

LESOTHO POWER GENERATION MASTER PLAN

PROJECT # LEC/GEN/1-2009

FINAL MILESTONES REPORT

VOLUME 1

PART 1.1

**HYDRO POWER GENERATION
OPTION**

ABBREVIATIONS

SEE	State Ecological Expert
EIA	Environmental Impact Assessment
IRR	Internal rate of return
CW	Civil Works
E&M	Equipment and Machinery
HPP	Hydropower Plant
mil.	Million
m.a.s.l.	meters above sea level
FSL	Full supply level
MSL	Minimum supply level
PMF	Probable maximum Flood
TPP	Thermal power plant
USD	US Dollar
USc	US Cents
Min.	Minimum
Max.	Maximum
h/station, h/s	Hydro meteorological Station
PGA	Peak ground acceleration

LIST OF MEASUREMENT UNITS

t	ton
kg	Kilogram
mg	Milligram
mm	Millimetre
cm ²	square centimetre
m	meter
m ²	square meter
m ³	cubic meter
km	kilometre
km ²	square kilometre
kW	kilowatt
MW	megawatt
kWh	kilowatt-hour
MWh	megawatt-hour
kV	kilovolt
s	second
kg/sec	kilogram/second
gr/m ³	gram/cubic meter
l/sec	litre/second
MPa	mega Pascal
rpm	revolutions per minute
MVA	megavolt ampere
Hz	Hertz
m/s	meter/second
m ³ /s	cubic meter/second

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1. PROJECT OVERVIEW

1.1 Introduction

This report provides a preliminary assessment of the hydropower potential of three main rivers in Lesotho, namely, the Senqu, Makhalleng and Mohokare Rivers.

1.2 Background and project concept

Lesotho is supplied with electricity from Muela hydro power station which has a capacity of 72 MW. The current peak requirement of Lesotho is 129 MW, so there is a shortfall in the amount of power that can be produced domestically. Lesotho imports 30 MW from South Africa through ESKOM. The import requirement will have increased up to 40 MW by the end of 2010. It is noteworthy that South Africa itself has an electricity crisis. Lesotho has unexploited hydropower resources, estimated at some 361 MW (installed capacity). It may also be possible to build pumped storage plants and additional transmission lines, which will later ensure export of the local electricity to the South African market.

During this study, the Lesotho Highlands Water Project (LHWP) has been taken into account (Phase 1 has been finished and phase II, III, IV and V are prospective).

1.3 Summary description of the HPPs

The proposed schemes entail utilizing the significant hydropower potential of the Senqu, Makhalleng and Mohokare Rivers, and their tributaries, being the Hlotse, Putiatsana, Khubelu, Mokhotlong, Tsoelike, Makhalleng and Quthing Rivers. Single stage hydropower stations have been identified on the Hlotse, Putiatsana, Khubelu, Mokhotlong and Tsoelike Rivers, with four stage cascades on the river Makhalleng, and two stage cascades on the river Senqu. It may also be feasible to construct an 1800 MW (generation regime) pump storage plant on the Quthing River. The feasibility of this pumped storage scheme should be investigated taking South African surplus base load availability and peaking power requirements into account. Main characteristics of the proposed sites are given below in Table 1.

Situation Map of the Proposed Sites



No.	Site	Name of the River	GPS coordinates for the Powerhouse		Rated water discharge (m ³ /sec)	Rated Head (m)	Installed Capacity (MW)	Annual Generation (GWh)
			X	Y				
1	Hlotse HPP	Hlotse	28.184926	-28.900489	6.0	119	6.5	39.70
2	Phuthiatsana HPP	Phuthiatsana	27.695344	-29.335783	6.0	100	5.4	18.87
3	Khubelu HPP	Khubelu	28.906691	-29.187620	9.0	180	14.6	64.26
4	Polihale HPP	Mokhotlong	29.087780	-29.264696	9.0	237	19.3	83.89
5	Tsoelike HPP	Tsoelike	28.821433	-30.033732	7.0	290	17.7	69.86
6	Makhaleng 1 HPP	Makhaleng	27.88401	-29.459964	1.7	130	2.0	15.00
7	Makhaleng 2 HPP	Makhaleng	27.878764	-29.500586	4.0	38	1.4	6.15
8	Makhaleng 3 HPP	Makhaleng	27.863071	-29.622528	8.0	123	8.9	39.40
9	Makhaleng 4 HPP	Makhaleng	27.683601	-29.763382	11.0	92	9.1	58.30
10	Quthing 1 HPP	Quthing	28.135510	-30.355021	1.0	70	0.63	2.31
11	Quthing 2 HPP	Quthing	28.118918	-30.345221	1.2	221	2.4	9.61
12	Quthing 3 PSP	Quthing	28.096204	-30.324584	378.0	538	1 800.0	7 878.50
	Total						1 887.93	8 285.85

Table 1: Key characteristics of the prospective sites in Lesotho

The detailed information regarding the proposed sites is given in Appendix 1.

Note: The assessment was fulfilled based on the existing documentation provided by Lesotho Electric Company (LEC)

1.4 Costing of the project and economic framework

The project costing and economic framework has been prepared based upon the existing information, recent project data collected, South African market prices and project analogues.

1.5 Review of the existing and potential hydropower sites in Lesotho

Table 2,

Table 3 and

Table 4 show the review of the existing and projected sites.

Project	River	Capacity/Specification	Cost	Remarks	Comments
1. Muela Hydropower Project (Phase-1)	Malibamatšo / Senqu(orange)	Capacity=72MW	M483.0 mil Sept 1989	Plant was commissioned in 1998 and has been under commercial operations since.	Taking into account the existing situation in the region (ecological, energetic and other) this project is considered to be positive
2. Muela Hydropower Project (Phase-1)	Malibamatšo/ Senqu (orange)	Capacity =110MW Output=516GWh/annum Ave net head=170m		Plant is an expansion (phase) of the 'Muela Hydropower generating station, the detailed feasibility of which will be considered holistically with LHWP phase 2 feasibility studies.	The expansion of the Muela Hydropower has to be made with Polihale project after full feasibility study, as it is envisioned in the second phase of the LHWP.
3. Oxbow Hydroelectric Project	Malibamatšo	Capacity=80MW Output= 516GWh/ annum	US\$	Feasibility studies completed in 1989 by Monenco Consultants Ltd of Canada under funding from CIDA. Project suspended due to LHWP Phase 1 certainty.	Despite of lack of information the project needs to be restudied. As the project was finished in 1989, the feasibility study has to be reassessed and it has to be defined whether it envisions current demands or not.
4. Jordan Multipurpose Project	Senqunyane	Capacity=36MW Output=200 GWh/annum	M396.0 mil Jan.1984	Original pre-feasibility done by HYDROPLAN Consultants under west German Aid Program. Project also envisaged as a water supply scheme to the lowland. Project suspended due to LHWP Phase 1.	N/C
5. Quthing small Hydropower Project	Quthing	Capacity=15MW		Identification and pre-feasibility studies funded by the Austrian Government in 1984. SADCC Energy Ministers approved in 1989 as SADCC project 3.3.5 Attracted very little interest in favor of big plants.	As the project was finished in 1984, the feasibility study has to be reassessed and it has to be defined whether it envisions current demands or not. It can be reviewed as the last stage of Quthing cascade.

Table 2: Large hydropower stations

Project	River	Capacity/ Specification	Cost (USD million)	Remarks	Comments
1. Tlokoeng	Khubelu	670 KW	0.321	Commissioned in early 1990	Despite the fact that the station is in operation, the negative part of this project is lack of generation balance and duration of operation.
2. Motete	Motete	524 KW	0.408	Feasibility Study was conducted in early 1980s by SOGREAH Consulting of France	As the project was finished in 1980s, the feasibility will have to be reassessed, to define exact technical parameters and its ability to comply with current requirements.
3. Qacha's Nek	Tsoelike	482 KW	0.526	Feasibility Study was done by SOGREAH funded by France. Commissioned in mid 1990.	As the study was conducted in 1990, the feasibility will have to be reassessed, to define exact technical parameters and its ability to comply with current requirements.
4. Mokhotlong	Bafali	242 KW	0.400	Feasibility Study was conducted in early 1980s by SOGREAH Consulting of France.	As the study was conducted in 1980s, the feasibility will have to be reassessed, to define exact technical parameters and its ability to comply with current requirements.
5. Mokhotlong	Sehonghong	205KW	0.480	Feasibility Study was conducted in early 1980s by SOGREAH Consulting of France.	As the study was conducted in 1980s, the feasibility will have to be reassessed, to define exact technical parameters and its ability to comply with current requirements.
6. Semonkong 1	Maletsunyane	120 KW	0.320	Phase-1 180 KW Plant commissioned in November 1988. Phase-2 not started although provisions are in place to expand the station to 400KW	As the study was conducted in 1988, the feasibility will have to be reassessed, to define exact technical parameters and its ability to comply with current requirements.
7. Lesobeng	Lesobeng	110 KW	0.496	Feasibility Study was conducted in early 1980s by SOGREAH Consulting of France.	As the study was conducted in 1980s, the feasibility will have to be reassessed, to define exact technical parameters and its ability to comply with current requirements.
8. Sehonghong	Sehonghong	700KW	1.640	Feasibility Study done by SOGREAH, funded by France	The feasibility will have to be reassessed, to define exact technical parameters and its ability to comply with current requirements.
9. Sehlabathebe	Tsoelike (Leqooa)	100/245 KW	0.760	Feasibility Study was conducted in early 1980s by SOGREAH Consulting of France.	As the study was conducted in 1980s, the feasibility will have to be reassessed, to define exact technical parameters and its ability to comply with current requirements.
10. Mokhotlong 1A	Mokhotlong	800 KW	0.281		N/C
11. Mokhotlong 2A	Mokhotlong	700 KW	0.265		N/C
12. Mokhotlong B	Mokhotlong	1500 KW	0.288		N/C
13. Semonkong	Maletsonyane	340 KW	0.088	Feasibility Study done by NORPLAN, funded by Norway.	As the study was conducted in 1984, the feasibility will have to be reassessed, to define exact technical parameters and its ability to comply with current requirements.
14. 'Mantšonyane	Mantšonyane	2000 KW	0.098	Feasibility Study done by NORPLAN, funded by Norway.	As the study was conducted in 1984, the feasibility will have to be reassessed, to define exact technical parameters and its ability to comply with current requirements.
15. Sehlabathebe	Tsoelike (Leqooa &	150 KW	0.680		N/C

Project	River	Capacity/ Specification	Cost (USD million)	Remarks	Comments
	Tsoelikana)				
16. St. Teresa	Masnat	200 KW	0.380		N/C
17. Lethena	Quthing	2000 KW	0.244		N/C
18. Moselelo	Quthing	2500 KW	0.344		N/C
19. Likhabaneng	Likhebaneng	4500 KW	0.400		N/C
20. Pitseng	Tsainyane	70 KW	0.384	Pre-feasibility studies were conducted by Taiwan Power Company in the mid-1980s.	As the study was conducted in 1980s, the feasibility will have to be reassessed, to define exact technical parameters and its ability to comply with current requirements.
21. Ha Ntsi	Liphiring	30 KW	0.904	Pre-feasibility studies were conducted by Taiwan Power Company in the mid-1980s.	As the study was conducted in 1980s, the feasibility will have to be reassessed, to define exact technical parameters and its ability to comply with current requirements.
22. Mokhothlong	Mokhothlong	795 KW	0.235		N/C

Table 3: Micro and mini hydropower stations

Project	River	Capacity/ Specifications	Cost	Remarks	Comments
1. Monontša Pump/ Storage	Pitseng River (tributary of the Caledon River)	Capacity=1 000MW Net Static Head=620m		Memorandum of Understanding on the Project was signed between LHDA and Eskom in April 2004. Pre-feasibility studies shortly to commence.	The project is acceptable, but for the next stage of the project development diversion length has to be reassessed together with the reservoir location.
2. Three other pumped storage project	On 4 different Location.	≥1 000MW each option at net head of ≥500 m		The first pumped storage project Monontša was the most preferred site of the three identified in comparison of a number of factors. The 3 rd option to consider is the feasibility of up to 1,500 MW peaking plant at LHWP Phase2 Mashai Dam.	Despite of the lack of information on LHWP phases 2, 3, 4, and 5, we still can conclude that during the reservoir operation the water level changes down to minimum operation level will cause the increase of waterway length, which will have negative influence on Pumped Storage Plant.

Table 4: Pumped storage plants

2. CLIMATE AND HYDROLOGY

2.1 Short description

The Kingdom of Lesotho is the smallest country in Southern Africa. It is the only independent state in the world that lies entirely above 1 400 metres in elevation.

2.2 Physical-geographic description

Lesotho is located between latitudes 28° and 31° South and longitudes 27° and 30° East. Lesotho is a landlocked country, entirely surrounded by the Republic of South Africa (RSA). The country stretches over 30 648 km². It is a country with high mountains and deep valleys. More than 75% of the country is above an elevation of 1 750 m. In the east and northeast of the country lies the Drakensberg Mountain range containing the highest peak in Southern Africa, Thabana-Ntlenyana (3 482 m). The lowest area is at the junction of river Senqu and Makhaleng, 1 400 m. The Maluti Mountain range is located in the middle of the country with several high mountain peaks, which reach 3 000 m in height.

The country can be divided into three main topographic and geomorphic units:

- (a) Mountains;
- (b) Mountain foothills (between lowland and 2 050 m elevation); and
- (c) Lowlands – Mainly in the western part of the country, between the Mohokare (Caledon) River, which constitutes the border with the RSA and the foothills. The lowland area is the most highly populated and cultivated region.

Vegetation is subject to zoning. In the highlands sub-alpine meadows are widely spread, below it there are grasslands and occasional trees.

2.3 Climate

The climate of Lesotho is primarily influenced by the country's location in the Karoo basin, with altitudes ranging from 1 400 m to 3 480 m above sea level. The ocean influences of both the Atlantic Ocean and the Indian Ocean are not significant on the climate of Lesotho, but the altitude and latitude do have significant contribution. The country is under the influence of the sub-tropical zone and the basic air mass circulation is anti-cyclonic, with a westerly air current superimposed at heights of 3 000 m above sea level.

The climate is relatively cold. The summers (October to April) are humid, warm and have high rainfall. The winters are cold and dry. In the lowlands the average monthly temperature varies between 6,7 °C (June – July) and 21 °C (January). In the highlands it varies between -0,7 °C and -10,8 °C.

Precipitation in Lesotho depends on the variation in altitude. Annual precipitation is approximately 500 – 1 200 mm. Maximum precipitation occurs from December

– February, when the monthly average precipitation can be above 100 mm. The lowest precipitation is in the winter period when it is less than 12 mm, which can drop to 0 mm. The average monthly evaporation in June – July is 60 – 40 mm and in December – January it is 175 – 225 mm. The average annual evaporation in the highlands varies between 1 200 mm – 1 400 mm and it is 1 600 mm in the lowlands. Total evaporation exceeds precipitation.

Snow occurs in the beginning of winter in the highlands and sometimes in the lowlands. Occasionally snow can fall during late autumn and early spring. The snow cover in the high mountains can reach a depth of 50 cm. The frost risk in the lowlands is 110 days per year and in the mountains it is 250 days per year.

2.4 Water resources

The main resource of the Kingdom of Lesotho is water, which can satisfy the population, irrigation and hydropower demands in the country.

There are three main rivers in Lesotho:

- (a) Senqu River (becomes the Orange River): This river flows from the highlands to the west and joins the Atlantic Ocean. The total catchment area is 20 847 km²;
- (b) Makhaleng River: The total catchment area is 2 911 km². It joins the river Senqu at the border, and
- (c) Mohokare River (becomes the Caledon River): This is the trans-boundary river between Lesotho and the Republic of South Africa. The total catchment area in Lesotho is 6 890 km². It joins the Senqu River at the Gariep Reservoir.

All three rivers are characterized by a well-developed network of tributaries, which are short, but with high runoff during the rainfall periods, due to the location in the highlands.. The river flow, which is dependant upon precipitation, is therefore seasonal. The highest flow in the Senqu River occurs during six months (November - April), of which 75% of precipitation occurs in this period. The eastern part from the Maluti and Drakensberg mountain slopes is used for pastures. Rivers are characterized by good water quality and low sediment composition. Rivers are fed from different sources: rain, snow and groundwater, with the primary source being rainfall.

Eighty percent of the total rainfall occurs during the seven wettest months (October – March), which is when most floods occur. Spring is the high flow period.

According to the Food and Agriculture Organization (FAO) in 2000 the total water consumption was estimated at 43.6 million m³ which is 1,5% of total actual renewable water resources of 2000 (Water Report no.29, 2005). Industry is the main water user with 22 million m³ (51%), followed by the domestic sector with 21 million m³ (48%), and agriculture with only 0.6 million m³ (1%).

Distribution of water and reliability of rainfall are serious constraints on agricultural production in Lesotho. Taken as a whole, rainfall in Lesotho is at a level that is adequate to sustain healthy agricultural activity. However, the erratic nature of its distribution is a major constraint for food production:

- The seasonal distribution of precipitation varies considerably and therefore may not meet the demands at the appropriate time;
- Extreme weather conditions occur periodically; droughts are said to occur three years out of every ten, heavy frosts are frequent and heavy unseasonable rains also occur from time to time, and
- Rainfall may not always be easily accessible for agriculture, which may introduce a need for construction of storage and conveyance systems.

Reservoirs are therefore required in the system to ensure regulation of the rivers through calculated releases. The water deficit during low flows will then be supplemented by reservoir releases, and the flood absorption capability of reservoirs can also result in the decrease in the magnitude of the flood peaks. The sizing of the reservoir and the development of operating rules governing the releases can be calculated through analysis of historical data (a minimum of a 20 year record period should be used), or generation of stochastic data, through statistical and probabilistic methods.

For example the graphs prepared based on the flow data series for the hydro meteorological station SG 005 on the Senqu River are shown below. Figure 1 shows the flow duration curve for Gauge SG005 based on daily data (1967 - 2010) plotted on a logarithmic scale, while Figure 2 shows the annual flow for the same gauge .

From Figure 1 it can be seen that the flow that is exceeded 50% of the time is only 14 m³/s, while the flow exceeded 90% of the time is 2.4 m³/s. The opportunity for run-of-river generation is therefore limited.

Figure 2 shows that on an annual basis, the river flows vary between 500 and 4 400 million cubic metres per annum with the average (the mean annual run-off or MAR) at about 15 million m³/annum or 48 m³/s. With a reservoir in the system it would be possible to utilise a significant proportion of this flow for hydropower development. For example, with a live reservoir storage equal to the MAR it would be possible to draw off about 90% of the MAR on a continual basis with a 90% level of assurance. This option is more expensive than utilizing the run-of-river flows, but needs to be assessed thoroughly before the next phase of the project. For the next phase of the project, flow data will be patched in order to provide a longer record period of historic data (>60 years).

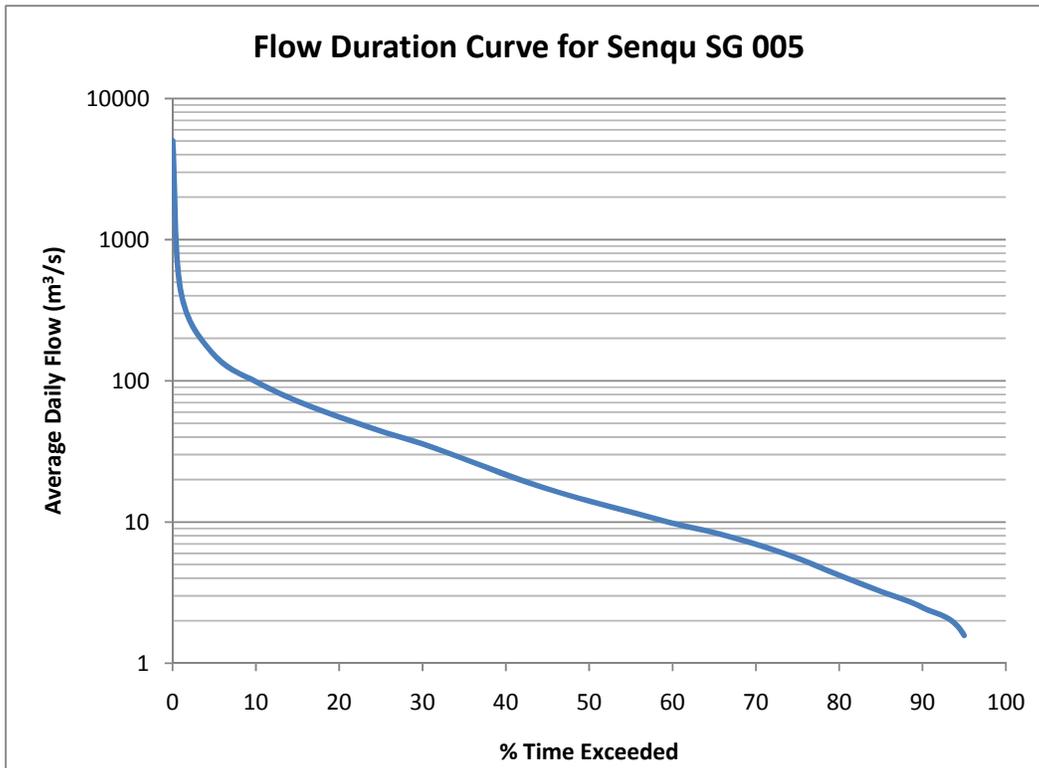


Figure 1: Flow Duration Curve for Gauge SG005

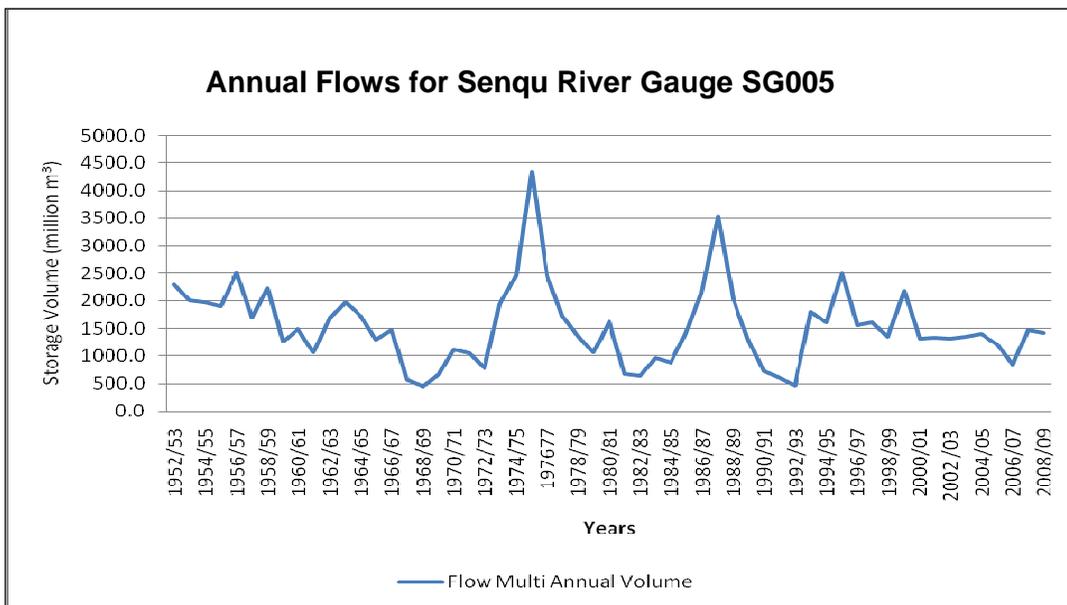


Figure 2: Annual Flows for Gauge SG005 on the Senqu River

2.5 Methodology and sources

In order to identify the hydropower potential of the proposed rivers in Lesotho, the annual data for the meteorological stations has been used. For the next phase of

the project more detailed hydrological assessments will need to be carried out. For the Senqu, Makhaleng and Mohokare Rivers, a hydrological analysis has been performed based on the data from the Water Resources 2005 Report, published by the Water Research Commission and the Department of Water Affairs and Forestry in South Africa (www.dwa.gov.za), which are shown in Table 5: **Hydrological Stations** below.

