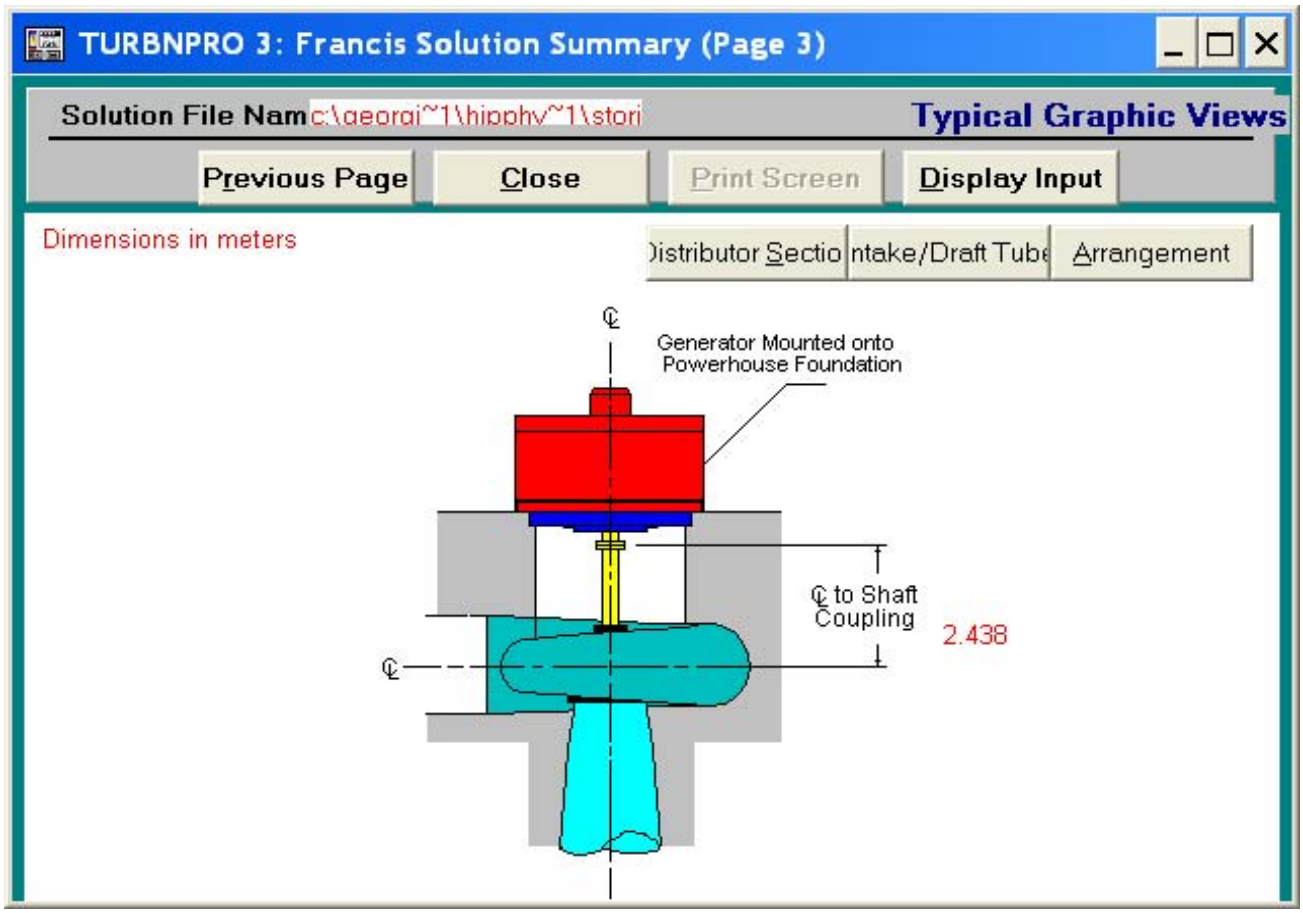
Solution File Name: c:\georgi~1\hipphy~1\storip~1\stori3~1\sto3-lgf.dat
Runner Diameter: 1273 mm
Net Head at Rated Discharge: 119.00 meters
Unit Speed: 375.0 rpm



Solution File Name: c:\georgi~1\hipphy~1\storip~1\stori3~1\sto3-lgf.dat
Runner Diameter: 1273 mm
Net Head at Rated Discharge: 119.00 meters
Unit Speed: 375.0 rpm