River	Hydrological Station	Catchment area(km ²)	Record Period
Senqu	SC 006	1660	1967/68 – 2009/2010
Senqu	SC 005	7950	1966/67 – 2009/2010
Senqu	SC 004	11000	1964/65 – 2009/2010
Senqu	SC 003	19875	1972/73 – 2009/2010
Makhaleng	MG019	86	1964/65 – 1984/85
Makhaleng	MG021	2911	1948/49 – 2009/2010
Mohokare	CG 069	304	1993/94 – 2008/09
Mohokare	CG 039	5600	1972/73 – 2008/09
Mohokare	CG 022	8216	1989/90 – 2008/09

Table 5: Hydrological Stations

2.6 River multi annual flow

2.6.1 Senqu River

Historical data has been used for the hydrological analysis. There are a number of gaps in the daily flow data which require patching using statistical methods. The patched data is provided in Table 6-9 below.

Average Monthly Discharge (m³/s)

No.	Years	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Annual Total	Monthly Average
1	1964/1965									0.727*	0.601*	2.174*	4.706*		
2	1965/1966	2.134*	3.559*	3.425*					6.164*	0.666*	0.525*	0.339*			
3	1966/1967			8.041*			8.765*	7.34*	1.577*	0.876*	0.581*		1.444*		
4	1967/1968	0.052	8.402*	7.081*	1.911	2.516	4.072	3.113	1.255	0.760*	0.557*	0.229*	0.000*	29.947	2.496
5	1968/1969	0.033	3.136*	6.130*	4.965*	1.864*	6.034	7.912	1.789	1.511	0.522*	0.000*	0.006	33.902	2.825
6	1969/1970	0.998	0.030	2.573	12.152*	14.317*	1.429*	1.035*	0.989*	0.575*	0.477*	0.171*	1.694*	36.440	3.037
7	1970/1971	21.912*	7.460*	7.231*	9.897	22.884	4.658	7.875	2.264	0.894	0.677	1.194	0.000*	86.947	7.246
8	1971/1972	4.080	5.377	10.678	41.146	44.849*	-	-	1.672*	0.728*	0.513*	0.000*	0.000*		
9	1972/1973	1.054	9.928	5.171	1.479	11.321	8.540	9.376	1.533	0.370	0.139	4.186	3.904	57.001	4.750
10	1973/1974	16.078	9.024	8.434	54.412	79.641*	15.352*	5.279*	1.876	1.380	0.671	0.045	0.031	192.224	16.019
11	1974/1975	0.000	15.301	8.828	42.889	105.162	36.351	7.108	1.777	0.926	0.737	0.287	6.065	225.430	18.786
12	1975/1976	9.993	18.352	25.190	62.787	69.057	101.759	13.278*	7.846	3.782	1.184	0.432	0.710	314.371	26.198
13	1976/1977	37.798	39.702	6.703	18.230	47.340	26.298	8.746	1.289*	0.894	0.589	0.390	0.959	188.936	15.745
14	1977/1978	10.042	8.111	2.880	49.394*	9.476	11.582	23.822	3.291	0.890	0.562	0.415	3.692	124.156	10.346
15	1978/1979	6.502	4.111	30.028	6.471	9.660	22.125	1.323	2.540	1.317	1.048	6.692	8.628	100.445	8.370
16	1979/1980	4.855	5.734	12.450	11.699	18.428	14.032	2.603	0.899	0.532	0.406	0.314	1.940*	73.891	6.158
17	1980/1981	3.370*	5.323*	10.318	35.418	36.839	7.630	1.643	1.096	0.824	0.614	0.779	10.929	114.786	9.566
18	1981/1982	1.827	1.925	9.028	3.704	1.372	9.451	7.687	1.876	0.551	0.515*	0.034*	0.000*	37.935	3.161

No.	Years	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Annual Total	Monthly Average
19	1982/1983	1.836	16.621*	0.851	2.933	4.968	2.313	0.959	0.468	0.307	0.321	0.281	0.321	32.179	2.682
20	1983/1984	2.160*	6.280*	13.345*	32.914*	8.619	10.048	6.430	1.069	0.712	0.563	0.626	1.195	83.960	6.997
21	1984/1985	0.911	0.931	1.221	15.151	90.167	7.874	2.124	1.206	0.624*	0.507*	0.000*	0.000*	120.716	10.060
22	1985/1986	0.000*	29.706	28.745	9.802	17.655	4.379	2.684	1.809	1.716*	0.801	3.345	7.370	108.014	9.001
23	1986/1987	16.479	30.911	8.494	3.130	2.421	2.260	1.458	0.830	0.732	0.794	1.537	45.172	114.220	9.518
24	1987/1988	136.803	5.737	1.650	1.130	107.187	93.880	4.502	2.009	1.530	2.657	3.198	9.369*	369.653	30.804
25	1988/1989	3.017	10.503	18.704	30.443	48.294	10.168	2.521	1.997	1.229	0.893	0.331	0.232*	128.331	10.694
26	1989/1990	0.353	16.162*	13.074*	3.366	3.369	2.212	4.584	3.475	0.742*	0.523*	1.818*	0.643*	50.321	4.193
27	1990/1991	0.000*	3.374*	4.701*	23.433	43.651	7.051	1.479	0.553	0.370	0.296	0.231	0.000*	85.139	7.095
28	1991/1992	21.650*	8.041*	3.482	2.269	0.653	1.189	0.295	0.222	0.159	0.126	0.222	0.324*	38.632	3.219
29	1992/1993	0.000*	8.707*	0.542	4.005*	6.387*	3.679*	4.960*	1.366*	0.191	0.152	0.139	0.000*	30.128	2.511
30	1993/1994	24.965*	9.456*	12.690*	27.528*	114.661*	-	-	-	0.731*	0.540*	0.678*	0.000*		
31	1994/1995	0.000*	2.970*	1.961*	7.039*	12.241*	6.764*	4.342*	1.581*	0.304	0.523*	2.012	1.711	41.448	3.454
32	1995/1996	3.975	13.358	23.970*	-	57.608*	37.528*	-	1.284	0.703*	0.567*	4.405*	3.372*		
33	1996/1997	22.504	14.270	7.862	22.075	9.213*	16.434*	15.370*	2.071*	1.438*	0.643*	2.838*	3.205*	117.922	9.827
34	1997/1998	1.572	1.720	5.215	-	-	28.148*	3.168	1.276*	0.691*	0.539*	-	0.000*		
35	1998/1999	0.000*	9.858*	8.979*	10.383*	19.400*	8.135*	1.927	0.627	0.643*	0.523*	0.318*	0.000*	60.793	5.066
36	1999/2000	0.000*	2.970*	10.538*	9.308		24.277*	7.021*	0.627*	0.786*	0.548*	0.596	3.193*		
37	2000/2001	7.311*	9.480*	10.393*	16.173*	20.490*	8.973*	6.571*	2.007*	0.757*	0.577*	0.857*	13.484*	97.073	8.089
38	2001/2002	5.995*	37.259*	11.350*	23.948*	30.087*	7.234*	2.287*	2.381*	0.844*	0.593*	11.634	16.143	149.755	12.480
39	2002/2003	1.267	2.187	19.165	12.418	4.846	20.977*	4.112*	1.469	0.674	0.447	0.411	0.284	68.256	5.688
40	2003/2004	0.190	4.062	3.241*	11.777*	19.234*	11.171*	3.280	0.504	0.335	0.352	0.315	0.365	54.825	4.569
41	2004/2005	1.667	4.900	22.542	20.929*	8.710*	12.306*	4.327	0.996	0.585	0.504	2.004*	0.878*	80.348	6.696
42	2005/2006	5.126*	5.938*	4.754*	17.605*	88.237*	22.309*	7.248*	1.652*	0.852*	0.635*	-	2.396*		
43	2006/2007	-	-	-	-	-	3.109	0.786	1.403*	0.855*	0.640*	1.324*	0.162		
44	2007/2008	23.630	7.021	9.769	12.418*	14.795*	19.628	4.002	2.970	1.025	0.562	0.481	0.394	96.695	8.058
45	2008/2009	0.394	0.696	19.694	20.007	35.076	17.293	1.525	0.951	0.784	0.928	0.518	0.601	98.468	8.206
46	2009/2010	0.286	0.460	-	10.909*	116.602*	4.226*	3.517*	1.219*	0.740*	-	-	-		
														Average	8.674

Note: * Patched data

Table 6: Orange River (Senqu) - SG 006 Catchment Area =1660 km²

Average Monthly Discharge (m³/s)

No.	Years	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Annual Total	Monthly Average
1	1964/1965									7.322*	8.765*	15.748*	35.855*	67.69	
2	1965/1966	23.175*	4.945*	14.267*					6.079*	4.549*	3.689*	4.06*			
3	1966/1967	-		45.884	-	-	41.474*	55.071*	17.520*	14.084*	7.394*	-	15.339*	196.77	
4	1967/1968	1.668*	45.647*	39.310*	15.771*	9.947	21.426	19.687	40.994	8.832	5.777	3.354	5.444	217.86	18.15
5	1968/1969	7.666	1.399	32.793	8.566	10.170	28.674	47.131	16.878	11.386	3.452	1.590	1.252	170.96	14.25
6	1969/1970	44.199	28.125	54.540	39.545	50.342	7.509	2.530	1.185	0.405	0.483	2.989	16.911	248.76	20.73
7	1970/1971	92.573*	37.731*	40.334*	71.533	67.590	25.079*	56.074	17.469	4.493	4.418	4.980	4.961	427.23	35.60
8	1971/1972	6.556	15.654	34.663	130.003	148.832	-	-	20.163	7.348	2.862	1.725	1.453	369.26	
9	1972/1973	10.843	35.940*	11.153	4.080	72.363	40.845	37.554	6.723	2.861	1.451	40.479	32.561	296.85	24.74
10	1973/1974	52.773	29.542	51.601	171.353	261.066	71.966	37.902	16.757*	18.238*	6.784*	7.879	8.144	734.00	61.17
11	1974/1975	3.856	152.983	72.912	145.524	311.512	151.523	27.325	11.438	6.721	6.924	3.782	40.033	934.53	77.88
12	1975/1976	79.257	191.935	143.989	273.582	318.698	459.577	104.557	33.585*	21.800*	7.274*	2.645	15.501	1652.40	137.70
13	1976/1977	249.325	232.587	20.033	49.912	156.868	170.675	34.308	9.533	3.994	3.133	3.969	5.312	939.65	78.30
14	1977/1978	82.969	39.947	14.430	200.069	34.726*	34.534*	171.141	18.702*	5.569	3.789	3.504	45.680	655.06	54.59
15	1978/1979	49.842	7.432*	159.484	34.655	38.687*	36.165*	5.130	8.272	7.770	11.878*	70.972*	89.423	519.71	43.31
16	1979/1980	81.101	36.362*	92.014	43.166	63.603*	48.884	9.417	3.834	3.128	2.345	1.958	18.462	404.27	33.69
17	1980/1981	27.513*	19.773*	54.275	196.826	102.730	61.363	36.329	21.939	25.251	4.101	20.838	49.296	620.24	51.69
18	1981/1982	8.490	31.059	74.003	14.420	9.828	20.331	64.708	20.987	4.069	2.996	2.115	2.221	255.23	21.27
19	1982/1983	30.458	114.718	11.558	9.622	16.706	16.476	10.771	11.052	5.216	3.029	5.088*	6.430*	241.12	20.09
20	1983/1984	23.265	27.817	82.212*	129.036*	21.015*	28.112	21.012	13.708	3.466	2.593	2.264	14.419	368.92	30.74
21	1984/1985	8.954	25.154	16.104	30.147	188.572	39.518*	10.941	3.309	2.644	2.440	1.748	1.267	330.80	27.57
22	1985/1986	10.533	123.122	189.374	44.697	72.239	15.554	18.423	6.829	15.282	3.491	8.040	36.373	543.96	45.33
23	1986/1987	113.700	250.595	47.168	20.531*	15.862	17.762*	28.553	3.922	2.239	2.019	26.768	282.556	811.67	67.64
24	1987/1988	402.806	75.339	57.988	41.661	172.490*	435.523*	31.425*	16.768*	16.242*	11.735*	11.778*	65.182*	1338.94	111.58
25	1988/1989	50.910*	81.072*	127.758*	107.067*	159.945*	72.529*	28.666*	35.636*	66.799*	18.844*	8.842*	7.452*	765.52	63.79
26	1989/1990	6.803*	110.853	80.357*	31.295*	44.403	38.149	86.492	54.278*	7.984	3.541	13.476*	10.299*	487.93	40.66
27	1990/1991	3.881*	3.394	23.006	59.380	133.033	38.512	5.037	2.714	1.671	1.188	1.045	1.936	274.80	22.90
28	1991/1992	91.654	42.612	35.721	25.887*	4.886	8.486	1.809	2.140*	2.006*	2.970*	3.314*	8.293*	229.78	19.15
29	1992/1993	6.032*	48.207	8.969	4.426	24.762*	17.924*	35.239*	11.668*	4.036*	3.431*	4.546*	5.141*	174.38	14.53
30	1993/1994	103.285*	54.500*	77.723*	105.820*	374.031*	-	-	-	7.498*	4.688*	6.216*	4.935*	738.70	
31	1994/1995	0.092*	0.000*	4.242	17.504	43.644	32.207	30.092	17.645*	5.254	3.519	2.620	5.171*	161.99	51.18
32	1995/1996	1.693	6.389	154.988*	-	189.990*	174.634	-	11.619*	6.216*	6.456*	29.958*	27.465	609.41	
33	1996/1997	14.676	16.651	58.995	39.502	33.876	76.979	121.995	31.259*	39.614*	11.532*	19.977*	26.413*	491.47	49.25
34	1997/1998	11.400*	0.330*	29.832*	-	-	131.209*	20.308*	9.169*	5.682*	4.573*	-	4.467*	216.97	
35	1998/1999	2.532*	57.879*	52.311*	31.917*	66.738*	38.557*	9.967*	6.031*	3.485*	3.526*	3.926*	0.000*	276.87	42.72
36	1999/2000	1.930*	0.000*	62.986	27.284*	-	113.285	52.413	29.463*	10.008*	5.188	5.507	26.337	334.40	
37	2000/2001	41.342*	54.708*	61.992	56.873	70.256	42.435	48.666	39.866*	8.704	7.153	7.354	91.060	530.41	41.99
38	2001/2002	36.722	288.140	68.545	90.389*	101.212*	34.384	12.963	15.138*	12.631	8.201	51.574	104.736	824.64	42.47
39	2002/2003	15.799	20.752	47.618*	40.690*	38.781	98.007	28.178	10.270	6.953	5.611	5.974	4.023	322.66	41.93

No.	Years	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Annual Total	Monthly Average
40	2003/2004	1.211*	9.176*	13.006	37.927*	66.203*	52.613*	21.983*	10.320	6.634	6.230	8.764	12.073*	246.14	43.15
41	2004/2005	23.117	27.638	40.751	77.375	32.254	57.864	29.969	14.686	10.577	11.842	14.662	11.778	352.51	44.50
42	2005/2006	33.675	24.939	23.368	63.046*	288.793*	104.177	54.310	19.609	12.990	11.033	-	21.325	657.27	
43	2006/2007	-	-	-	-	-	24.923	19.494	12.703	13.144	11.324	10.333	8.526	100.45	
44	2007/2008	86.860	44.939	110.842	40.691	51.885	60.493	38.845	24.264	16.694	13.252	12.766	5.213*	506.74	46.50
45	2008/2009	1.332*	0.000*	66.726	110.808*	307.223*	97.606*	23.372*	9.373	9.779	8.247	10.272	7.544	652.28	45.09
46	2009/2010	31.728	25.811*	-	34.184	380.290*	20.460	23.220	7.577	7.900	-	-	-	531.17	
														Average	45.309

Note: * Patched data

Table 7: Orange River (Senqu) - SG005 F=7950 km²

Average monthly discharge (m³/s)

No.	Years	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Annual Total	Monthly Average
1	1964/1965		-	-	-	-	-	-	-	7.428	12.154	19.281	42.094		
2	1965/1966	28.356	15.58	12.962		-	-	-	5.984	4.367	2.807	2.292	-		
3	1966/1967		-	52.490		-	58.266	69.461	18.668	14.892	9.630	-	15.346		
4	1967/1968	2.964	60.20	49.736	15.248	9.967	22.295	22.555	42.358	7.954	5.651	3.503	7.461	249.898	20.82
5	1968/1969	5.747	7.22	45.447	12.172	12.867	38.004*	59.068*	18.928	17.895	2.895	3.137	3.181	226.560	18.88
6	1969/1970	46.856	32.21	46.345	34.964	49.607	7.204	3.778	2.154	2.100	2.057	3.162	11.238	241.676	20.14
7	1970/1971	110.290	51.52	51.239	80.011	66.941	32.365	56.420	20.058	6.826	5.708	4.192	3.627	489.200	40.77
8	1971/1972	5.294	17.25	43.670	158.774	193.890	-	-	20.947	8.552	4.017	3.061	3.056		
9	1972/1973	13.085	49.56	18.550	9.267*	91.491	42.855	47.097	7.523	3.659	3.011	36.534	30.353	352.985	29.42
10	1973/1974	49.349	18.84*	54.304	249.768	432.262*	120.781	46.988*	17.823	19.477	8.506	6.879	8.824	1033.804	86.15
11	1974/1975	4.064	170.14	100.807	117.969	349.294	177.562*	33.144*	9.463	4.801	5.371	2.532	36.443	1011.591	84.30
12	1975/1976	96.928	211.61	215.407	380.287	450.100*	718.776*	134.233*	36.479	23.408	9.409	5.540	11.746	2293.921	191.16
13	1976/1977	255.624	237.59	22.804	68.854*	268.153*	245.439*	42.284*	12.308	5.543	3.871	2.160	2.937	1167.569	97.30
14	1977/1978	85.705	53.06*	24.927*	263.841	96.014*	47.301	221.385*	19.979*	8.357	5.039	1.060*	47.410*	874.076	72.84
15	1978/1979	42.820*	18.30*	180.208	40.675*	47.611	49.879*	4.093*	5.699*	3.309*	17.887	99.548	91.431	601.461	50.12
16	1979/1980	87.111	50.02	112.412	56.174*	82.662*	50.479*	9.704*	5.460	3.022	2.010	1.613	2.063*	462.734	38.56
17	1980/1981	33.478	31.83	56.227	171.148*	181.595*	67.088	34.306	22.117	24.602	8.473	21.875*	58.506*	711.248	59.27
18	1981/1982	10.653	42.21*	100.680*	13.304*	15.450	33.059	65.699	20.782	4.932	4.260*	2.018*	3.109	316.155	26.35
19	1982/1983	28.251	135.93*	8.984*	11.167*	17.833	16.223	10.929	10.218	5.783	2.698	3.787	3.730	255.533	21.29
20	1983/1984	22.045	28.30	112.734	178.219	27.529	34.532	32.138	17.544	3.377	3.580*	5.360	13.626	478.982	39.92
21	1984/1985	7.809	24.02	15.929	30.857	183.819	55.176	13.490	2.881	5.602	1.972	1.403	1.159	344.112	28.68
22	1985/1986	17.299	145.16*	260.362	79.131*	115.063	25.358	33.416	10.272	16.360	3.895	2.869	42.769	751.950	62.66
23	1986/1987	133.857	289.81*	34.755*	22.096	18.764	20.805	34.622	5.007	2.185	1.988	26.063	281.616*	871.565	72.63
24	1987/1988	481.280	106.69*	67.337	49.617	199.664	680.776*	86.418*	17.835	17.274	17.624	13.510	80.330	1818.354	151.53
25	1988/1989	61.101	99.05	179.616	146.608	185.405*	107.326	34.899	38.753	73.076	30.717	9.243	5.063	970.852	80.90
26	1989/1990	9.207	131.70	110.010	37.584	46.118	79.006*	93.242	51.754	8.159	12.302	15.978	8.775	603.837	50.32
27	1990/1991	5.577	4.24	29.046	97.010	419.835*	137.491*	14.296	2.254*	2.438	1.790	1.055	2.114	717.152	59.76

No.	Years	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Annual Total	Monthly Average
28	1991/1992	108.671	48.09	44.466	29.803	15.302	12.201	3.856	1.618	1.561	1.483	1.208	6.159	274.422	22.87
29	1992/1993	8.117	76.18	30.529	19.926	31.787	21.061	43.503	12.181	3.801	2.331	2.999	2.050	254.471	21.21
30	1993/1994	122.937*	69.91	106.142	144.815	428.684*	-	-	-	7.623	4.646	5.426	1.780*		
31	1994/1995	1.104	4.78	2.541	17.474	49.760	55.386*	36.766*	18.807*	5.776	5.255*	3.172*	2.088*	202.912	16.91
32	1995/1996	11.136	46.74	219.600	-	219.547	268.629*	-	12.126	6.208	7.903	39.935	28.026		
33	1996/1997	114.897	111.92	76.388	155.674	60.861*	118.276*	157.058*	33.900*	43.071*	17.250*	25.427*	29.784	944.509	78.71
34	1997/1998	14.455	10.51	35.818	-	-	200.027	23.959*	9.410	5.618*	4.434	-	1.171*		
35	1998/1999	3.985	73.62	68.827	38.479	79.487	53.657*	20.675*	5.931	3.193	2.506	2.097	0.000*	352.453	29.37
36	1999/2000	3.274	4.68	67.773	33.603*	-	171.711*	100.965	31.909	10.393	5.567	4.395*	43.582*		
37	2000/2001	49.804*	70.14	87.253	73.890	109.344	53.492*	61.077*	43.442	6.182	5.224	4.646	133.237	697.729	58.14
38	2001/2002	51.425*	326.10*	113.482	122.611	118.662	39.108*	23.028*	16.028*	13.956	7.866	81.996	156.791*	1071.049	89.25
39	2002/2003	14.806*	25.27*	61.935*	52.809*	52.721*	147.575*	34.260*	8.471	4.761	3.501	3.494	2.283	411.886	34.32
40	2003/2004	2.425	15.45	13.026	47.126	78.879	75.863*	26.152	7.130	3.629	3.327	4.892*	11.087*	288.991	24.08
41	2004/2005	25.991	35.02	54.728	90.028*	32.711*	84.158*	34.053	10.681	5.207	5.523	7.342*	5.936*	391.377	32.61
42	2005/2006	40.753*	37.50*	31.282*	83.269*	331.823*	149.910*	38.348*	16.878	9.588*	-	-	23.150*		
43	2006/2007		-	-	-	-	12.987*	19.470*	6.467*	4.064*	-	11.410*	2.248		
44	2007/2008	103.545*	61.38*	154.775*	51.104*	66.187	83.938	36.337	22.676	10.903	6.471	5.237	2.143	604.697	50.39
45	2008/2009	2.568	11.06	110.042	151.991	352.766	146.942	27.970	5.862*	12.622*	12.339*	14.000*	7.079*	855.244	71.27
46	2009/2010	38.454	38.45*	-	67.340*	435.799*	36.599	27.771*	7.645*	8.066*	-	-	-		
														Average	55.23

Note: * Patched data

Table 8: Orange River (Senqu) - SG004 F=11000 km²

Average Annual Discharge (m³/s)

No.	Years	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Annual Total	Monthly Average
1	1964/1965									29.746*	51.262*	56.694*	94.614*		
2	1965/1966	70.49*	45.998*	22.329*					16.063*	18.325*	7.584*	9.503*			
3	1966/1967			102.184*			118.458*	178.597*	60.413*	57.597*	39.467*		38.184*		
4	1967/1968	22.167*	135.256*	96.62*	21.121*	45.051*	51.222*	43.421*	143.245*	31.709*	20.874*	12.867*	21.549*	645.102	53.76
5	1968/1969	27.504*	29.284*	87.956*	15.403*	49.057*	80.66*	148.646*	61.322*	68.802*	7.995*	11.85*	12.519*	600.998	50.08
6	1969/1970	105.662*	79.268*	89.77*	57.768*	99.802*	23.015*	7.488*	2.671*	9.866*	4.079*	11.919*	29.517*	520.825	43.40
7	1970/1971	226.259*	117.896*	99.657*	141.498*	123.744*	70.045*	141.014*	65.273*	27.5*	21.140*	14.781*	13.46*	1062.267	88.52
8	1971/1972	26.646*	49.34*	84.366*	287.898*	299.088*			68.381*	33.94*	13.238*	11.639*	12.255*	886.791	
9	1972/1973	30.941	70.178	30.373	10.004	143.397	85.765	94.836	15.664	5.579	3.996	69.320	51.844	611.898	50.99
10	1973/1974	59.986	52.532	80.549	384.368	628.331	212.827	126.539	45.076	70.178	38.895	55.766	32.724	1787.772	148.98
11	1974/1975	9.512	329.381	169.799	152.257	459.127	341.442	60.357	26.487	14.944	28.778	10.278	57.172	1659.533	138.29
12	1975/1976	130.870	324.509	431.309	671.885	652.969	1153.055*	239.068	122.689*	108.849	29.632	16.748	49.763	3931.346	327.61
13	1976/1977	614.755	465.630	39.281	120.761	401.662	468.296	90.159	41.301	16.180	10.703	9.136*	27.769	2305.633	192.14
14	1977/1978	186.676	120.966	46.502	394.677	163.901	89.640	470.327	66.018	17.308	10.108	6.081	105.830	1678.033	139.84
15	1978/1979	97.989	51.452	360.199	68.382	97.419	102.781	15.873	16.089	14.375	53.141	227.324	158.101	1263.125	105.26

No.	Years	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Annual Total	Monthly Average
16	1979/1980	195.097	83.769	163.070	97.191	145.459	103.902	30.815	9.754	5.584	3.290	2.548	10.161	850.640	70.89
17	1980/1981	69.321	66.749	131.142	310.897	282.106	156.031	66.223	63.270	93.828*	15.911	63.899	129.239	1448.615	120.72
18	1981/1982	32.169	99.264*	199.537*	17.507*	72.992	78.895	222.111	73.004	18.911	14.376	8.741	5.860	843.368	70.28
19	1982/1983	58.593	286.708*	14.293*	13.536	29.050	22.282	25.020	30.030	25.444	15.750	21.945	9.449	552.098	46.01
20	1983/1984	58.492	71.446*	223.889*	324.041*	69.308*	74.095*	71.037*	43.160	12.725	11.200*	5.450	42.625	1007.468	83.96
21	1984/1985	13.093	51.997	23.284	48.415	346.973	172.045	55.670	12.078	8.484	4.955	1.787	0.497	739.279	61.61
22	1985/1986	33.930	305.157*	433.222	139.863	161.096	44.304	30.708	16.919	35.979	8.326	6.267	102.047	1317.818	109.82
23	1986/1987	215.425	594.462	66.356	27.471	30.278	41.368	87.037	9.919	3.519	3.163	36.279	599.934	1715.211	142.93
24	1987/1988	732.697	228.224	126.380	93.436	340.438	1282.028*	227.464	69.887	69.478	74.236	34.204	221.975	3500.447	291.70
25	1988/1989	187.096	221.140	414.265	337.491	287.368*	224.036	97.807	85.626	191.906	88.164	40.511	24.652	2200.062	183.34
26	1989/1990	25.848	278.252*	218.386*	62.638*	100.739	157.225	240.607	139.506	67.833	98.648	71.009	24.321*	1485.013	123.75
27	1990/1991	27.265	27.043	94.941	268.506	611.167	266.542	19.620*	3.021*	11.127*	13.869	8.927	10.268*	1362.295	113.52
28	1991/1992	339.437	188.844	85.974*	48.175*	26.584	24.195	14.470	6.233	4.132	3.673	4.397	15.205	761.320	63.44
29	1992/1993	39.430	141.212	42.085	24.393	111.195	110.166	118.653	48.150	17.839	13.118	11.467*	10.133*	687.840	57.32
30	1993/1994	250.303	187.955	230.106	261.952*	623.390	-	-	-	30.474*	16.597	18.689	9.564		
31	1994/1995	2.899	24.414*	1.277*	44.703	100.014*	113.075	92.422	61.921	30.980	19.022	11.947	10.214	512.888	42.74
32	1995/1996	37.752*	108.332*	439.780*	-	376.803	511.659*	-	37.538*	25.194*	31.397*	114.067*	64.935*		
33	1996/1997	235.017*	335.979	150.463*	305.849	115.346	230.627	291.324	114.692	162.742	75.073	73.768	76.322	2167.201	180.60
34	1997/1998	50.742	35.876*	68.503*	-	-	383.432*	47.468*	76.611	20.035	11.457	-	8.278		
35	1998/1999	31.928	162.080*	135.188*	64.301*	148.405	109.843	38.002	15.878*	14.052	8.946	6.916	4.173	739.711	61.64
36	1999/2000	6.966	24.206*	133.059*	55.237*	-	330.504*	157.767	104.959	39.450	24.042	15.345	97.753		
37	2000/2001	111.268	131.853	195.045	130.121*	179.624	109.535	154.436*	170.593	35.681	22.637	34.016	267.593	1542.401	128.53
38	2001/2002	114.348	667.039	286.417	357.557	227.002	82.649	44.784	52.203	129.448	38.247	268.713	336.590	2604.997	217.08
39	2002/2003	44.731	65.387	121.264	90.935*	104.104	285.391*	77.154*	24.759*	19.795*	10.827*	19.173	12.112	875.633	72.97
40	2003/2004	9.705	26.260	35.950	85.157	146.348	151.349	98.930	26.492	16.232	13.658	16.726	29.198	656.003	54.67
41	2004/2005	70.508	66.830*	106.705*	160.118	76.465	166.854*	76.556*	48.441	21.911	17.658	23.531	18.332	853.908	71.16
42	2005/2006	94.059*	57.399	59.339	147.553	489.604	289.755	88.933	60.337	37.805	70.780	-	54.648*		
43	2006/2007	-	-	-	-	-	33.824	34.529	18.771	17.195	73.285	34.830*	6.961		
44	2007/2008	379.005*	137.607	308.820*	87.768	122.703*	166.443*	81.138*	76.912	78.896	39.849	22.806	16.453	1518.400	126.53
45	2008/2009	21.464*	19.984*	222.221	176.039	453.305	200.030	29.869	16.658	49.125	52.125	42.021	20.742	1303.584	108.63
46	2009/2010	267.156	170.573	-	117.947	633.217	77.959*	58.452*	21.871*	32.128*	-	-	-		
														Average	112.649

Note: * Patched data

Table 9: Orange River (Senqu) F=19 875 km²

Station	Catchment Area (km ²)	Standard (m ³ /s)	Sediment Volume (m ³ /annum)	Cv*	Cs*	Cs/Cv*
SG - 006	1660	9.45	324.4	0.572	1.853	3.2
SG - 005	7950	48.9	1575.5	0.457	1.481	3.2

Station	Catchment Area (km ²)	Standard (m ³ /s)	Sediment Volume (m ³ /annum)	Cv*	Cs*	Cs/Cv*
SG - 004	11000	60.9	1939.4	0.549	1.469	2.7
SG - 003	19875	116	3976.6	0.48	1.60	3.3

Note: * Will be defined for the next phase of project development

Table 10: Standards for hydrological stations

Hydrological analyses were carried out in which flow duration curves were produced over the full range of 0-100%. Three percentile flows were selected to be shown in Table 11 below: the 5th percentile (representing a flow which is exceeded 5% of the time), the 50th percentile (representing a flow which is exceeded 50% of the time), and the 95th percentile (representing a flow which is exceeded 95% of the time). These calculated flows were then matched to the hydrological year with the closest historical annual average flow. The distribution of the chosen year was then used to calculate the monthly average flows which are given in Table 11 below.

Orange River (Senqu) – 006 : Catchment Area = 1 660 km²

Provision	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Average
5% (1974/75)	0.000	15.301	8.828	42.889	105.162	36.351	7.108	1.777	0.926	0.737	0.287	6.065	18.79
50% (1985/86)	0.000	29.706	28.745	9.802	17.655	4.379	2.684	1.809	1.716	0.801	3.345	7.370	9.00
90% (1981/82)	1.83	1.92	9.03	3.70	1.37	9.45	7.69	1.88	0.55	0.52	0.034	0.00	3.16

Orange River (Senqu) - 005 : Catchment Area = 7 950 km²

Provision	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Average
5% (1987/88)	402.8	75.3	58.0	41.7	172.5	435.5	31.4	16.8	16.2	11.7	11.8	65.2	111.6
50% (1985/86)	10.5	123.1	189.4	44.7	72.2	15.6	18.4	6.83	15.3	3.49	8.04	36.4	45.3
90% (1969/70)	44.20	28.12	54.54	39.54	50.34	7.51	2.53	1.19	0.41	0.48	2.99	16.91	20.7

Orange River (Senqu) - 004 : Catchment Area = 11 000 km²

Provision	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Average
5% (1987/88/)	481.3	106.7	67.3	49.6	199.7	680.8	86.4	17.8	17.3	17.6	13.5	80.3	151.5
50% (1990/91)	5.58	4.24	29.05	97.01	419.84	137.49	14.30	2.25	2.44	1.79	1.06	2.11	59.8
90% (1982/83)	28.25	135.93	8.98	11.17	17.83	16.22	10.93	10.22	5.78	2.70	3.79	3.73	21.3

Orange River (Senqu) - 003 : Catchment = 19 875 km²

Provision	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Average
5% (2001/02)	114.3	667.0	286.4	357.6	227.0	82.6	44.8	52.2	129.4	38.2	268.7	336.6	217
50% (1990/91)	27.3	27.0	94.9	268.5	611.2	266.5	19.6	3.0	11.1	13.9	8.9	10.3	113
90% (1972/73)	30.9	70.2	30.4	10.0	143.4	85.8	94.8	15.7	5.58	4.00	69.3	51.8	51

Table 11: Average monthly and annual discharge of selected years

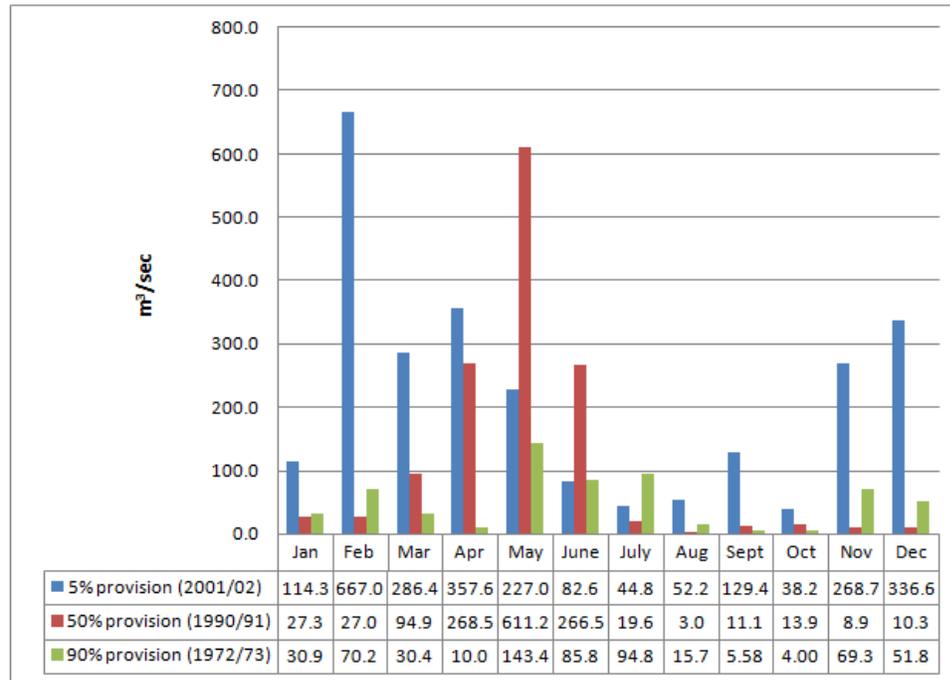


Figure 3: Senqu River – SG003 (Catchment Area = 19 875 km²)

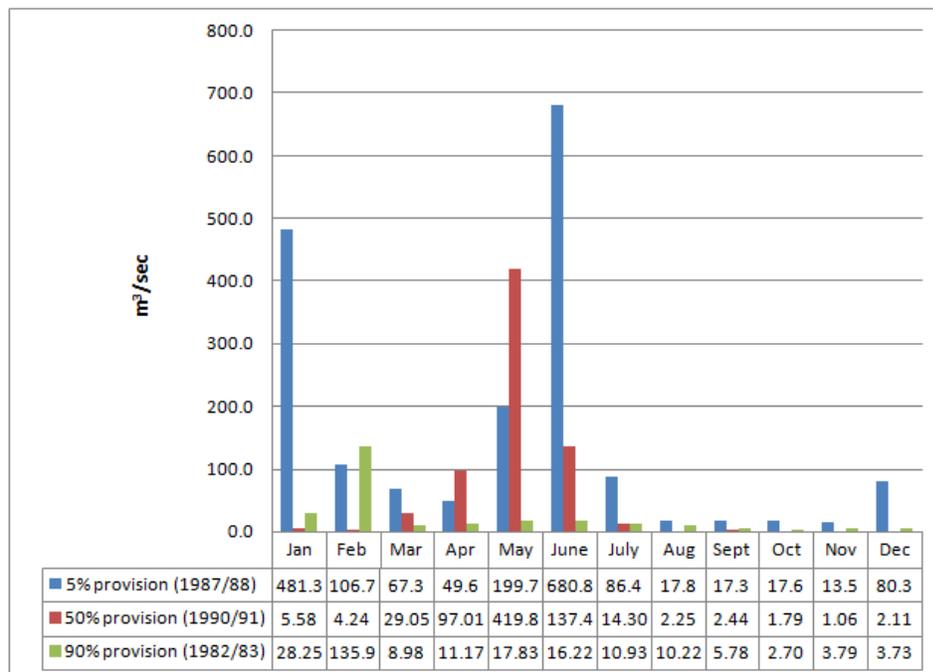


Figure 4: River Senqu SG004 (Catchment Area = 11 000 km²)

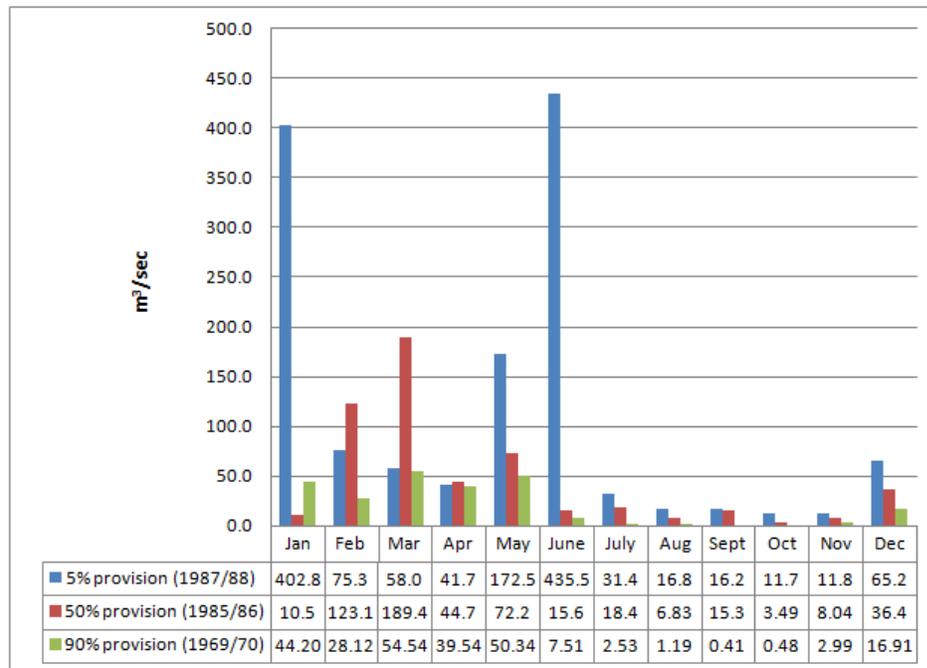


Figure 5: River Senqu SG005 (Catchment Area = 7 950 km²)

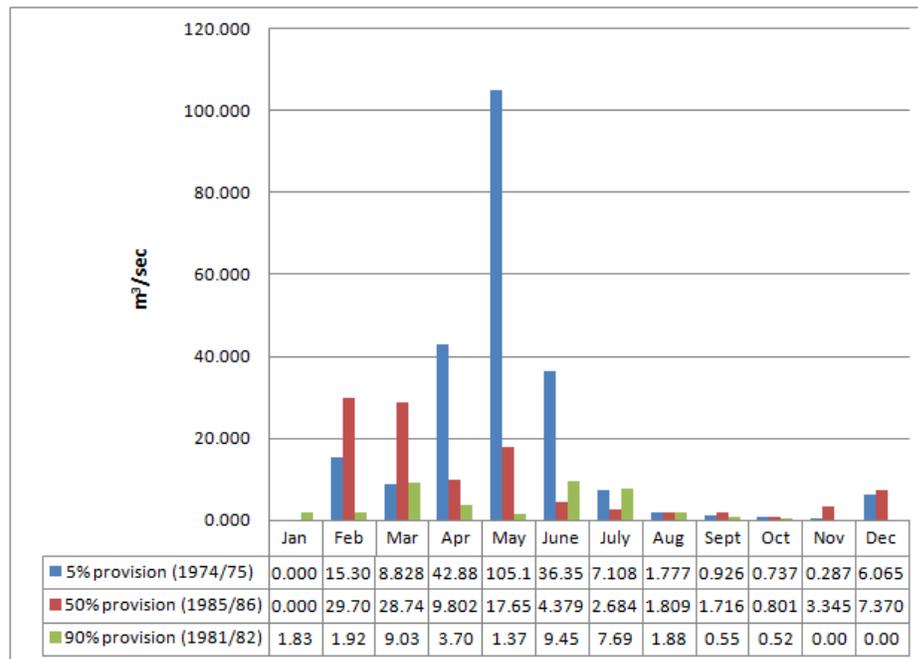


Figure 6: Senqu River SG006 (Catchment Area = 1 660 km²)

2.7 Flood flows

Flood flows for the river Senqu and its tributaries are observed in spring and summer, and reach the highest point mainly in January and February, which is

due to the higher precipitation in these months, although high flows can be observed in September as well.

Table 12 below shows the peak flows at various probabilities.

River	Catchment area (km ²)	Maximum discharge (m ³ /s)	Probability (%)						
			0.1	1	3	5	10	20	25
Senqu – SG 006	1660	271.5	2030	1450	1140	955	740	495	410
Senqu – SG 005	7950	665.2	2970	2210	1820	1620	1350	1040	940
Senqu – SG 004	11000	879.3	4031	2997	2433	2168	1770	1349	1217
Senqu – SG 003	19875	1588.7	7390	5420	4400	3920	3200	2440	2200

Table 12: Peak Flows

The peak flow data is preliminary assessment based on the flow gauging station data and requires further detailed analysis.