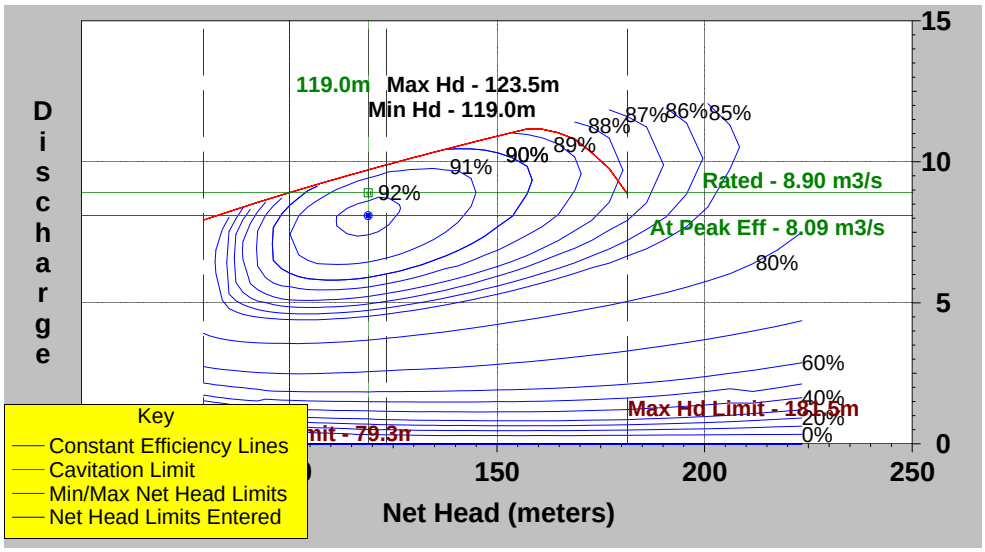


Solution File Name: c:\georgi~1\hipphy~1\storip~1\stori3~1\sto3-lgf.dat
Runner Diameter: 1273 mm
Net Head at Rated Discharge: 119.00 meters
Unit Speed: 375.0 rpm



Solution File Name: c:\georgi~1\hipphy~1\storip~1\stori3~1\sto3-lgf.dat

Runner Diameter:	1273	mm
Net Head at Rated Discharge:	119.00	meters
Unit Speed:	375.0	rpm
Peak Efficiency:	92.3	%
Multiplier Efficiency Modifier:	1.000	
Flow Squared Efficiency Modifier:	0.0000	

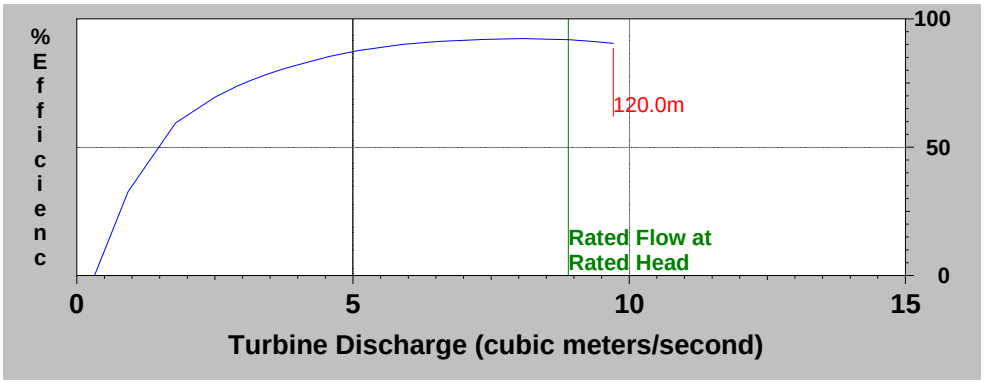


NOTE: Discharge is in cubic meters per second

Solution File Name: c:\georgi~1\hipphy~1\storip~1\stori3~1\sto3-lgf.dat
Runner Diameter: 1273 mm
Net Head at Rated Discharge: 119.00 meters
Unit Speed: 375.0 rpm
Multiplier Efficiency Modifier: 1.000
Flow Squared Efficiency Modifier: 0.0000