2.7.1 Makhaleng River

The Makhaleng, station at Molimo-Nthuse has a catchment area of 86km². The monthly discharge data is available from 1964 to 1984. Accordingly 20 year data has been collected, which is given in Table 13.

Average Monthly Discharge, m³/sec

No.	Years	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Average
1	1964/65	1.99	1.28	1	0.65	0.14	0.06	0.63	0.54	0.3	0.25	0.29	0.24	0.61
2	1965/66	0.1	0.21	0.21	1.58	3.24	0.37	0.32	0	0	0.04	0.02	0.01	0.51
3	1966/67	0.03	0.75	0.24	1.37	4.73	0.91	2.08	1.16	1.19	0.28	0.14	0.1	1.08
4	1967/68	0.05	1.27	0.25	0.14	0.08	0.16	0	0	0.39	0.44	0.15	0	0.24
5	1968/69	0	0.27	1.57	0.23	0.33	2.21	2.37	1.46	0.76	0.24	0.23	0.12	0.82
6	1969/70	0.53	0.64	0.4	0.24	0.36	0.1	0.06	0.07	0.07	0.07	0.07	0.21	0.24
7	1970/71	0.69	0.26	2.18	1.45	1.22	0.7	1.28	1.28	0.23	0.22	0.24	0.03	0.82
8	1971/72	0.09	0.05	0.3	3.11	2.45	5.8	0.96	1.52	0.49	0.28	0.13	0.09	1.27
9	1972/73	0.38	0.71	0.09	0.02	1.41	1.02	1.87	0.43	0.16	0.1	1.18	0.31	0.64
10	1973/74	0.04	0.57	0.91	5.72	5.48	1.14	0.64	0.52	0.37	0.22	0.64	0.69	1.41
11	1974/75	0.15	3.32	1.52	1.94	4.33	6.14	1.38	0.6	0.29	0.31	0.26	0.41	1.72
12	1975/76	1.07	3.35	2.54	6.5	6.4	6.5	3.7	1.3	1.1	0.42	0.24	1.1	2.85
13	1976/77	5.6	3.35	0.4	1.4	5.38	5.69	0.67	0.4	0.22	0.13	0.07	0.73	2.00
14	1977/78	2.1	1.6	1.5	6.67	2.54	3.12	3.5	0.42	0.2	0.1	0.06	0.45	1.86
15	1978/79	0.17	0.1	4.35	0.45	0.86	0.38	0.2	0.28	0.14	1.1	2.72	0.58	0.94
16	1979/80	3.43	2.5	1.3	0.68	0.57	0.36	0.37	0.13	0.1	0.17	0.14	0.33	0.84
17	1980/81	0.24	1.34	1	3.5	3.2	2.8	0.74	0.53	1.4	0.35	1.8	1	1.49
18	1981/82	0.4	2.4	1.6	1.3	2.9	0.54	5.44	0.43	0.25	0.23	0.17	0.16	1.32
19	1982/83	1.5	3.1	0.34	0.16	0.16	0.25	0.21	0.3	0.23	0.33	0.29	0.16	0.59
20	1983/84	0.26	2.1	2.4	2	0.18	0.3	0.17	1.3	0.21	0.17	0.16	0.3	0.80
Average		0.941	1.459	1.205	1.956	2.298	1.928	1.33	0.634	0.405	0.273	0.45	0.351	1.10

Table 13: Makhaleng River Molimo-Nthuse (Area = 86 km²)

The catchment of the Makhaleng river area at the national border is 2911 km². Monthly data has been converted into discharge and put in order according to the hydrological year (October to September) as shown in Table 14 below.

Average annual discharge (m³/s)

No.	Years	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Average
1	1948/1949	0.25	2.23	0.86	1.73	3.70	20.95	0.64	5.60	1.28	0.63	0.51	0.44	3.23
2	1949/1950	0.56	9.92	11.86	8.44	41.75	69.82	152.39	57.87	12.42	23.15	29.76	53.24	39.26
3	1950/1951	3.74	1.99	111.04	19.96	16.12	44.43	22.22	2.36	2.99	2.44	1.92	1.57	19.23
4	1951/1952	95.82	20.18	1.38	5.13	26.78	5.86	2.36	1.70	1.50	5.23	4.70	15.01	15.47
5	1952/1953		11.00	12.09	5.40	18.60	8.33	37.85	6.72	2.41	0.84	0.77	1.28	
6	1953/1954	21.56	9.57	33.88	7.87	11.66	52.27	15.97	8.62	4.24	2.25	1.72	2.13	14.31
7	1954/1955	1.64	1.67	0.54										
8	1955/1956						46.30	60.57	11.95	6.67	4.07	2.27	2.21	
9	1956/1957	1.89	17.09	78.71	13.84	42.99	13.78	9.49	2.23	1.46	1.55	3.70	41.67	19.03
10	1957/1958	74.15	29.48	21.29	73.01	21.74	10.83	22.07	28.82	12.27	4.89	3.18	2.21	25.33
11	1958/1959	1.78	24.27	12.78	14.79	32.74	18.03	7.79	1.34	10.15	14.67	7.28	2.69	12.36
12	1959/1960	5.97	13.00	52.10	12.13	14.81	17.77	28.94	18.41	7.29	4.74	9.97	5.67	15.90
13	1960/1961	7.22	20.83	16.77	15.82	14.84	24.38	55.56	29.01	46.68	9.52	6.24	2.99	20.82
14	1961/1962	0.19	31.40	76.05	19.62	77.71	23.78	11.81	3.68	0.89	0.30	1.72	1.15	20.69
15	1962/1963	0.62	26.54	13.31	44.11	28.19	19.60	106.10	12.99	6.83	13.22	7.73	3.60	23.57
16	1963/1964	4.26	46.30	33.35	8.52	14.25	16.39	44.37	5.15	5.02	3.81	2.43	2.02	15.49
17	1964/1965	41.07	15.20	13.58	9.20	4.67	2.06	21.76	2.66	3.74	3.20	2.47	2.68	10.19
18	1965/1966	2.19	5.17	5.21	89.36	88.05	8.70	4.48	3.71	1.86	1.52	1.22	0.99	17.70
19	1966/1967	1.52	8.14	7.95	33.73	78.13				8.95	11.57	5.75	3.55	
20	1967/1968	8.44	24.34	4.87	3.52	0.83	7.50	13.66	25.05	6.79	8.21	2.20		
21	1968/1969	2.30	2.86	20.38	4.60	11.53	50.03	39.35	8.29	6.71	3.36	6.94	1.31	13.14
22	1969/1970	26.28	10.84	3.79	10.08	8.64	0.84					1.54	14.35	
23	1970/1971	12.89	6.83	30.69	14.72	15.96	16.13	12.58	13.07	3.81	3.10	1.76	0.59	11.01
24	1971/1972	1.60	1.73	4.94	38.41	46.70	81.39	28.28	25.01	17.28	4.85	2.54	2.13	21.24
25	1972/1973	6.81	5.13	2.56	0.12	32.53	19.00	7.72	4.33	1.90	1.38	10.04	3.94	7.95
26	1973/1974	1.97	2.88	3.95	49.81	113.67	73.92	36.34	8.36	4.44	2.98	0.81	0.62	24.98
27	1974/1975	1.79	27.93	13.73	15.97	35.59	61.98	1.46			5.94	2.81	10.34	
28	1975/1976	9.35	29.24	35.71	116.74	98.58	64.22	47.07	27.03	16.55	8.44	4.74	10.65	39.03
29	1976/1977	96.21	44.37	10.27	3.84	32.04	0.00	8.49	5.11	4.13	2.90	1.98	9.22	18.21
30	1977/1978	16.01	13.58	16.88	55.14	25.21	26.47	91.05	19.86	6.17	4.14	3.55	2.77	23.40
31	1978/1979	5.97	3.12	49.81	9.39	13.35	10.19	3.85	3.37	0.99	3.92	24.19	15.86	12.00
32	1979/1980	39.55	8.10	5.59	5.74	9.38	5.82	2.41	0.81	0.90	0.77	0.76	1.76	6.80
33	1980/1981	1.14	9.18	18.37	43.73	54.98	48.54	18.25	10.72	20.25	5.45	26.88	18.40	22.99
34	1981/1982	5.17	12.27	17.53	6.65	12.48	8.14	52.08	12.54	7.25	5.90	2.91	2.53	12.12
35	1982/1983	14.94	49.38	9.39	3.84	2.43	2.72	3.78	4.29	4.05	8.18	3.96	1.70	9.06
36	1983/1984	2.42	12.81	21.56	24.68	4.75	3.85	2.92	16.69	2.55	1.47	2.84	4.48	8.42
37	1984/1985	4.68	6.40	9.35	7.83	11.04	15.20	2.80	2.19	4.82	1.29	0.51	0.23	5.53
38	1985/1986	10.08	22.18	39.93	26.16	15.05	11.50	2.82	1.64	5.44	1.77	3.12	8.76	12.37
39	1986/1987	21.71	54.78	9.73	2.48	6.90	3.68	7.91	1.97	1.47	1.39	11.65	65.97	15.80

No.	Years	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Average
40	1987/1988	23.04	35.11	37.46	9.13	71.84	136.65	42.44	13.14	9.30	8.51	3.71	27.78	34.84
41	1988/1989	28.94	24.92	47.15	41.07	100.03	26.73	17.48	14.04	24.19	7.73	4.52	2.38	28.26
42	1989/1990	2.88	33.14	11.48	14.03	4.55	16.02	51.70	20.16	10.53	12.10	8.21	3.85	15.72
43	1990/1991	1.33	0.79	4.75	55.14	83.09	53.02	12.04	4.52	4.05	2.37	1.52	4.32	18.91
44	1991/1992	46.01	22.53	16.12	3.04	3.40	0.99	1.51	0.57	0.63	0.63	0.87	1.01	8.11
45	1992/1993	7.30	11.84	1.30	4.60	22.32	11.69	12.69	4.07	1.17	0.80	2.39	0.27	6.70
46	1993/1994	23.01	18.90	18.90	62.74	57.04	16.28	1.11	3.61	1.82	1.65	1.05	0.38	17.21
47	1994/1995	0.13	0.03	0.06	5.48	2.70	5.15	2.78	3.53	0.85	0.52	0.12		
48	1995/1996													
49	1996/1997	0.44	55.56	33.84	27.53	10.04	87.37	44.37	6.16					
50	1997/1998													
51	1998/1999													
52	1999/2000													
53	2000/2001										0.65	10.08	30.83	
54	2001/2002	26.28	140.82	74.15	92.02	57.87	27.14	14.66	25.69	39.74	9.15	45.55	47.84	50.08
55	2002/2003	10.38	11.42	43.35	27.83	16.70	30.47	8.72	3.30	2.01	1.78	2.50	1.50	13.33
56	2003/2004	0.88	9.95	3.71	18.56	16.24	38.46	22.34	3.92	1.96	1.88	0.77		
57	2004/2005				38.79	25.13	30.17	26.77	12.10	3.11	1.78	2.76	1.03	
58	2005/2006	1.71	6.21	3.84	48.29	142.20	104.54	65.59	38.08	12.62	5.19	58.99	18.06	42.11
59	2006/2007	15.93	65.97	26.31	9.54	6.28	3.03	5.79	1.49	3.35	1.50	1.14	3.06	11.95
60	2007/2008	28.79	24.54	73.77	58.56	24.03	26.55	14.78	11.91	22.53	5.34	2.27	1.20	24.52
61	2008/2009	0.95	18.60	73.77	69.97	122.77	25.84	5.71	4.11	13.19	6.98	4.03	1.20	28.93
62	2009/2010	71.11	54.78	13.23	41.83	44.64	22.18	29.94	14.67	13.35	4.11			
Average														18.61

**Table 14: Catchment Area of the Makhaleng River at the state border
(Area = 2911 km²)**

It is important to patch series in order to define the selected year. Relationship trends based on Table 13 and Table 14 average annual discharges have been created. The trends were used for filling the series (Figure 7).

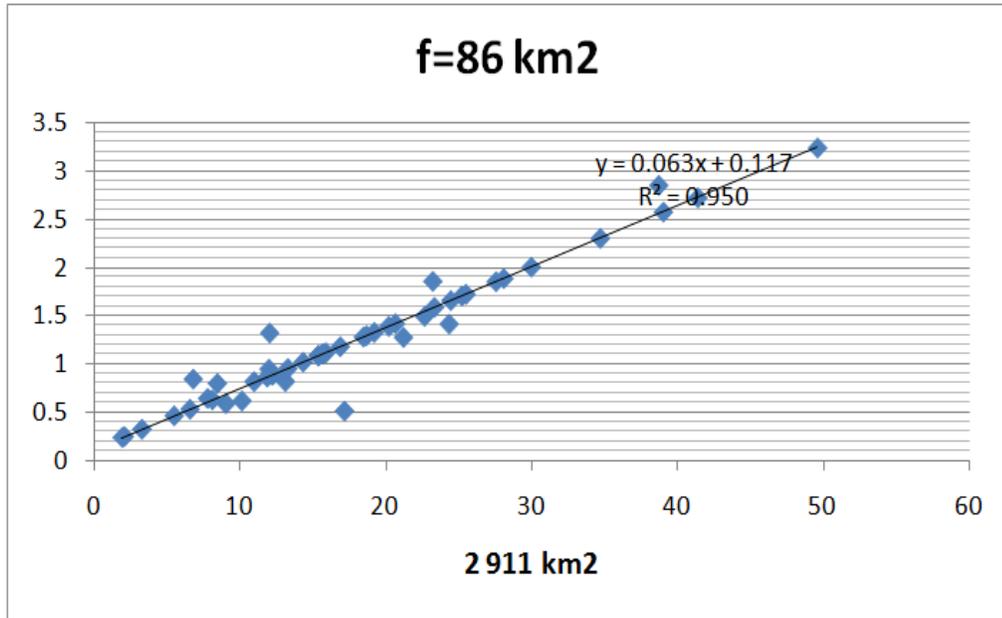


Figure 7: Relationship trend between the average annual discharge parallel observations

The patched data is given in Table 16, from which the continuous series of data according to both catchment areas between the years 1956/1957-1993/1994 (record period = 38 years) has been identified (see Table 16).

No.	Years	F = 2911km ²	F = 86 km ²
1	1948/1949	3.240	0.32
2	1949/1950	39.018	2.57
3	1950/1951	19.182	1.32
4	1951/1952	15.357	1.08
5	1952/1953		
6	1953/1954	14.306	1.02
7	1954/1955		
8	1955/1956		
9	1956/1957	18.657	1.29
10	1957/1958	25.195	1.70
11	1958/1959	12.159	0.88
12	1959/1960	15.864	1.12
13	1960/1961	20.636	1.42
14	1961/1962	20.178	1.39
15	1962/1963	23.309	1.58
16	1963/1964	15.368	1.08

No.	Years	F = 2911km ²	F = 86 km ²
17	1964/1965	10.103	0.61
18	1965/1966	17.137	0.51
19	1966/1967	15.328	1.08
20	1967/1968	2.034	0.24
21	1968/1969	13.081	0.82
22	1969/1970	1.889	0.24
23	1970/1971	10.934	0.82
24	1971/1972	21.186	1.27
25	1972/1973	7.753	0.64
26	1973/1974	24.318	1.41
27	1974/1975	25.474	1.72
28	1975/1976	38.702	2.85
29	1976/1977	29.958	2.00
30	1977/1978	23.199	1.86
31	1978/1979	11.956	0.94
32	1979/1980	6.765	0.84
33	1980/1981	22.639	1.49
34	1981/1982	12.004	1.32
35	1982/1983	9.005	0.59
36	1983/1984	8.415	0.80
37	1984/1985	5.457	0.46
38	1985/1986	12.259	0.89
39	1986/1987	15.641	1.10
40	1987/1988	34.695	2.30
41	1988/1989	27.539	1.85
42	1989/1990	15.670	1.10
43	1990/1991	18.437	1.28
44	1991/1992	8.076	0.62
45	1992/1993	6.540	0.53
46	1993/1994	16.847	1.18
47	1994/1995		
48	1995/1996		
49	1996/1997		
50	1997/1998		
51	1998/1999		
52	1999/2000		
53	2000/2001		
54	2001/2002	49.597	3.24
55	2002/2003	13.258	0.95
56	2003/2004		
57	2004/2005		
58	2005/2006	41.385	2.72
59	2006/2007	11.834	0.86

No.	Years	F = 2911km ²	F = 86 km ²
60	2007/2008	24.438	1.66
61	2008/2009	28.066	1.88
	Average	18.4	1.24

Table 15: Makhaleng River Average Annual Discharge (intermittent) (m³/s)

No.	Years	F = 2911km ²	F = 86 km ²
1	1956/1957	18.66	1.29
2	1957/1958	25.19	1.70
3	1958/1959	12.16	0.88
4	1959/1960	15.86	1.12
5	1960/1961	20.64	1.42
6	1961/1962	20.18	1.39
7	1962/1963	23.31	1.58
8	1963/1964	15.37	1.08
9	1964/1965	10.10	0.61
10	1965/1966	17.14	0.51
11	1966/1967	15.33	1.08
12	1967/1968	2.03	0.24
13	1968/1969	13.08	0.82
14	1969/1970	1.89	0.24
15	1970/1971	10.93	0.82
16	1971/1972	21.19	1.27
17	1972/1973	7.75	0.64
18	1973/1974	24.32	1.41
19	1974/1975	25.47	1.72
20	1975/1976	38.70	2.85
21	1976/1977	29.96	2.00
22	1977/1978	23.20	1.86
23	1978/1979	11.96	0.94
24	1979/1980	6.76	0.84
25	1980/1981	22.64	1.49
26	1981/1982	12.00	1.32
27	1982/1983	9.00	0.59
28	1983/1984	8.42	0.80
29	1984/1985	5.46	0.46
30	1985/1986	12.26	0.89
31	1986/1987	15.64	1.10
32	1987/1988	34.69	2.30
33	1988/1989	27.54	1.85
34	1989/1990	15.67	1.10
35	1990/1991	18.44	1.28
36	1991/1992	8.08	0.62

No.	Years	F = 2911km ²	F = 86 km ²
37	1992/1993	6.54	0.53
38	1993/1994	16.85	1.18
	Average	16.43	1.15

Table 16: Makhaleng River Average Annual Discharge (patched) (m³/s)

The data has been accurately evaluated and relationship trends have been prepared. The results are given in Table 17 below.

Makhaleng River	Catchment area (km ²)	Average (m ³ /s)	Number of Years	Asymmetry Coefficient	Variation Coefficient	
	F	Q	n	Cv	Cs	Cs/Cv
Molimo-Nthuse	86	1.15	38	0.485	0.896	1.8
At the Border	2 911		38	0.515	0.599	1.2

Table 17: Relationship Results between sites

Table 18 shows the 5%, 50% and 95% flows.

Makhaleng River at the state border F = 2911 km²

Provision	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Average
5% (1987/88)	22.61	35.10	36.77	8.96	71.84	136.65	42.44	13.14	9.30	8.51	3.71	27.80	34.74
50% (1989/90)	2.83	33.10	11.30	13.70	4.55	16.00	51.20	20.10	10.50	12.10	8.21	3.85	15.62
90% (1992/93)	7.17	11.80	1.28	4.52	22.30	11.69	12.70	4.07	1.17	0.80	2.39	0.27	6.68

Table 18: Average monthly and annual discharge (m³/s)

Makhaleng River Molimo-Nthuse F = 86 km²

Provision	X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Average
5% (1987/88)	1.50	2.32	2.43	0.59	4.76	9.05	2.81	0.87	0.62	0.56	0.25	1.84	2.30
50% (1989/90)	0.20	2.33	0.80	0.96	0.32	1.13	3.61	1.42	0.74	0.85	0.58	0.27	1.10
90% (1992/93)	0.57	0.94	0.10	0.36	1.77	0.93	1.01	0.32	0.09	0.06	0.19	0.02	0.53

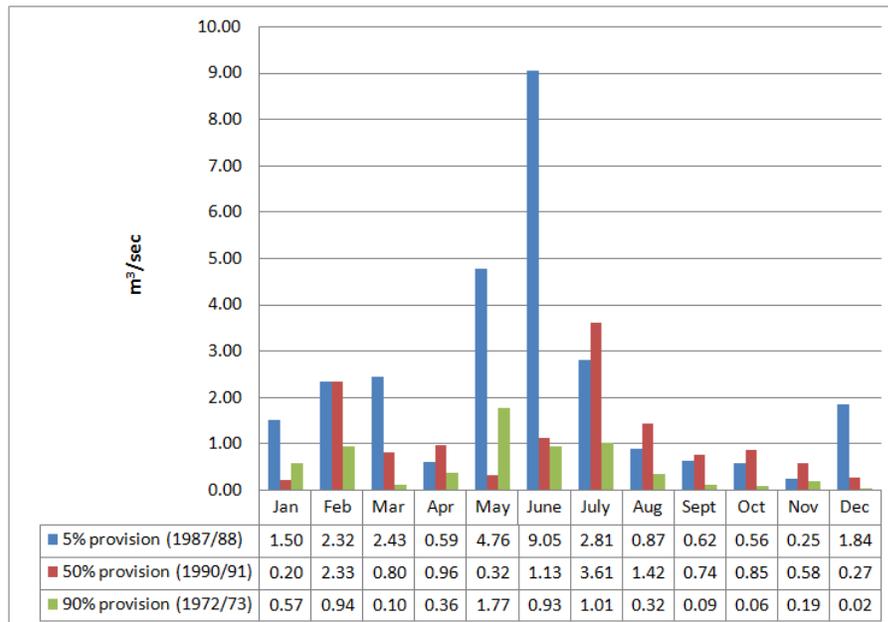


Figure 8: Makhaleng River (F= 86 km²)

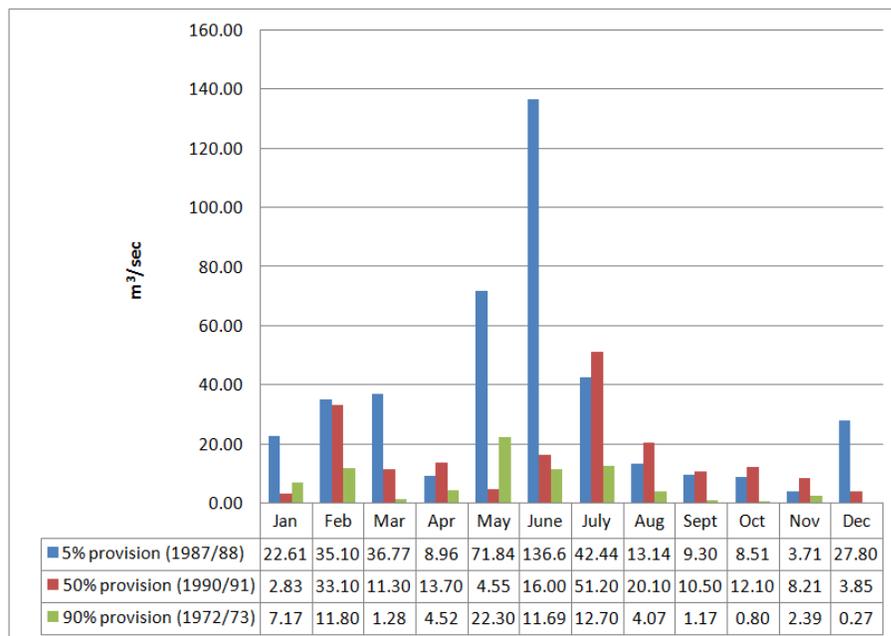


Figure 9: Makhaleng River (F= 2911km²)

2.7.2 Mohokare River

The Mohokare River hydrological data parameters have been defined based on the information received, as follows.

CG69 - Area=304km² - 1995/1996 - 2007/2008 – 10 years

CG39 - Area=5600km² - 1978/1979 – 2007/2008 – 17 years

CG22 - Area=8216km² - 1989/1990 – 2007/2008 – 20 years

The data for CG69 and CG39 are intermittent while one year 2008/2009 is missing in CG22, which has not been taken into account during the study; for CG22 continuous 19 year data has been created, which has been used for calculations of provision trend parameters $Q_0=25.01\text{m}^3/\text{sec}$, $C_v=0.779$, $C_s=2.719$, $C_s/C_v=3.5$. The result $Q_0=25.01\text{m}^3/\text{sec}$ accuracy with formula: $\frac{\sum Q_0}{\text{---}} = 17.9\%$ is unsatisfactory. The standard should be 5-10%. The data needs to be filled, which could not be fulfilling due to the lack of information.

Data for the river Mohokare D2H035, F=3820km² and D2H022, F=12852km² has been gathered from internet, the data is between the years 1989-2008. The data is not sufficient and there is no connection, which does not allow filling the series. Some relationships with neighboring rivers has been studied but no connections have been found for the following areas: River Senqu SG017, River Makhaleng MG019-MG021, river Malibatso – CG080, river Hlotse – CG25.

The comparison table of the average annual discharge is given for the river Mohokare CG69, CG39, CG22 full data in Table 19, which has revealed irrelevance between the average annual discharges. Due to the lack of information irrelevance could not be solved.

Years	Hydrological Station				
	CG69	CG39	CG22	D2h035	D2H022
	F=304	F=5600	F=8216	F=3800	F=12852
1978/79		54.8			
1979/80		20.66			
1980/81					
1981/82					
1982/83		11.57			
1983/84		7.19			
1984/85					
1985/86					
1986/87					
1987/88					
1988/89		34.65			
1989/90			14.193		26.17
1990/91		7.55	47.561		25.23
1991/92			4.481		
1992/93			9.165	6.31	
1993/94		7.71	16.789		
1994/95		7.86	4.799	2.92	
1995/96	14.708	8.24	30.09		43.43
1996/97	9.469		82.726		46.52

Years	Hydrological Station				
	CG69	CG39	CG22	D2h035	D2H022
	F=304	F=5600	F=8216	F=3800	F=12852
1997/98		25.8	25.116	14.29	33.27
1998/99		23.08	16.793	13.66	25.09
1999/00			21.388		33.94
2000/01	9.663	26.5	33.363	17.55	31.06
2001/02	21.728	19.93	34.834	30.96	52.79
2002/03	2.182	20.13	13.832	10.71	23.09
2003/04	0.409		11.199	4.37	19.14
2004/05	1.713	6.17	20.606	11.69	24.59
2005/06	2.398	9.69	51.122	30.8	58.12
2006/07	0.925	43.05	20.823	14.7	23.43
2007/08	2.419		15.899	25.22	28.69
2008/09		20.04		20.77	23.48
Average	6.56	19.7	24.99	15.68	32.38

Table 19: Mohokare River average annual discharge (m³/s)

The data given for the river Mohokare tributaries was not enough to perform corresponding studies. Filling of the series is not possible due to the lack of connections between the existing data.

The relationship between tributaries' discharge and corresponding meteorological stations' precipitation data has been performed, accordingly relationship between hydrological station CG 025 and meteorological station Leribe CG49(4) precipitation $y=1.489x-0.826$ generated average annual discharge of the river Mokokare tributary river Hlotse 68 years data (see Table 20) ($Q=4.16$ m³/sec, $C_v=0.705$, $C_s=1.49$, $\epsilon_Q=85\%$).

No.	Years	CG49(4)	CG 025
1	1937/38	17.2	3.72*
2	1938/39	20.3	5.37*
3	1939/40	19.2	4.78*
4	1940/41	17.8	4.06*
5	1941/42	15.1	2.61*
6	1942/43	23.8	7.24*
7	1943/44	26.3	8.56*
8	1944/45	17.3	3.77*
9	1945/46	13.7	1.87*
10	1946/47	17.2	3.74*
11	1947/48	20.5	5.46*
12	1948/49	15.1	2.61*
13	1949/50	26.8	8.85*

No.	Years	CG49(4)	CG 025
14	1950/51	19.9	5.15*
15	1951/52	15.5	2.80*
16	1952/53	13.6	1.81*
17	1953/54	18.7	4.52*
18	1954/55	20.4	5.42*
19	1955/56	21.4	5.96*
20	1956/57	26.8	8.81*
21	1957/58	25.1	7.93*
22	1958/59	15.8	3.00*
23	1959/60	23.3	6.99*
24	1960/61	19.7	5.05*
25	1961/62	34.2	12.77*
26	1965/66	25.0	2.60
27	1966/67	30.5	13.63
28	1967/68	12.7	3.10
29	1968/69	15.4	2.48
30	1969/70	12.0	2.21
31	1970/71	14.4	2.25*
32	1971/72	15.1	2.61*
33	1972/73	13.2	1.59*
34	1973/74	13.1	1.54*
35	1974/75	17.2	3.75*
36	1975/76	21.0	5.75*
37	1976/77	14.5	2.32*
38	1977/78	23.0	6.84*
39	1978/79	17.8	4.05*
40	1979/80	15.2	2.65*
41	1980/81	17.7	3.52
42	1981/82	14.9	2.47
43	1982/83	13.5	1.48
44	1983/84	13.4	1.61
45	1984/85	8.4	0.79
46	1985/86	12.4	1.36
47	1986/87	18.2	2.16
48	1987/88	22.4	5.11
49	1988/89	17.3	5.24
50	1989/90	17.3	1.51
51	1990/91	14.3	1.42
52	1991/92	10.2	0.36
53	1992/93	11.8	0.85*
54	1993/94	15.7	2.95*
55	1994/95	9.5	0.68*

No.	Years	CG49(4)	CG 025
56	1995/96	20.4	12.19
57	1996/97	23.7	9.18
58	1997/98	16.1	2.96
59	1998/99	16.0	3.62
60	1999/2000	21.4	4.93
61	2000/01	18.4	4.34*
62	2001/02	22.3	9.22
63	2002 /03	14.4	0.74
64	2003/04	14.8	0.90
65	2004/05	18.3	1.78
66	2005/06	21.9	5.39
67	2006/07	14.3	2.33
68	2007/08	19.1	3.53
	Average	18.0	4.16

Note: * Patched data

Table 20: Hlotse River average annual discharge (m³/s)

2.8 Run-of-River Hydro-power potential (theoretical)

Simulation models are drawn up by means of the presented on figures below combined diagrams of average increase and the river length in relation to its actual elevations.

2.8.1 Senqu River

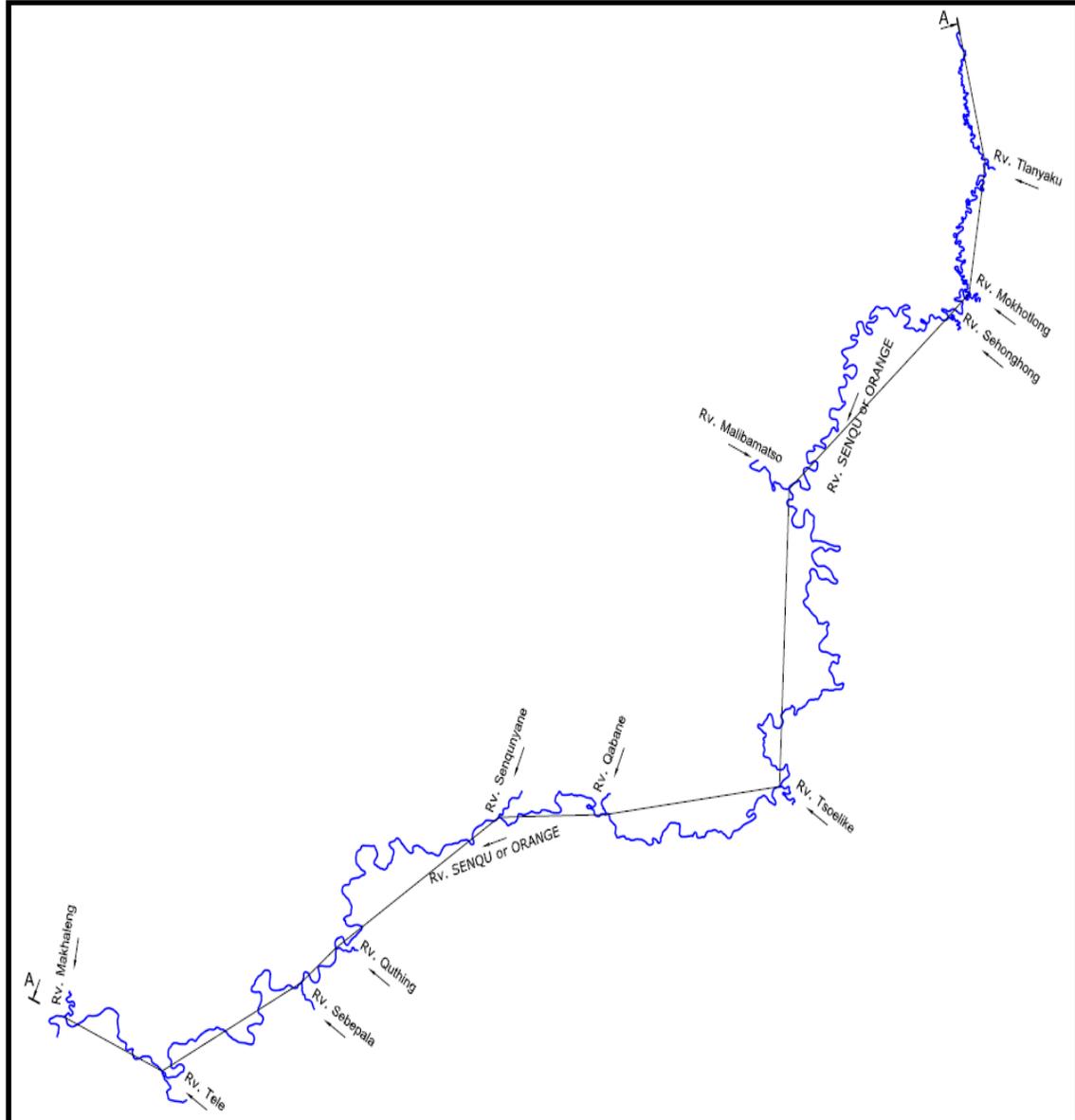


Figure 10: Senqu River Plan

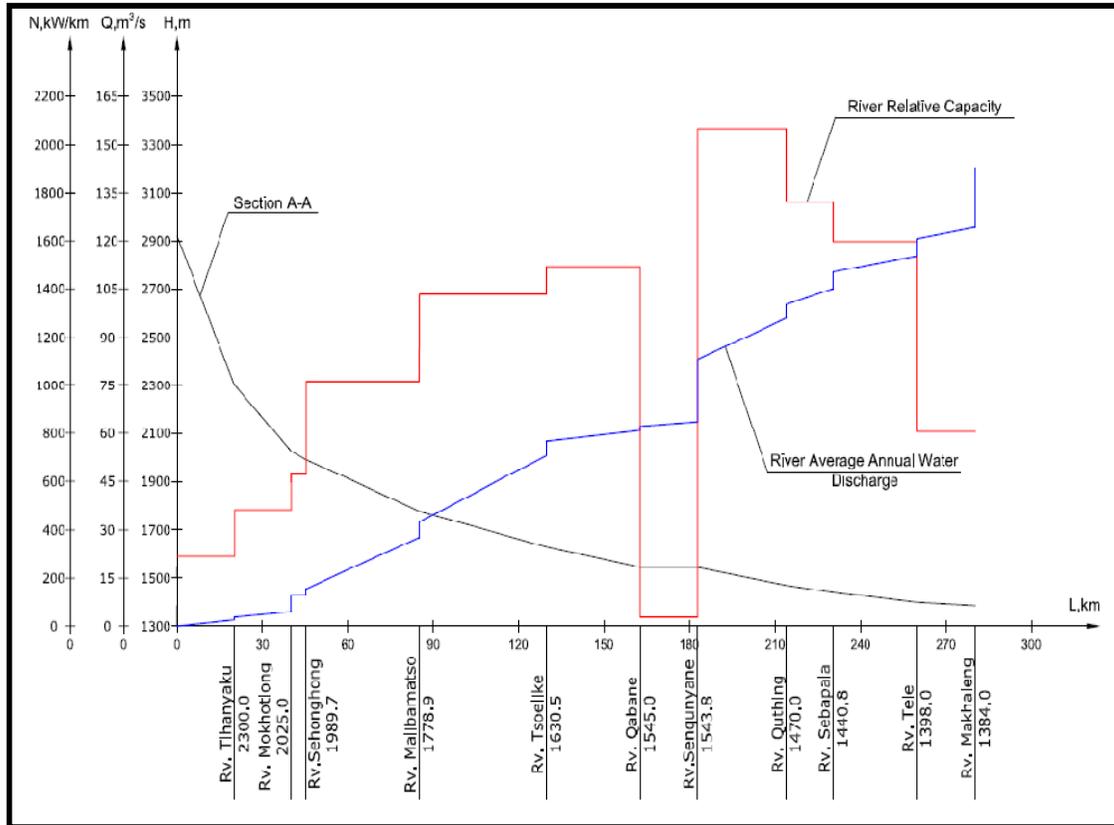


Figure 11: Senqu River Potential Energy Usage

Total approximate theoretical hydro energy potential for the Senqu River is 330.6 MW.

2.8.2 Makhaleng River

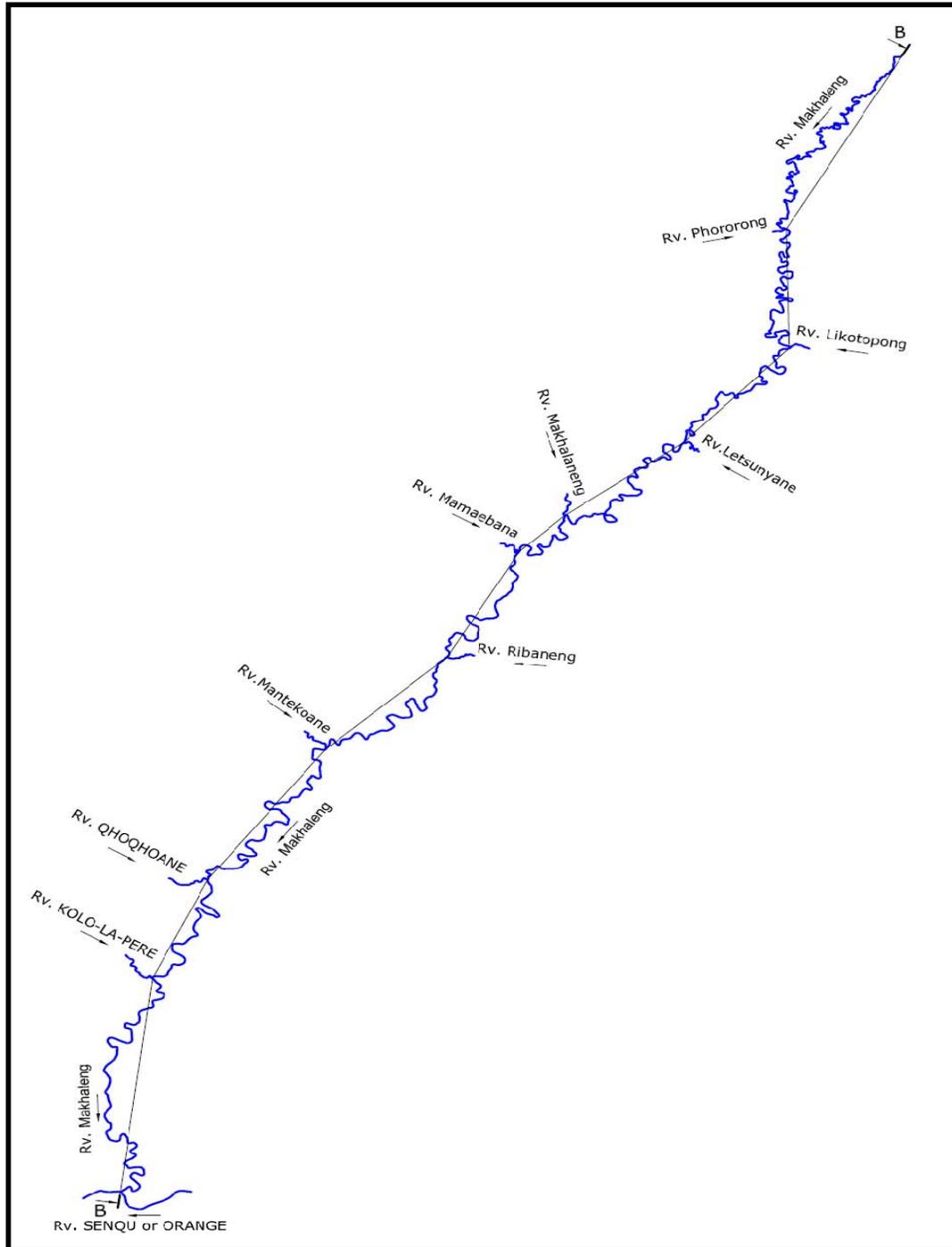


Figure 12: Makhaleng River Plan

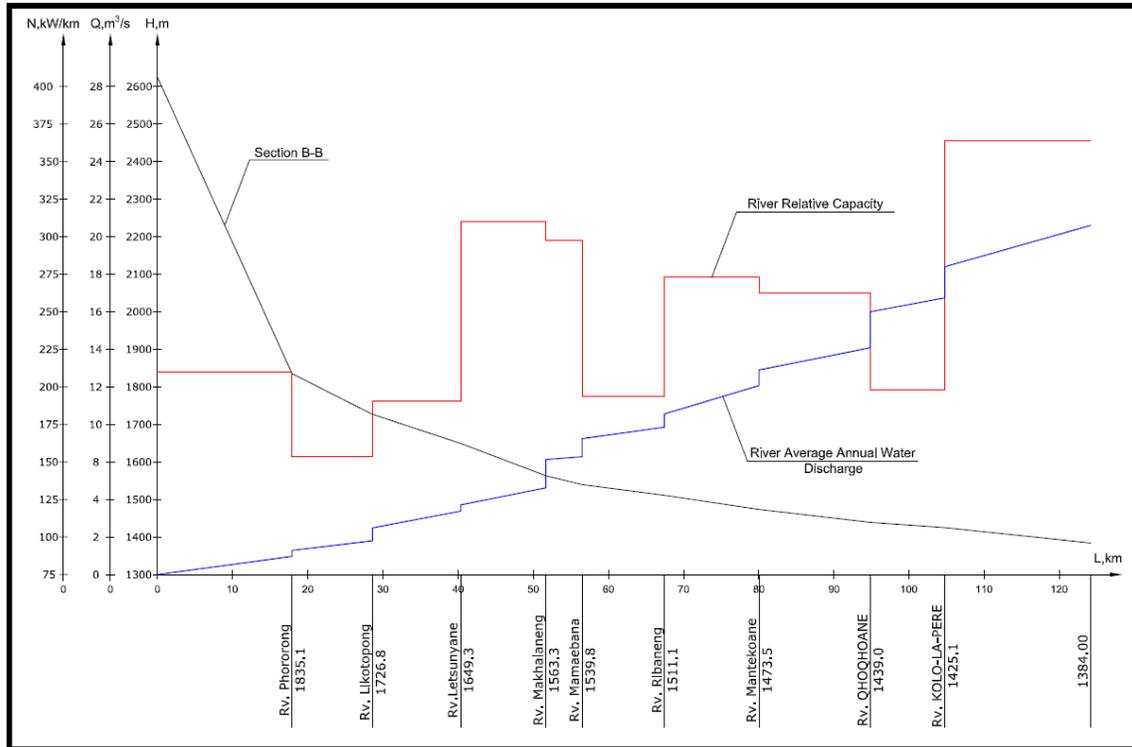


Figure 13: Makhaleng River Potential Energy Usage

Total approximate theoretical hydro energy potential for the Makhaleng River is 31.0 MW.

2.8.3 Mohokare River

Total approximate theoretical hydropower potential for the Hlotse River (a tributary of the Mohokare River) tributary is 30.7 MW.

3. SHORT GEOLOGIC DESCRIPTION

The rocks exposed in Lesotho are almost entirely of Triassic and Jurassic age, belonging to the Karoo Supergroup (Schmitz and Rooyani 1987). The Karoo sediments were largely deposited in continental environments. Large parts of Lesotho are made up of basalt flows of the Drakensberg Group.

The foothills are defined as the area between the South African high land and narrow coastline valley, lowland and Karoo caves – there is a Kapi mountain south to the Karoo caves – Dragon Mountains are the highest point. There are Kalahari valleys north to the Senqu River at an elevation 200-1000m.

Karoo Super-group is found in Southern Africa, which covers two third of the whole territory. Main components of this formation are slates and crags. Total thickness reaches 12 km. The formation is covered by Lavas (Drakensberg formation), thickness – 1.4km.