Performance Data Shown is for a Net Head of: 120

Power (KW)	Efficiency (%)	Discharge (m3/s)	Notes
10341	90.4	9.71	-
9924	91.4	9.23	-
9459	91.9	8.74	-
8960	92.2	8.26	-
8793	92.3	8.09	Best Efficiency Condition
8429	92.2	7.77	-
7879	91.9	7.28	-
7318	91.4	6.80	-
6745	90.8	6.31	-
6159	89.8	5.83	-
5556	88.4	5.34	-
4948	86.6	4.86	-
4329	84.1	4.37	-
3720	81.3	3.88	-
3121	78.0	3.40	-
2532	73.8	2.91	-
1954	68.4	2.43	-
1407	61.5	1.94	-
841	49.0	1.46	Low efficiency; not used in energy calculation
388	33.9	0.97	Low efficiency; not used in energy calculation
50	8.7	0.49	Low efficiency; not used in energy calculation



TURBNPRO Version 3 - FRANCIS TURBINE SOLUTION SUMMARY

Solution File Name: No File Name

TURBINE SIZING CRITERIA

Rated Discharge:	158.9	cfs	/	4.5	m3/s
Net Head at Rated Discharge:	390.4	feet	/	119.0	meters
Gross Head:	405.2	feet	/	123.5	meters
Site Elevation:	1969	feet	/	600	meters
Water Temperature:	68	Degrees F	/	20	Degrees C
Setting to Tailwater:	-6.6	feet	/	-2.0	meters
Efficiency Priority:			5		
System Frequency:			50 Hz		
Minimum Net Head:	390.4	feet	/	119.0	meters
Maximum Net Head:	405.2	feet	/	123.5	meters

FRANCIS TURBINE SOLUTION DATA

Arrangement:	VERTICAL WITH RUNNER ON TURBINE SHAFT
Intake Type:	SPIRAL CASE
Draft Tube Type:	ELBOW

Runner Diameter:	36.3	inches	/	922	mm
Unit Speed:	500.0	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:	23.1	88.1
At Peak Efficiency Condition:	22.1	84.2

SOLUTION PERFORMANCE DATA

At Rated Net Head of: 390.4 feet / 119.0 meters

% of Rated Discharge	Output (KW)	Efficiency (%)	cfs	m3/s
** 109.1	5156	90.0	173.4	4.9
100	4798	91.3	158.9	4.5
* 90.9	4384	91.8	144.5	4.1
75	3579	90.8	119.2	3.4
50	2215	84.3	79.4	2.3
25	863	65.7	39.7	1.1
+ 46.6	2025	82.7	74.1	2.1

** - Overcapacity

* - Peak Efficiency Condition

+ - Peak Draft Tube Surging Condition

At Maximum Net Head of: 405.2 feet / 123.5 meters

Sigma Allowable	Max. Output (KW)	Efficiency (%)	cfs	m3/s
0.050	5405	90.0	175.1	5.0

At Minimum Net Head of: 390.4 feet / 119.0 meters

Sigma Allowable	Max. Output (KW)	Efficiency (%)	cfs	m3/s
0.050	5156	90.0	173.4	4.9

Solution File Name: No File Name

MISCELLANEOUS DATA

Maximum Runaway Speed (at Max. Net Head):	818 rpm		
Turbine Discharge at:			
Runaway Speed (at Rated Net Head & 100% gate):	69 cfs	/	2.0 m3/s
Synchronous Speed-No-Load (at Rated Net Head):	12 cfs	/	0.3 m3/s
Site's Atmospheric Pressure minus Vapor Pressure:	30.8 feet	/	9.4 meters
Sigma Allowable (at 100% Output & Rated Net Head):	0.037		
Sigma Plant (at 100% Output & Rated Net Head):	0.096		
Maximum Hydraulic Thrust (at Max. Net Head):	24883 lbs	/	11311 kg
Approximate Runner and Shaft Weight:	4548 lbs	/	2067 kg
Vel. at Draft Tube Exit (at Rated Head & Discharge):	3.2 fps	/	1.0 m/s

DIMENSIONAL DATA

Intake Type: SPIRAL CASE

	inches	/	mm
Inlet Diameter:	36.0		914
Inlet Offset:	63.3		1607
Centerline to Inlet:	67.3		1709
Outside Radius A:	81.3		2064
Outside Radius B:	77.7		1973
Outside Radius C:	72.8		1849
Outside Radius D:	66.4		1686

Draft Tube Type: ELBOW

	inches	/	mm
Centerline to Invert:	117.4		2983
Shaft Axis to Exit Length:	174.2		4426
Exit Width:	108.9		2766
Exit Height:	65.3		1660

Shafting Arrangement: VERTICAL WITH RUNNER ON TURBINE SHAFT

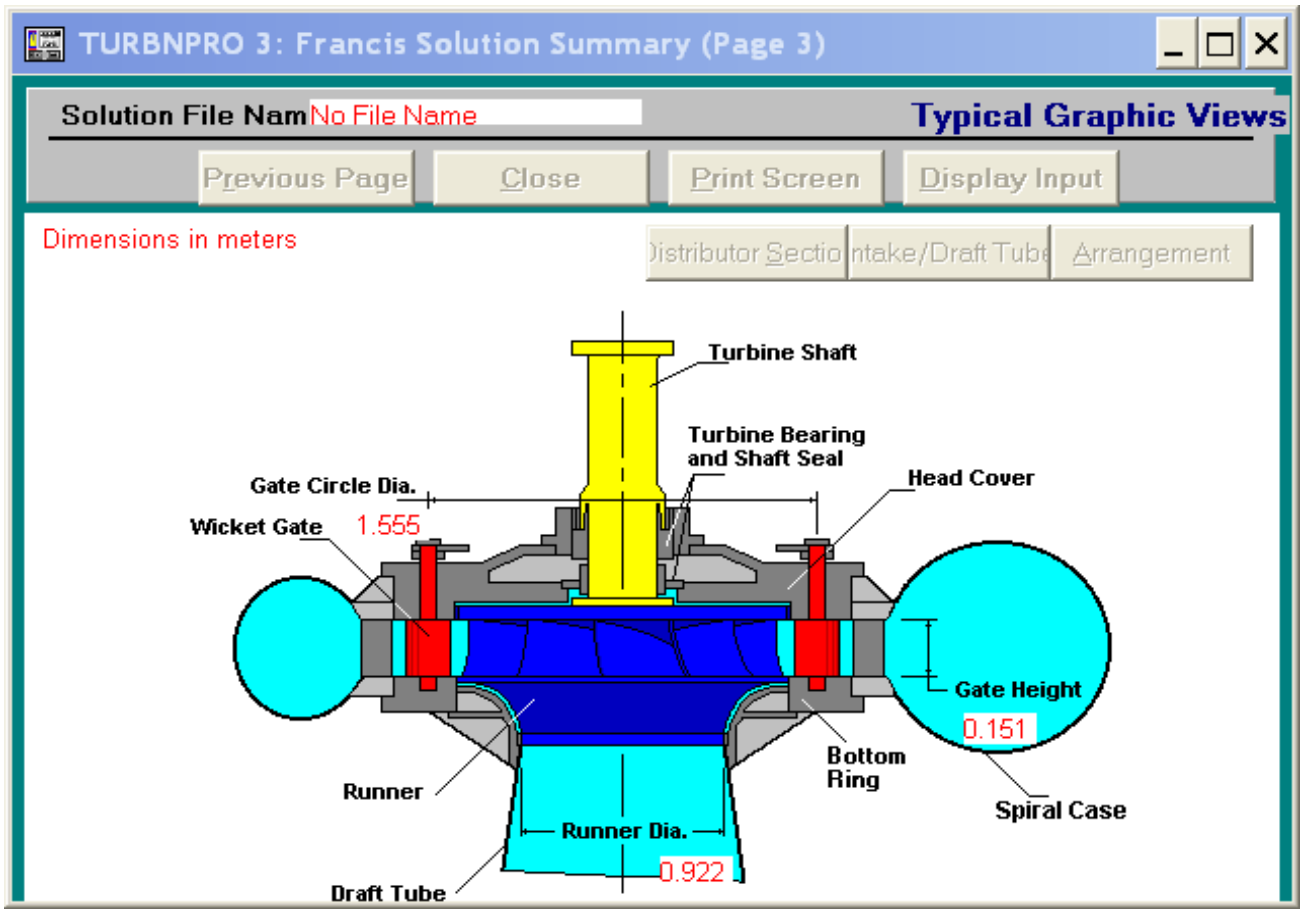
	inches	/	mm
Centerline to Shaft Coupling:	96.0		2438
Turbine Shaft Diameter:	10.2		260

Miscellaneous:

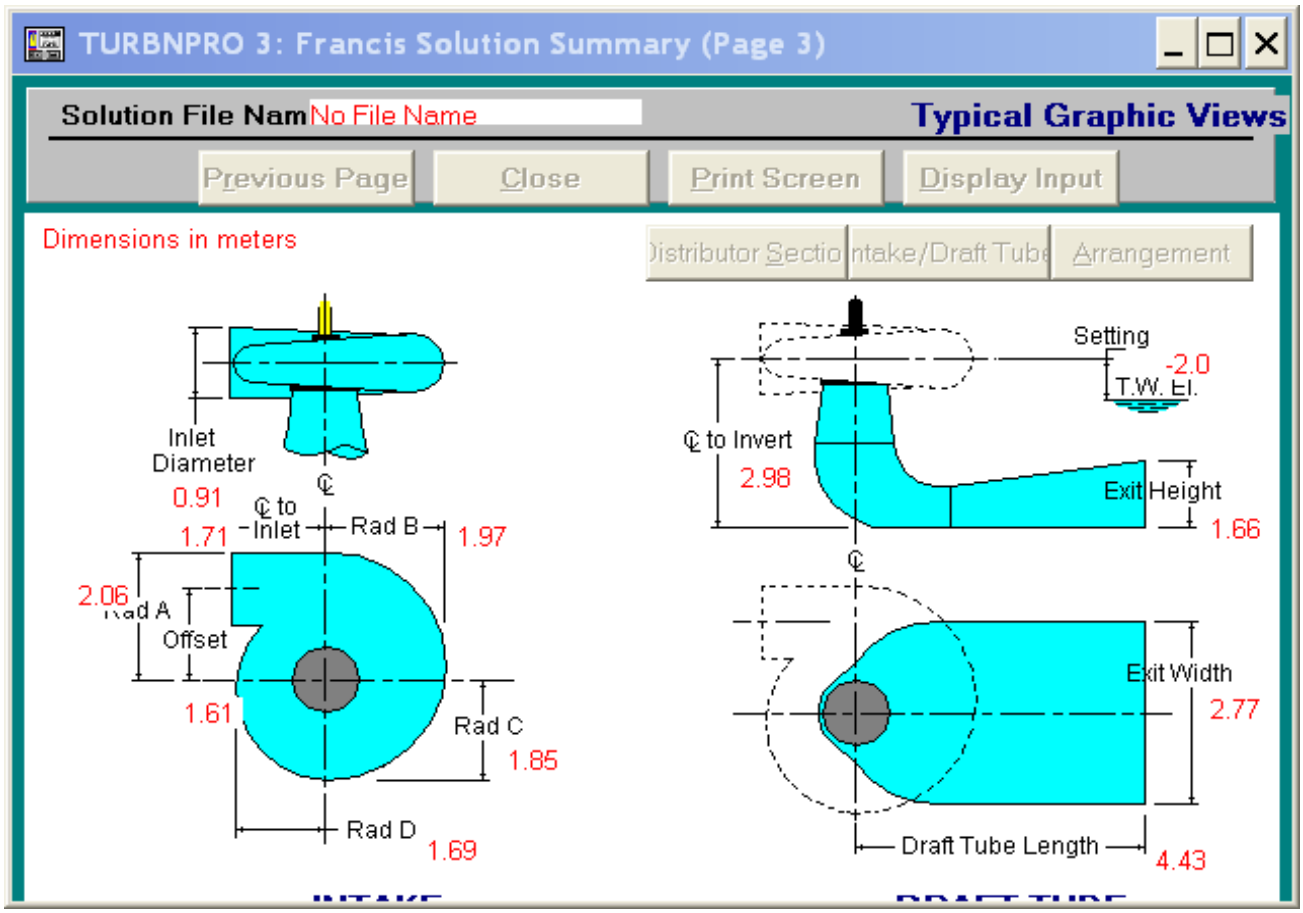
	inches	/	mm
Wicket Gate Height:	5.9		151
Wicket Gate Circle Diameter:	61.2		1555