Karoo formation is divided into following strategic units (from lower to upper part):

- (a) Molteno Formation – quartzite sandstones;
- (b) Conglomerates; and
- (c) Elliot Formation – (this is divided into three sub categories).
 - i. Metamorphic formations are represented by crystal shale, glist and crystalline silica limestone;
 - ii. The middle layer is dark mortar, with dolomite limestone on top, crystalline shale, crystalline limestone (marble); and
 - iii. III – On the upper part there is granite crystalline shale and glist crystalline shale.

Clarens Formations – volcanogenic sedimentary rocks and quartz sandstones.

Lesotho Formations - Create an extensive volcanic plateau and they are presented by sedimentary rocks sediments - volcanic breccias, conglomerate, and tuff sandstones. Series are often intersected by basalt and volcanic veins.

Clarens, Elliot and Molteno formations are mainly exposed in the bottom of the valley – in the vicinity of the river bed and they set up the vertical walls of gorges.

Lesotho formation is mainly seen in plateaus and watersheds and covers the largest part of the territories.

Despite the development of Lesotho formation – in the Senqu river gorge, the dams will probably be located in Clarens and Elliot formations.

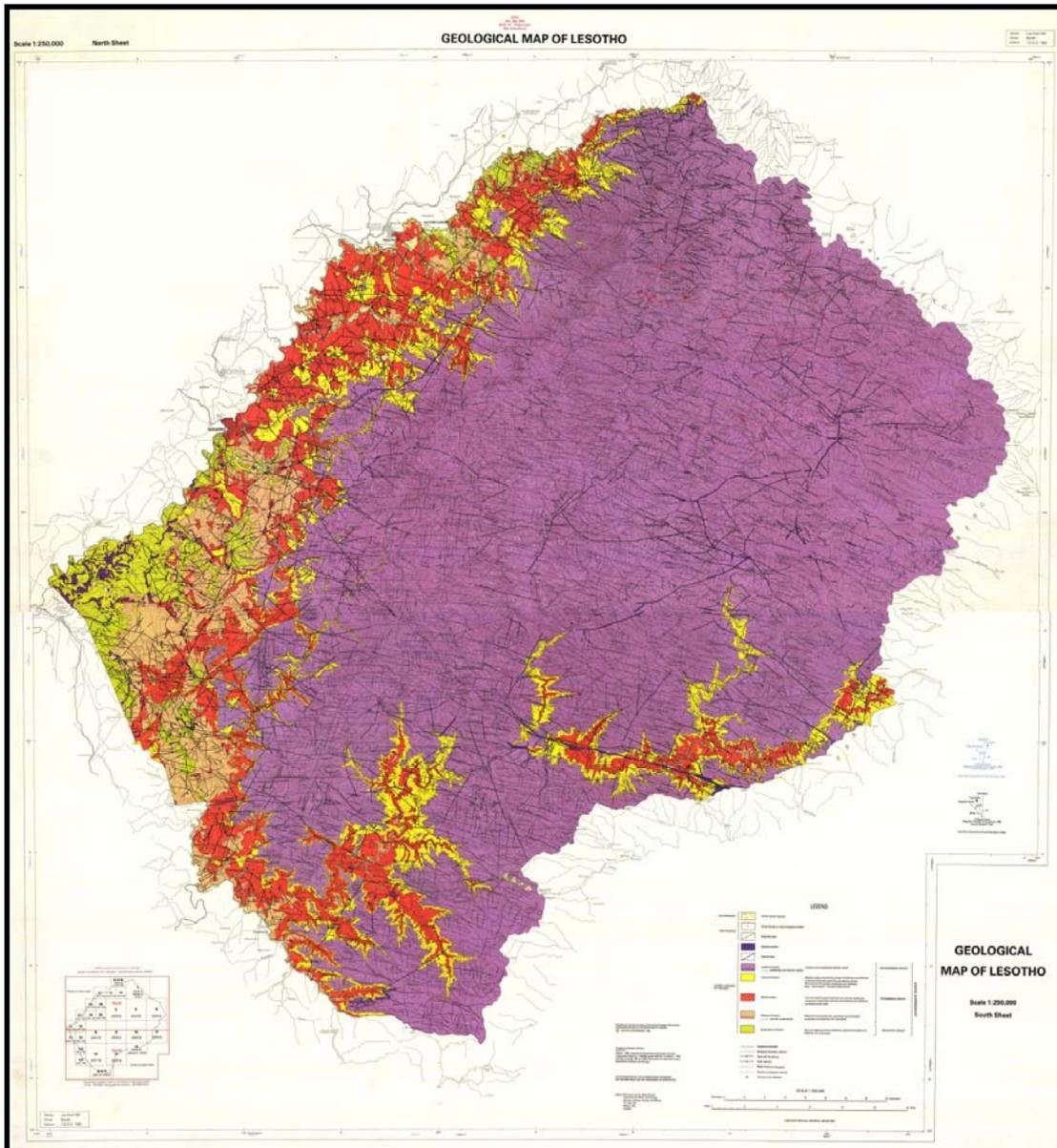
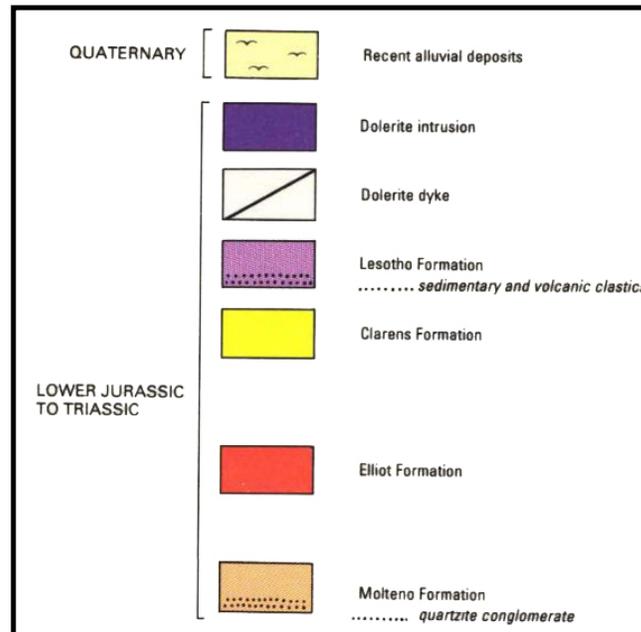


Figure 14: Geological Map of Lesotho



Legend for Figure 14: Geological Map of Lesotho

4. SITE SELECTION

4.1 General

The objective of the project has been to identify potential small (more than 1MW and up to 10 MW capacity) and large (greater than 10 MW capacity) hydropower sites within Lesotho. The sites have been identified based on a desktop study, with the more promising sites being visited by helicopter to further assess their suitability.

Should any of these sites be selected for further investigation, more detailed pre-feasibility level investigations would need to be carried out which would include topographic surveys, field geotechnical investigations and initial environmental impact assessments.

4.2 Design considerations

(a) General

The design work performed for the study is sufficient for achieving the necessary degree of detail. This allows description of concept, estimation of main data, costs, benefits and comparison of the schemes.

During the full feasibility study the degree of detail will be increased for the selected scheme.

(b) Optimization and Main Design Parameters

A preliminary optimization was performed to define the following main design parameters:

- (i) Installed capacities of schemes (IC);
- (ii) Full supply level of reservoirs (FSL); and
- (iii) Reservoir surface area and volume calculations.

Please see Appendix 1, in which the key characteristics of each of the selected sites.

(c) Design of Waterways (Diversion)

- (i) Main Components

Waterways are required to convey the water from the reservoir to the turbines (=“headrace”)

and from the turbines to the reservoir of the next lower scheme or to the downstream river

(=“tailrace”). The main parts of the waterways are:

- (1) De-sander;
 - (2) Intake to transition pipeline or channel;
 - (3) Transition pipeline (or channel);
 - (4) Headrace tunnel;
 - (5) Surge chamber;
 - (6) Pressure shaft;
 - (7) Powerhouse;
 - (8) Tailrace tunnel and channel; and
 - (9) Outlet.
- (ii) Sediment Trap

The sediment trap is provided to prevent any coarse sediment from being washed into the headrace tunnel. Each stage is equipped with sluice chambers.

(iii) Intake to transition tunnel

The intake forms the entrance of the power tunnel (or pipeline) and will be integrated at the concrete dam (Tyrol type) or will be situated separately at the flanks of the reservoirs near the dam sites. Where possible, rock flanks will be used for the location of the intake. The intake level lies below the MOL (minimum operation level) and above the planned reservoir sedimentation level.

Integrated intakes will be equipped with removable trash bar screens, a raking machine, bulkhead gates with lifting gantry and guard gates with hydraulic lifting cylinders. The construction of an access road is planned.

(e) Dam types considered

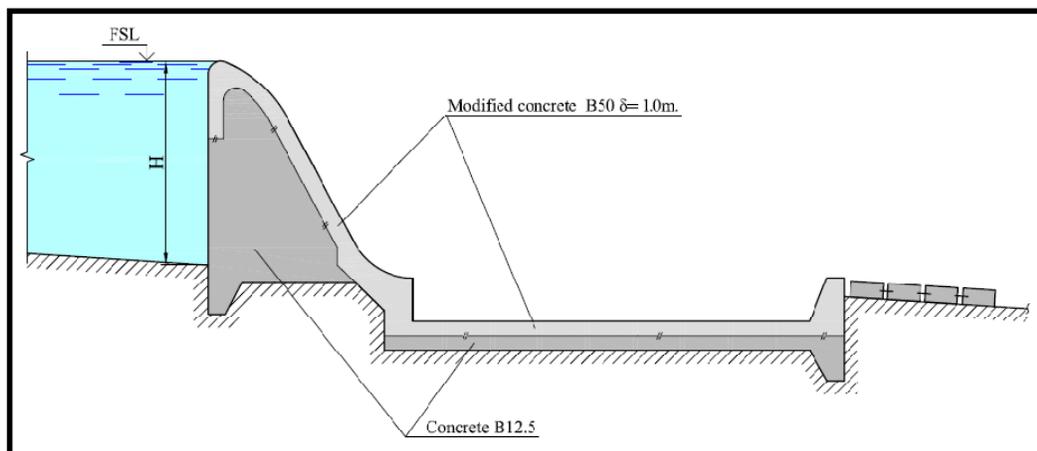
(i) Concrete faced Rock Fill Dam

(1) Description

A rock fill structure is often used to dam water. For water retention purposes the upstream face of the dam is sealed with a concrete slab (as for Mohale Dam) or alternatively the dam is constructed with an internal clay core.

(ii) Concrete Dam (Roller Compacted Concrete or Mass Gravity)

The dam wall consists of a mass concrete structure capped by higher quality concrete on the outside to ensure durability.



(iii) Intake to pressure tunnel

The intake forms the entrance of the power tunnel and will be integrated with the concrete dam or will be located close to the dam area.

Integrated intakes will be equipped with removable trash bar screens, a raking machine, bulkhead gates with lifting gantry and guard gates with hydraulic lifting cylinders. Access is possible from a proposed motor road.

(iv) Headrace tunnel

Tunnels will have reinforced concrete lining. Based on further studies it will be determined whether the tunnel will be pressure or free flow.

(v) Surge Chamber

Surge chambers are situated at the end of the headrace tunnel and at the beginning of the pressure shaft. They will be designed in such a way that the effects of changes of flow rates on water levels and pressures can be restricted. The surge chambers will probably be of the double chamber type and include a backflow throttle device.

(vi) Pressure shaft

The pressure shafts are vertical, gradient 52 - 90 degrees; a short horizontal pressure tunnel will be divided in two or three and will lead to the turbines of the powerhouse.

The shafts will be constructed by blasting or TBM.

(vii) Tailrace

The tailrace tunnels will deliver water from the turbines to the downstream reservoir or river bed.

(viii) Outlet

At the outlet of the tailrace tunnel a rough bed channel with a continuously widening shape will provide dissipation of flow energy, it is equipped with a stop log.

(f) Selection of Powerhouse (PH) Types and Design

The powerhouses for HPPs are designed as underground stations, due to the complicated relief, safety measures and environmental issues. For some HPPs above ground powerhouse are envisioned. Each powerhouse cavern consists of two caverns:

- (i) The main cavern accommodates the main generating units, the erection bay, the main inlet valves, the control room, and auxiliary services such as a battery room, heating, ventilation and air conditioning unit, compressed air, sanitary room, etc.
- (ii) For the transformer and gas insulated switchgear a separate cavern, located parallel to the main cavern, is planned. By locating the transformers away from the main cavern, the fire risk to the plant related to oil filled transformers can be limited, and the safety for personnel increased.

As no detailed geological data are available for the selection of location and orientation of the PH cavern, the following points were taken into consideration:

- (i) Elevation was chosen to maximize the possible head and minimize the risk of flooding
- (ii) Proposed site is minimizing access and cable tunnel length
- (iii) Orientation to optimize hydraulic conditions.

It has to be pointed out that the orientation and location of the PH cavern might be changed during the next project phase considering geological and geotechnical site conditions.

Thickness of shotcrete in the power cavern is assumed with 0.2 m; rock-bolts are placed according to geological conditions. The cavern ceiling is supported by a pre-fabricated steel structure.

In order to avoid filtration water, the arch ceiling will have anti-filtration cementation; in addition, a drainage gallery will be located around the powerhouse. Ventilation and light will be installed within the fabricated ceiling.

During potential emergencies, the head building will be supplied with electricity from reservation sources (diesel generators).

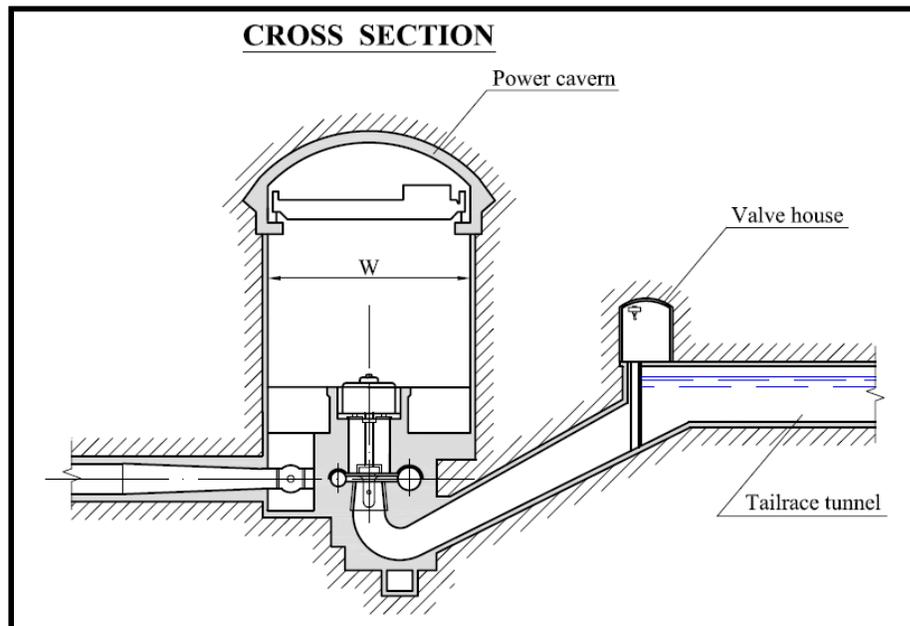
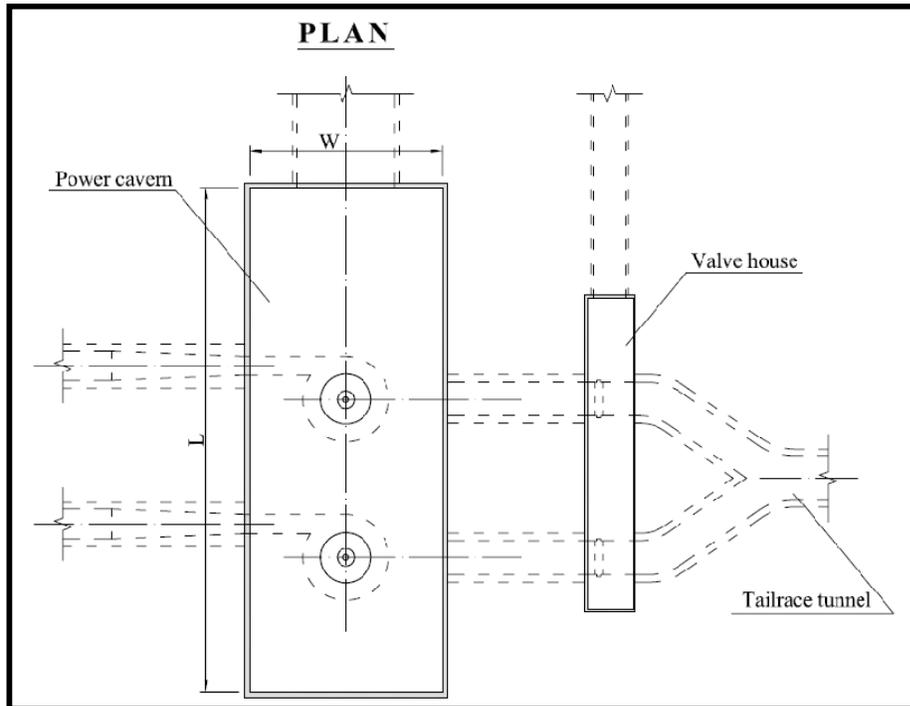
The powerhouse crane will be supported by concrete columns and a crane beam. The crane beam is supported by rock bolts during construction in order to allow use of a small temporary crane.

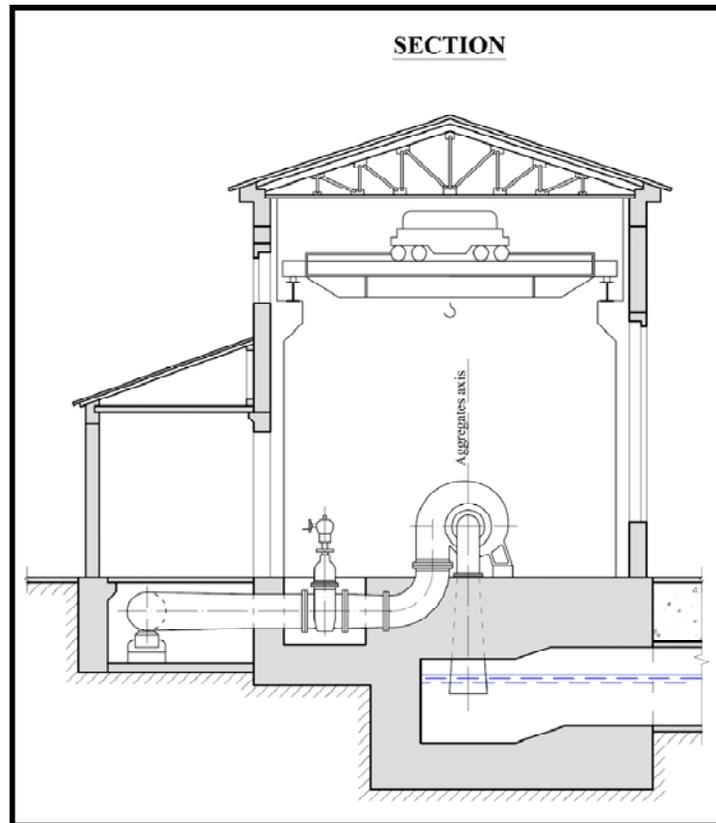
For the erection and dismantling of the runners and the main inlet valves respectively, hatches will be constructed in the floors, so they can be moved by an overhead crane to the erection bay.

Cable-ventilation shafts will be used to convey cables from the transformer. They will be equipped with stairs and lifts. In addition to that, the power house has an access tunnel.

For installation purposes there is a built in bridge crane and a supporting crane with a capacity of 150/30 t.

Power House





5. REQUIRED INFRASTRUCTURE UPGRADES

5.1 Roads

5.1.1 Access roads

In general, paved roads are in good condition.

The earth roads need rehabilitation in order to use them for transporting the construction materials and equipments. First of all the roads need to be widened and paved and safety rails should be installed.

5.2 Transmission lines

The connection of the HPPs to the national grid is envisioned via existing and planned transmission lines. The HPPs in the cascade will be connected to each other by substations and connected to the local transmission line. From local line it is possible to export electric power through 132 kV and prospective 765 kV transmission line to South Africa as well as connection to local grid.

6. GENERATION

6.1 Electricity generation calculations

The power generation calculations are based on the estimated water intake elevations. Appendix 1 gives detailed information regarding the expected water discharge and capacity characteristics, which are based on universal turbine characteristics as well as the elevation, head, discharge and output characteristics for the HPPs.

Calculations have been made based on the characteristics of turbines produced in China. However, it is possible to change the turbine type and manufacturer. The proposed turbine and discharge pipe type, including the associated parameters, are tentative and depend on turbine and generator specific dimensions and volume. This will prove particularly important in identifying the final location of the HPP power house, scope of work, main technical decisions and cost estimation for the construction. The turbine type and parameters will be finalized during eventual feasibility work by the turbine-processing factory.

6.1.1 *Electricity generation profile*

The established capacity usage period and usage coefficient is show in the Appendix 1.

The calculations have been made based on the fact that the reservoirs are multi annual or seasonal regulation complex usage hydropower units.

7. GENERAL ISSUES OF HYDRO ENERGETIC POTENTIAL ESTIMATION OF THE RIVER FLOW

Hydropower resource is the renewable source of energy, which makes it particularly valuable.

If Wm^3 volume falls from Hm height, then water gross energy in kWh will be:

$$E=W \cdot H / 367$$

If we consider Qm^2/sec instead of water volume, then corresponding energy (kWh) per annum (8760hours) will be:

$$E = 8760 \cdot 9,8 \cdot QH = 86000 QH$$

Whereas, average capacity (kW) will be:

$$P=9,8QH$$

According to the given classification, the river flow hydro energetic resources are divided into:

- ❖ Potential (theoretical) hydro energetic resources of the river flow;

- ❖ Technical hydro energetic resources of the river flow, which is that part of theoretical potential, which can be used technically for conversion of water energy to hydro power; and
- ❖ Economic hydro energetic potential, which is that part of general technical potential, which is economically viable for the given period.

The river (part of the river) hydro energetic potential has been estimated based on the simulations. The simulations are made based on river elevations (H), average discharge $Q=f(H)$ and its length $L=\phi(H)$.