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

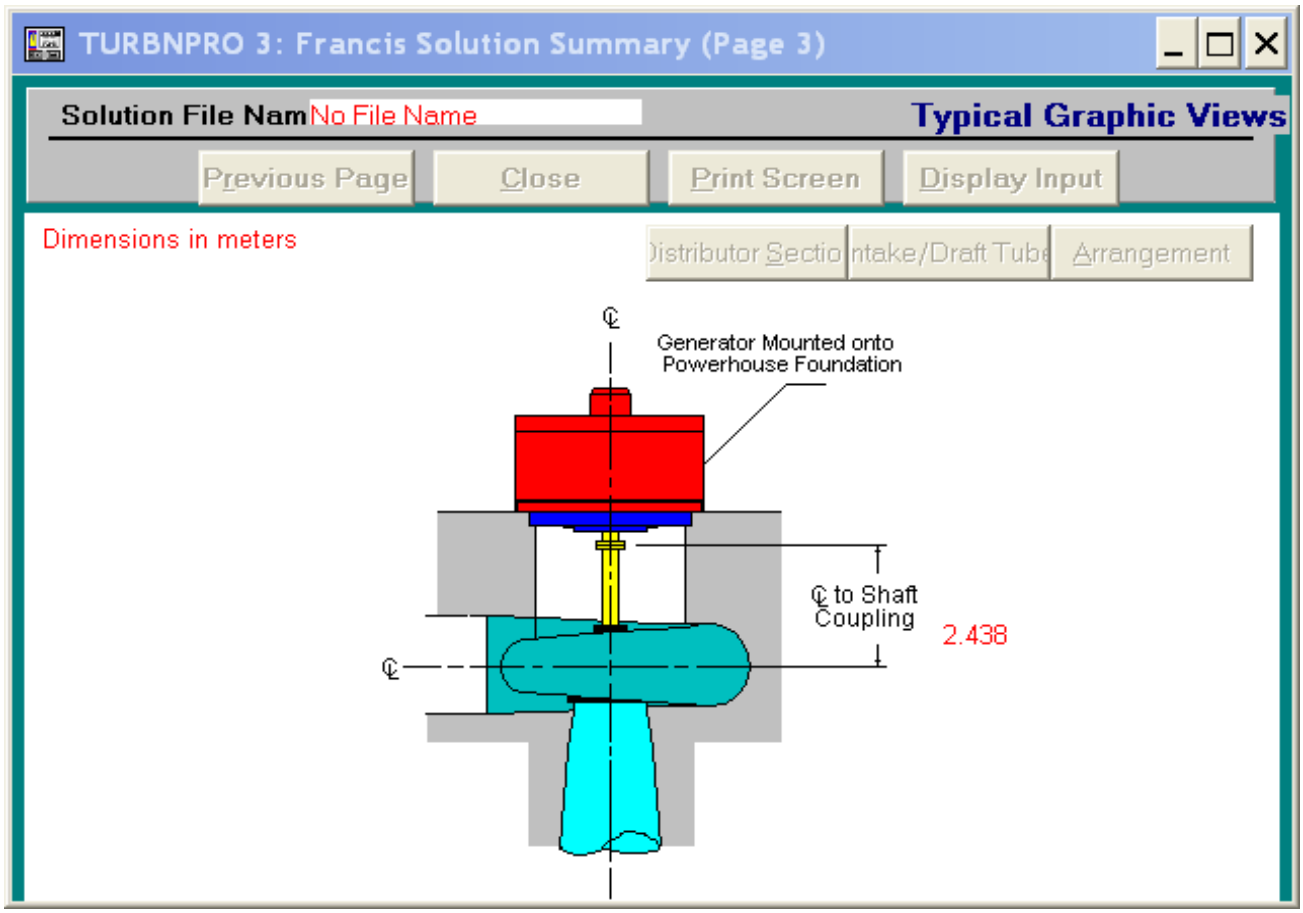
Solution File Name: No File Name
Runner Diameter: 922 mm
Net Head at Rated Discharge: 119.00 meters
Unit Speed: 500.0 rpm



Solution File Name: No File Name
Runner Diameter: 922 mm
Net Head at Rated Discharge: 119.00 meters
Unit Speed: 500.0 rpm



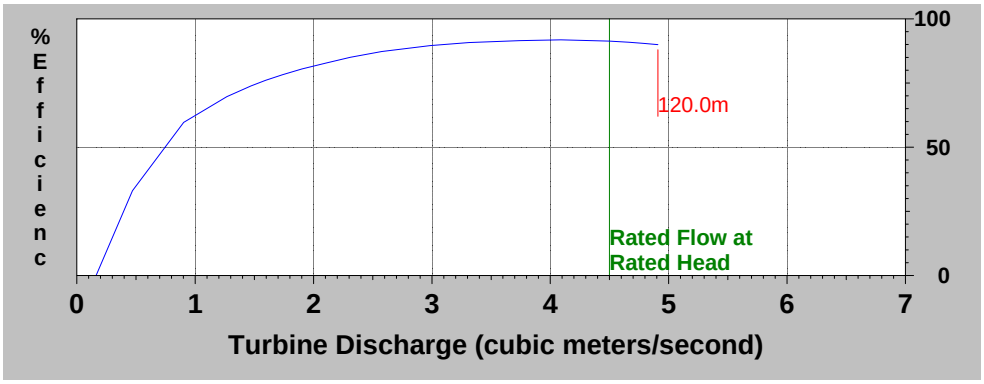
Solution File Name: No File Name
Runner Diameter: 922 mm
Net Head at Rated Discharge: 119.00 meters
Unit Speed: 500.0 rpm



Solution File Name: No File Name
Runner Diameter: 922 mm
Net Head at Rated Discharge: 119.00 meters
Unit Speed: 500.0 rpm
Multiplier Efficiency Modifier: 1.000
Flow Squared Efficiency Modifier: 0.0000

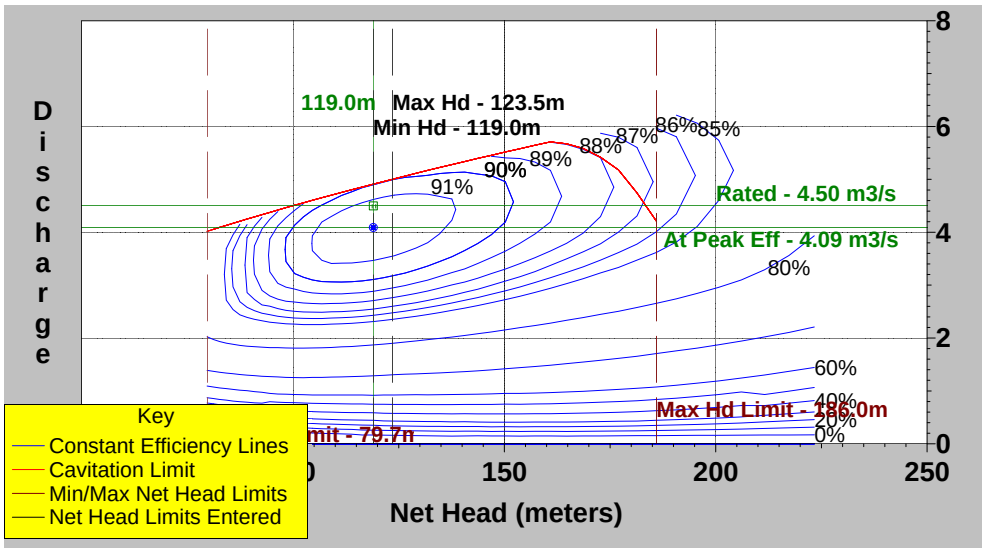
Performance Data Shown is for a Net Head of: 120

Power (KW)	Efficiency (%)	Discharge (m3/s)	Notes
5199	90.0	4.91	-
4989	90.9	4.66	-
4756	91.4	4.42	-
4505	91.7	4.17	-
4421	91.8	4.09	Best Efficiency Condition
4238	91.7	3.93	-
3961	91.4	3.68	-
3680	90.9	3.44	-
3392	90.3	3.19	-
3099	89.4	2.95	-
2796	88.0	2.70	-
2492	86.2	2.45	-
2182	83.9	2.21	-
1876	81.2	1.96	-
1576	77.9	1.72	-
1281	73.9	1.47	-
990	68.5	1.23	-
714	61.8	0.98	-
428	49.4	0.74	Low efficiency; not used in energy calculation
198	34.3	0.49	Low efficiency; not used in energy calculation
25	8.8	0.25	Low efficiency; not used in energy calculation



Solution File Name: No File Name

Runner Diameter:	922	mm
Net Head at Rated Discharge:	119.00	meters
Unit Speed:	500.0	rpm
Peak Efficiency:	91.8	%
Multiplier Efficiency Modifier:	1.000	
Flow Squared Efficiency Modifier:	0.0000	



NOTE: Discharge is in cubic meters per second

USAID Hydropower Investment Promotion Project (USAID-HIPP)

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