Potential capacity is defined according to the given formula:

$$P = 9,8 \sum_{i=1}^n \frac{Q_i + Q_{i+1}}{2} \Delta H_i \quad \text{kW}$$

And river potential energy E has been defined as:

$$E = 86000 \sum_{i=1}^n \frac{Q_i + Q_{i+1}}{2} \Delta H_i \quad \text{kWh}$$

Where, n= number of sections.

Q_i and Q_{i+1} - accordingly water discharges i at the beginning and at the end m^3/sec ;

ΔH_i - i – section fall, m.

List of Literature used for this study:

- Topographic Map - 1:50000 scale;
- Geologic Map - 1:25000 and 1:50000 scale;
- Map of hydrological and meteorological stations;
- Multiannual data of meteorological stations (temperature, humidity, wind, evaporation, precipitation);
- Scheme of High and low voltage grid, detailed technical parameters;
- Map of main communications;
- Water Resources Management, Policies and Strategies, Final Report;
- WRSM 90 Modeling Parameters; and
- LHWP Report.

8. APPENDIXES

Following files are attached to this report:

Appendix 1.1.1	HLOTSE HPP
Appendix 1.1.2	PHUTHIATSANA HPP
Appendix 1.1.3	MAKHALENG 1 HPP
Appendix 1.1.4	AMAKHALENG 2 HPP
Appendix 1.1.5	MAKHALENG 3 HPP
Appendix 1.1.6	MAKHALENG 4 HPP
Appendix 1.1.7	POLIHLE HPP
Appendix 1.1.8	TSOELIKE HPP
Appendix 1.1.9	KHUBELO HPP
Appendix 1.1.10	QUTHING 1 HPP
Appendix 1.1.11	QUTHING 2 HPP
Appendix 1.1.12	QUTHING 3 PSPP

LESOTHO POWER GENERATION MASTER PLAN

PROJECT # LEC/GEN/1-2009

FINAL MILESTONES REPORT

VOLUME 1 - PART 1.1

HYDROPOWER GENERATION OPTION

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HLOTSE HPP

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1.8	Generation.....	58
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1. HLOTSE HPP

1.1 Brief description of the site

Three head units, diversion pressure tunnel, surge tank, turbine conduit, power-cavern, tailrace tunnel.

Head unit on the river Hlotse conveys rock-fill earth dam, height – 19.0m, reinforced concrete water intake, and surface and bottom spillways. Diversion is 2.0m diameter pressure tunnel, length – 9.1km.

Head unit on the river Mphosong conveys rock-fill earth dam, height – 47.0m, reinforced concrete water intake, and surface and bottom spillways. Diversion is 2.0m diameter pressure tunnel, length – 4.3km.

Head unit on the river Morotong conveys rock-fill earth dam, height – 48.0m, reinforced concrete water intake, and surface and bottom spillways. Diversion is 2.0m diameter pressure tunnel, length – 9.9km.

Reinforced concrete surge tank is located at the end of diversion, diameter - 4.0m. Turbine conduit is 1.2m diameter metal pipe with concrete layer. Power-cavern dimensions 19.0x52.0m, height – 45.0m. Tailrace tunnel is trapezoidal section reinforced concrete construction, dimensions – 2.0x2.0m, length – 260.0m.

1.2 Location

1.2.1 Location map



1.2.2 Site location

- Leribe, Ha Seetsa; and
- GPS coordinates for the main structures

No.	Name of Structure	Coordinates	
		X	Y
1	Dam on the river Hlotse	28.324727	-28.888583
2	Dam on the river Mphosong	28.244306	-28.995409
3	Dam on the river Morotong	28.261752	-28.957036
4	Powerhouse	28.184926	-28.900489

1.2.3 **Name of the river**

- Hlotse

1.2.4 **Site hyperlinks (See appendix 2)**

[HI Dam on the river Hlotse.kmz](#)

[HI Dam on the river Morotong.kmz](#)

[HI Dam on the river Mphosong.kmz](#)

[HI Hlotse Powerhouse.kmz](#)

1.3 **Type of HPP**

- Reservoir

1.4 **Existing site access**

- Earth Road, approximately 6.0 km; and
- Distance from the paved road: 9.0 km.

1.5 **Distance to the nearest connection point with national or regional grid:**

- Distance: 4.2 km; and
- Existing Grid Voltage level: 132 kV.

1.6 **List of literature used for this study:**

- Topographic Map - 1:50000 scale;
- Geologic Map - 1:25000 and 1:50000 scale;
- Map of hydrological and meteorological stations;
- Multiannual data of meteorological stations (temperature, humidity, wind, evaporation, precipitation);
- Scheme of High and low voltage grid, detailed technical parameters;
- Map of main communications;

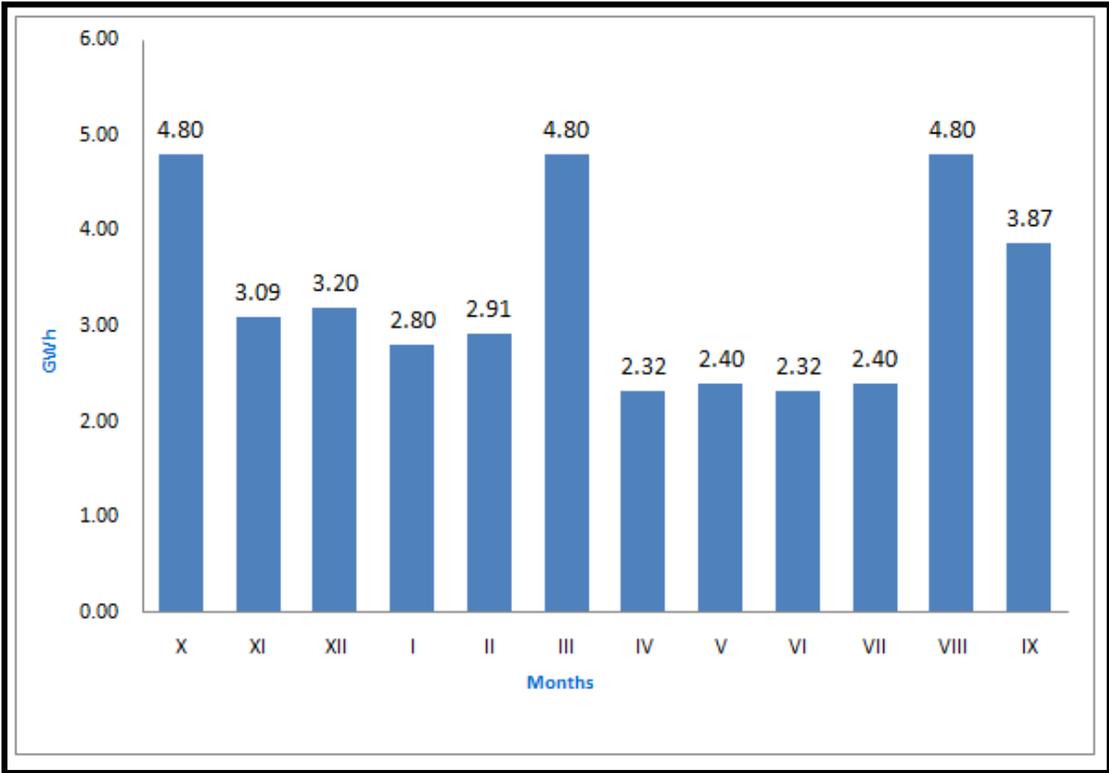
- Water Resources Management, Policies and Strategies, Final Report; and
- WASM 90 Modeling Parameters.

1.7 Key characteristics

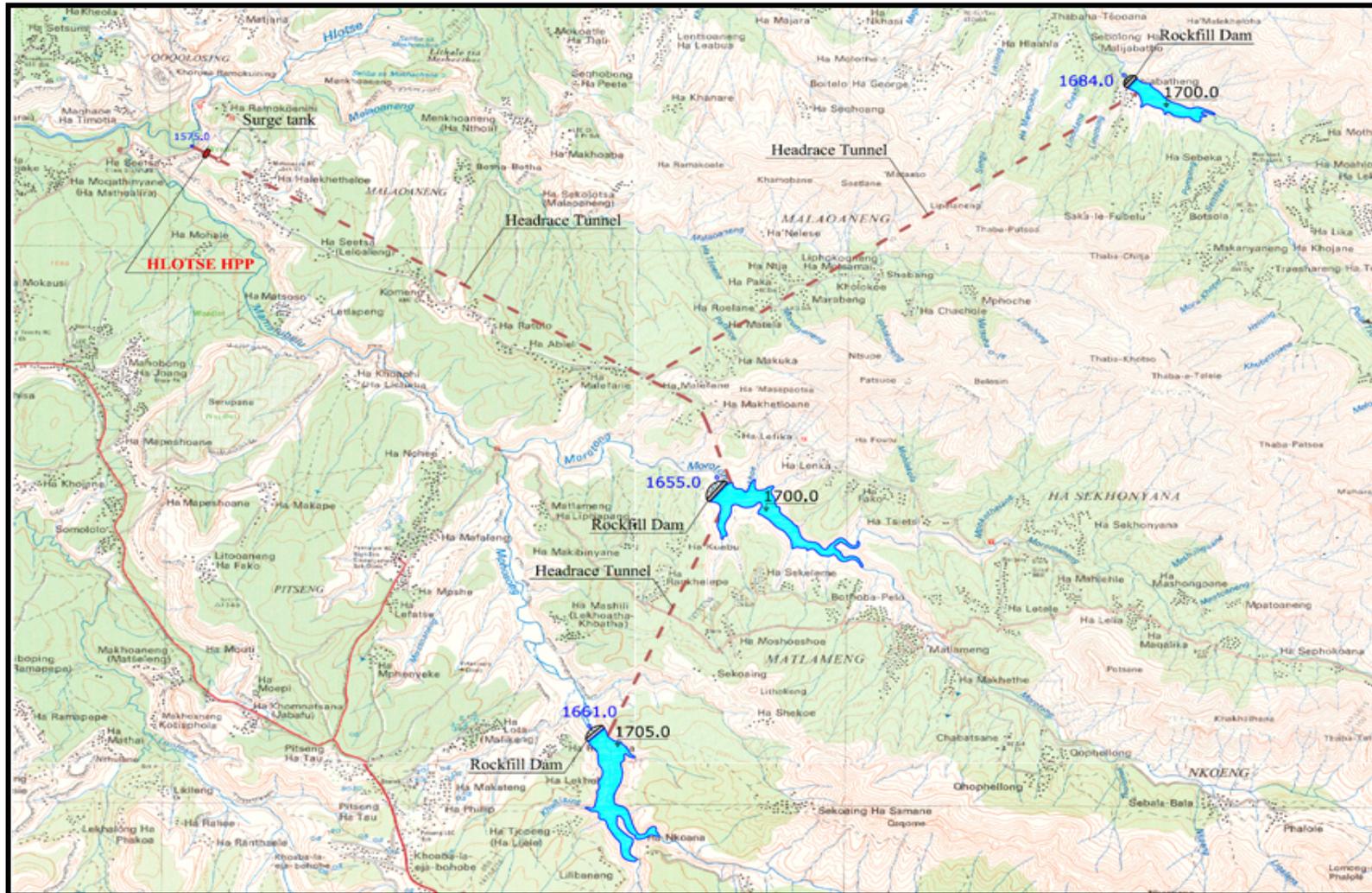
No.	Characteristics	Unit	Index
1	2	3	4
I	Technical Parameters		
1.1	Installed Capacity	MW	6.50
1.2	Average Annual output	GWh	39.70
1.3	Capacity usage ratio/Efficiency	%	69.72
1.4	Type of regulation		Reservoir
1.5	Scheme of energetic usage potential		N/A
	Hydrology		
1.6	Hydrological Data (number of years)	Year	28
1.7	Year of the average multi annual discharge	Year	1986/87
1.8	Catchment area	km ²	396.20
1.9	High water flow	m ³ /sec	10.00
1.10	Average water flow	m ³ /sec	4.70
1.11	Low water flow	m ³ /sec	2.00
1.12	Rated water discharge	m ³ /sec	6.00
1.13	Maximum gross head	m	125.00
1.14	Minimum gross head	m	98.00
	Reservoir		
1.15	Full supply level (FSL)	masl	1700.00
1.16	Minimum Operation level (MOL)	masl	1673.00
1.17	Total volume at FSL	mln. m ³	14.80
1.18	Active reservoir level	mln. m ³	10.40
	Dam		
1.19	Type		Rock fill
1.20	Crest Elevation	masl	1703.00
	Spillway		
1.21	Type		Surface
1.22	Crest Elevation	masl	1700.10
	Water intake		
1.23	Sill elevation	masl	1670.50
1.24	Stop log type and number		Butterfly valve
1.25	Quantity	unit	1
	Sluice or bottom spillway		
1.26	Type and number		Bottom
1.27	Quantity	unit	1
	Diversion		
1.28	Type of diversion		Tunnel
1.29	Dimensions (w; l) or (d; l)	m	2.0; 23300
	Stilling basin or shaft		
1.30	Dimensions (w x l x h) or (d x h)	m	4.0; 65.0
	Powerhouse		
1.31	Type		Underground
1.32	Dimensions (w x h x l)	m	19x45x52
1.33	Elevation of tailrace outlet sill	masl	1572.00
	Tailrace		
1.34	Type		Tunnel

No.	Characteristics	Unit	Index
1	2	3	4
1.35	Dimensions (w x h)	m	2x2
1.36	Elevation of outlet sill	masl	1573.50
	Turbines/Generators		
1.37	Turbine Type and number		F. HLD 46-WJ-71; 2
1.38	Rated discharge	m ³ /sec	3.00
1.39	Rated output	MW	3.37
1.40	Maximum output	MW	3.74
1.41	Generator Type		SFW3200-6/1730
1.42	Generator nominal output	MW	3.25
1.43	Generator nominal output	rpm	1000/1879
	Transformers		
1.44	Type		Three-phase
1.45	Number	unit	2
1.46	Nominal power	MVA	3.6
1.47	Transformer dimensions (l x w x h)	m	4,5x3,15x4,8
II	Economic - Financial Parameters		
2.1	Costing	mln. USD	39.00
2.2	Duration of the construction	Year	3.00
2.3	Investment per 1 kW	Thousand USD	6.00
2.4	Investment per 1 kW/h	USD	0.98
2.5	Revenue per USD spent (Average price new HPP - 4,8 cents)	USD	0.08
2.6	Estimated carbon credit generation	T.	13.9
III	Social and Environmental Parameters		
	Special environmental requirements		
3.1	Social Impact		Additional workplace; Development of infrastructure
3.2	Ecological risks		Medium
	Transmission lines		
3.3	Parameters	kV	132
3.4	Distance to inter connection point	km	4.20
	Infrastructure		
3.5	Existing roads		Paved, Earth
3.6	Roads to be constructed	km	6.00

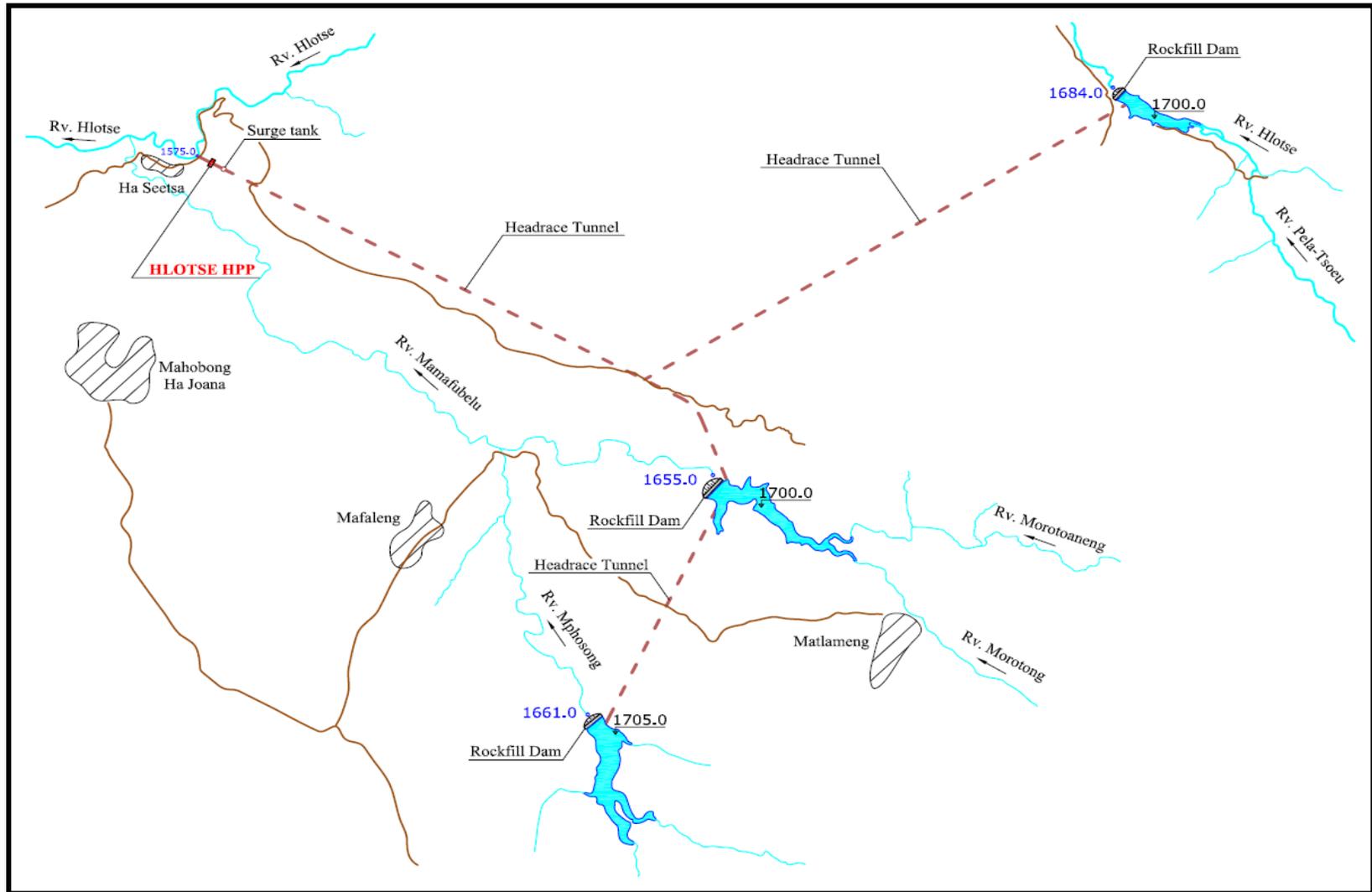
1.8 Generation



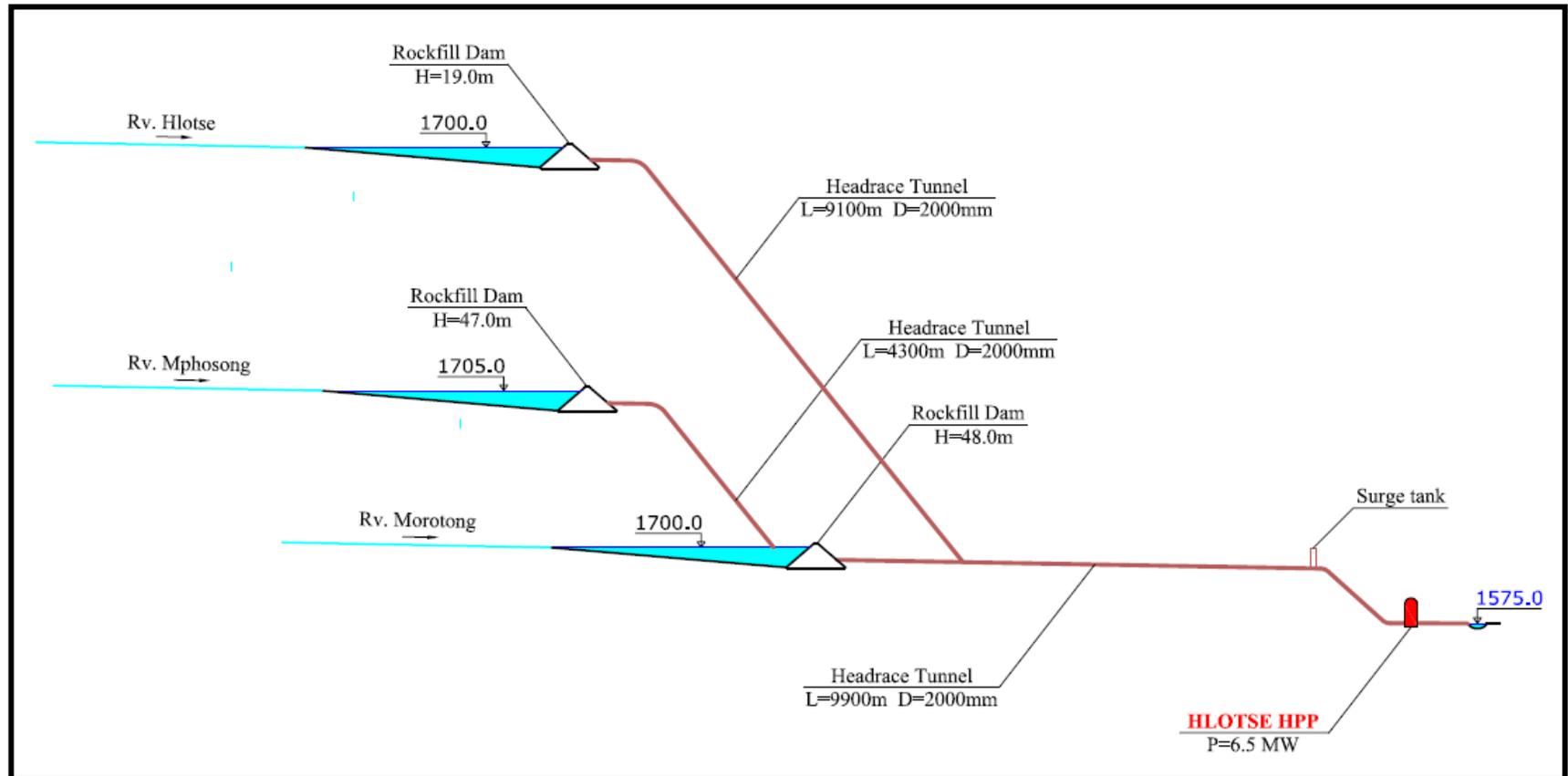
1.9 Topographic map



1.10 Plan



1.11 Longitudinal section



LESOTHO POWER GENERATION MASTER PLAN

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PHUTHIATSANA HPP

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1.4	Site access	66
1.5	Nearest connection point with national or regional grid.....	66
1.6	List of literature used for this study:	66
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1.8	Generation.....	69
1.9	Topographic map.....	70
1.10	Plan.....	71
1.11	Longitudinal section.....	72

1. PHUTHIATSANA HPP

1.1 Brief description of the site

Head unit, diversion pressure tunnel, surge tank, turbine conduit, powerhouse, tailrace channel.

Head unit conveys rock-fill earth dam, height – 89.0m, reinforced concrete water intake, surface and bottom spillways. Diversion is a pressure tunnel with a diameter of 2.0m, length – 4.7km. Reinforced concrete surge tank is located at the end of the diversion, diameter – 4.0m. Turbine conduit is 1.2m diameter metal pipe. Powerhouse dimensions are 12.0 x 24.0m, height – 18.0m. Tailrace covered channel is rectangular reinforced concrete construction, dimensions – 2.0 x 2.0m, length – 200.0m.

1.2 **Location**

1.2.1 **Location map**



1.2.2 **Site Location**

- Maseru, Liphokoaneng; and
- GPS coordinates for the main structures.

No.	Name of Structure	Coordinates	
		X	Y
1	Dam on the Phuthiatsana river	27.738931	-29.353574
2	Powerhouse	27.695344	-29.335783

1.2.3 **Name of the River**

- Phuthiatsana

1.2.4 **Site Hyperlink (See appendix 2)**

- [Ph Dam on the river Phuthiatsana.kmz](#)
- [Ph Phuthiatsana Powerhouse.kmz](#)

1.3 **Type of HPP**

- Reservoir.

1.4 **Site access**

- Earth Road, approximately 4.73 km; and
- Distance from the paved road: 2.8 km.

1.5 **Nearest connection point with national or regional grid**

- Distance: 4.3 km; and
- Existing grid Voltage level: 33 kV.

1.6 **List of literature used for this study:**

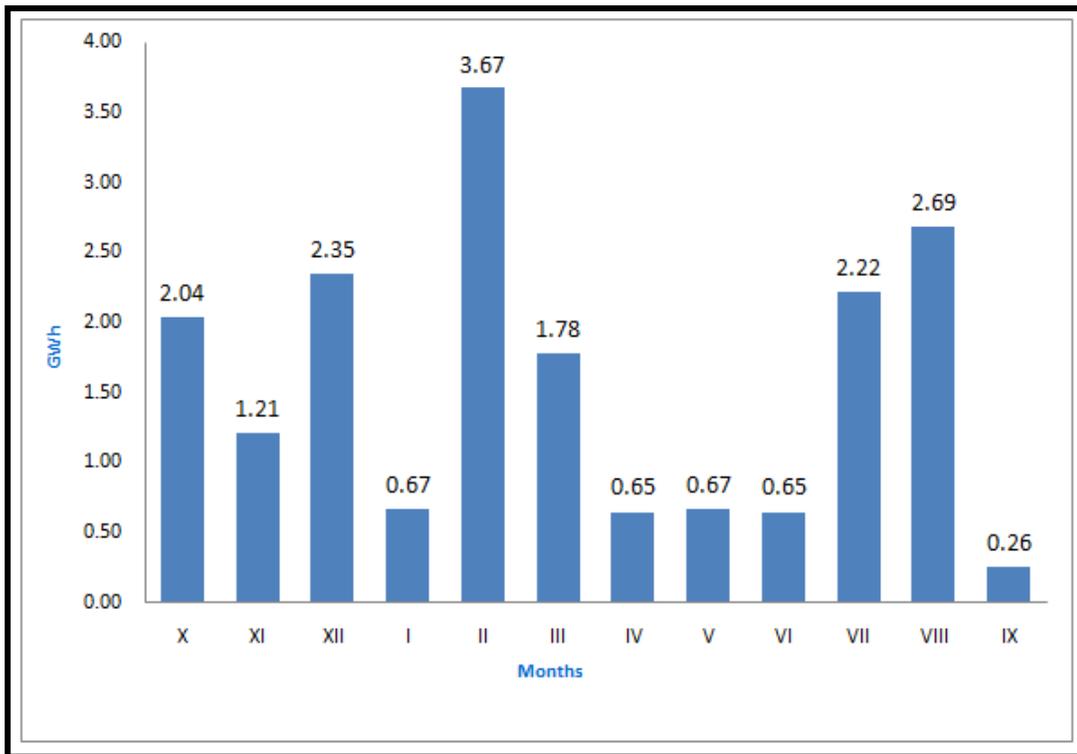
- Topographic Map - 1:50000 scale;
- Geologic Map - 1:25000 and 1:50000 scale;
- Map of hydrological and meteorological stations;
- Multiannual data of meteorological stations (temperature, humidity, wind, evaporation, precipitation);
- Scheme of High and low voltage grid, detailed technical parameters;
- Map of main communications;
- Water Resources Management, Policies and Strategies, Final Report; and
- WASM 90 Modeling Parameters.

1.7 Key characteristics

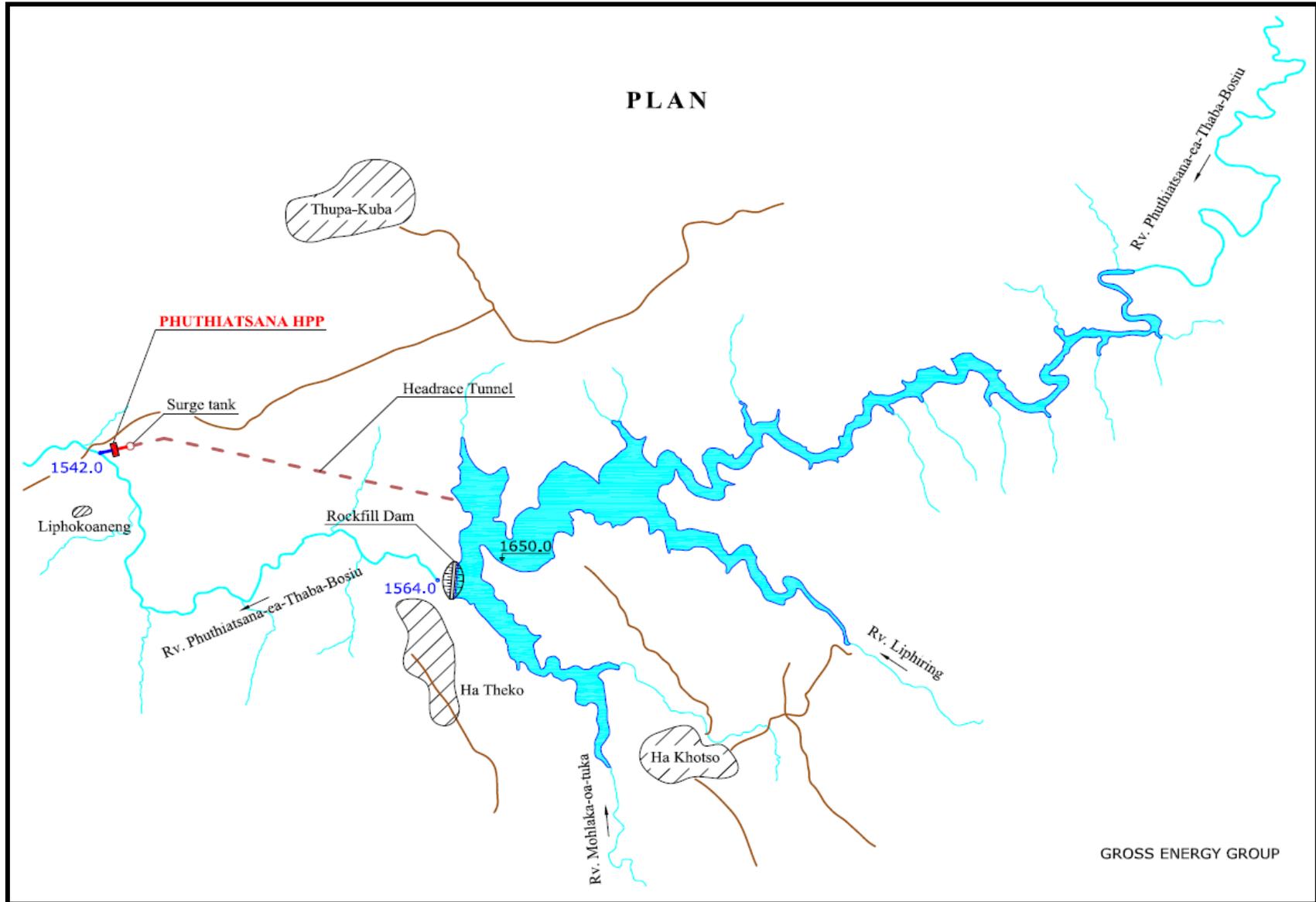
No.	Characteristics	Unit	Index
1	2	3	4
I	Technical Parameters		
1.1	Installed Capacity	MW	5.40
1.2	Average Annual output	GWh	18.87
1.3	Capacity usage ratio/Efficiency	%	39.89
1.4	Type of regulation		Reservoir
1.5	Scheme of energetic usage potential		N/A
	Hydrology		
1.6	Hydrological Data (number of years)	Year	45
1.7	Year of the average multi annual discharge	Year	1987/88
1.8	Catchment area	km ²	403.40
1.9	High water flow	m ³ /sec	3.51
1.10	Average water flow	m ³ /sec	1.43
1.11	Low water flow	m ³ /sec	0.12
1.12	Rated water discharge	m ³ /sec	6.00
1.13	Maximum gross head	m	108.00
1.14	Minimum gross head	m	54.00
	Reservoir		
1.15	Full supply level (FSL)	masl	1650.00
1.16	Minimum Operation level (MOL)	masl	1596.00
1.17	Total volume at FSL	mln. m ³	250.90
1.18	Active reservoir level	mln. m ³	175.60
	Dam		
1.19	Type		Rock fill
1.20	Crest Elevation	masl	1653.00
	Spillway		
1.21	Type		Surface
1.22	Crest Elevation	masl	1650.10
	Water intake		
1.23	Sill elevation	masl	1593.50
1.24	Stop log type and number		Butterfly valve
1.25	Quantity	unit	1
	Sluice or bottom spillway		
1.26	Type and number		Bottom
1.27	Quantity	unit	1
	Diversion		
1.28	Type of diversion		Tunnel
1.29	Dimensions (w; l) or (d; l)	m	2.0; 4700
	Stilling basin or shaft		
1.30	Dimensions (w x l xh) or (d xh)	m	4.0; 74.0
	Powerhouse		
1.31	Type		Above-ground
1.32	Dimensions (w x h x l)	m	12x18x24
1.33	Elevation of tailrace outlet sill	masl	1545.00
	Tailrace		
1.34	Type		Covered channel
1.35	Dimensions (w x h)	m	2x2
1.36	Elevation of outlet sill	masl	1574.50

No.	Characteristics	Unit	Index
1	2	3	4
	Turbines/Generators		
1.37	Turbine Type and number		F. HLA 134-Wi-71; 2
1.38	Rated discharge	m ³ /sec	3.00
1.39	Rated output	MW	2.80
1.40	Maximum output	MW	3.11
1.41	Generator Type		SFW3200-6/1730
1.42	Generator nominal output	MW	2.70
1.43	Generator nominal output	rpm	1000/1847
	Transformers		
1.44	Type		Three-phase
1.45	Number	unit	2
1.46	Nominal power	MVA	3.0
1.47	Transformer dimensions (l x w x h)	m	4,5x3,15x4,9
II	Economic - Financial Parameters		
2.1	Costing	mln. USD	10.80
2.2	Duration of the construction	Year	2.00
2.3	Investment per 1 kW	Thousand USD	2.00
2.4	Investment per 1 kW/h	USD	0.57
2.5	Revenue per USD spent (Average price new HPP - 4,8 cents)	USD	0.19
2.6	Estimated carbon credit generation	T.	6.6
III	Social and Environmental Parameters		
	Special environmental requirements		
3.1	Social Impact		Additional workplace; Development of infrastructure
3.2	Ecological risks		Medium
	Transmission lines		
3.3	Parameters	kV	33
3.4	Distance to inter connection point	km	4.30
	Infrastructure		
3.5	Existing roads		Paved, Earth
3.6	Roads to be constructed	km	4.70

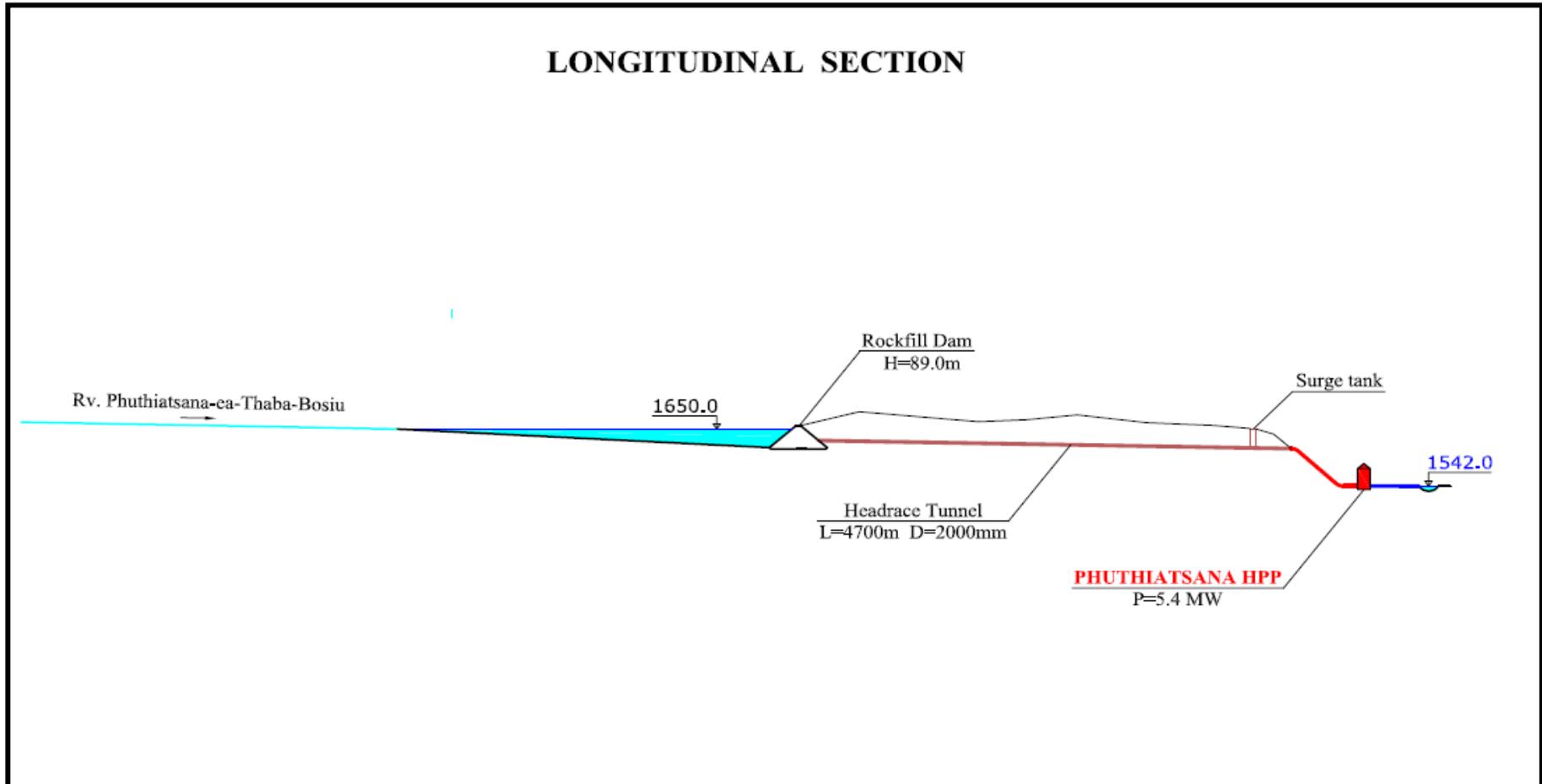
1.8 **Generation**



1.10 Plan



1.11 Longitudinal section



LESOTHO POWER GENERATION MASTER PLAN

PROJECT # LEC/GEN/1-2009

VOLUME 1 - PART 1.1

HYDROPOWER GENERATION OPTION

APPENDIX 1.1.3

MAKHALENG 1 HPP

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1. MAKHALENG 1 HPP

1.1 Brief description of the site

Three head units, diversion pressure tunnel, surge tank, turbine conduit, powerhouse, tailrace channel.

Head unit on the river Makhaleng left upper tributary conveys concrete dam, height – 5.0m, reinforced concrete water intake, sluice, spillway and silt basin with sluice. Diversion is 2.0m diameter pressure metal pipe, length – 0.5km.

Head unit on the river Makhaleng left lower tributary conveys concrete dam, height – 3.0m, reinforced concrete water intake, sluice, spillway and silt basin with sluice. Diversion is 0.2m diameter pressure metal pipe, length – 0.11km.

Head unit on the river Makhaleng conveys rock-fill earth dam, height – 38.0m, reinforced concrete water intake, and surface and bottom spillways. Diversion is 0.8m diameter pressure tunnel, length – 5.0km.

Metal surge tank is located at the end of diversion, diameter - 1.0m. Turbine conduit is 0.6m diameter metal pipe. Powerhouse dimensions 12.0×24.0m, height – 18.0m. Tailrace covered channel is rectangular reinforced concrete construction, dimensions – 1.5×1.5m, length – 100.0m.

1.2 Location

1.2.1 Location map



1.2.2 **Site location**

- Maseru, Kutumane; and
- GPS coordinates for the main structures.

No.	Name of Structure	Coordinates	
		X	Y
1	Dam on the river Makhaleng	27.900926	-29.419589
2	Dam on the river Makhaleng left tributary	27.904276	-29.424710
3	Dam on the river Makhaleng left tributary	27.893995	-29.433072
4	Powerhouse	27.884010	-29.459964

1.2.3 **Name of the river**

- Makhaleng.

1.2.4 **Sites hyperlink (See appendix 2)**

- [Mk1 Dam Makhaleng left tributary.kmz](#)
- [Mk1 Dam on the river Makhaleng left tributary.kmz](#)
- [Mk1 Dam on the river Makhaleng.kmz](#)
- [Mk1 Makhaleng 1 Powerhouse.kmz](#)

1.3 **Type of HPP**

- Reservoir.

1.4 **Existing Site Access**

- Earth Road: approximately 0.5 km; and
- Distance from the paved road: 3.5 km.

1.5 **Nearest connection point with national or regional grid: 3.5 km; 132 kV**

1.6 **List of Literature used for this study:**

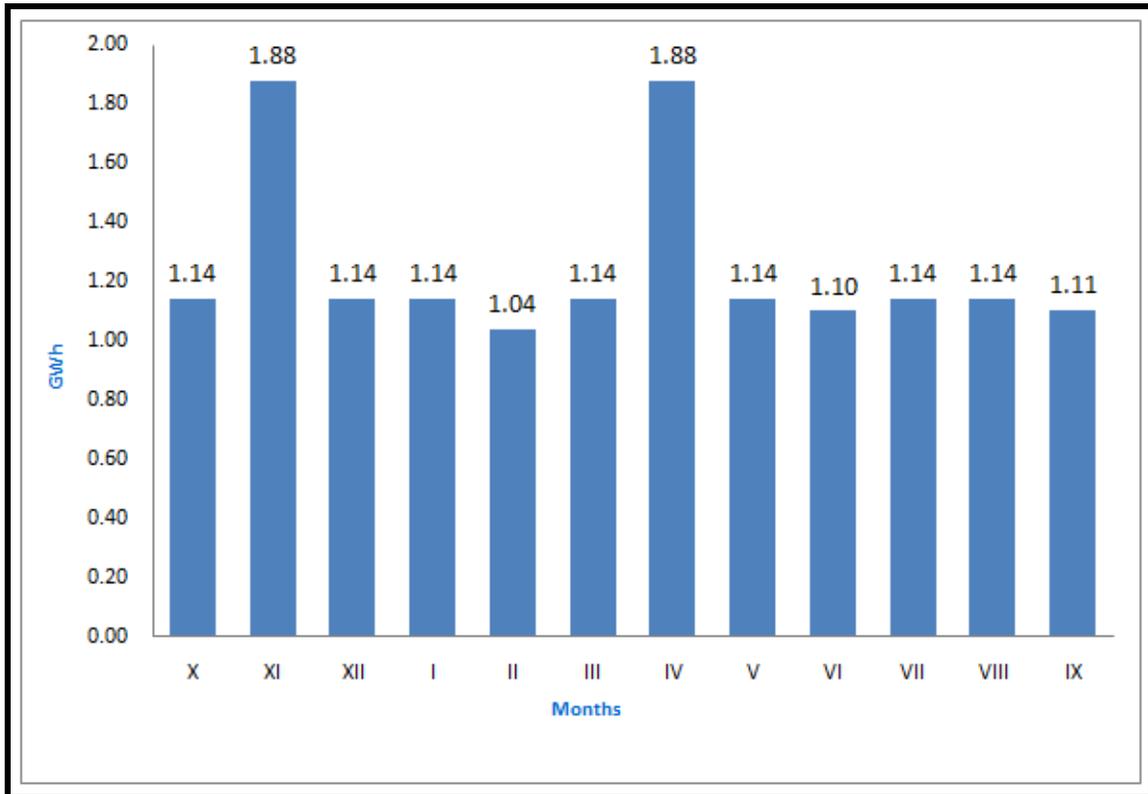
- Topographic Map - 1:50000 scale;
- Geologic Map - 1:25000 and 1:50000 scale;
- Map of hydrological and meteorological stations;
- Multiannual data of meteorological stations (temperature, humidity, wind, evaporation, precipitation);
- Scheme of High and low voltage grid, detailed technical parameters;
- Map of main communications;
- Water Resources Management, Policies and Strategies, Final Report; and
- WASM 90 Modeling Parameters.

1.7 Key Characteristics

No.	Characteristics	Unit	Index
1	2	3	4
I	Technical Parameters		
1.1	Installed Capacity	MW	2.00
1.2	Average Annual output	GWh	15.00
1.3	Capacity usage ratio/Efficiency	%	85.62
1.4	Type of regulation		Reservoir
1.5	Scheme of energetic usage potential		Full
	Hydrology		
1.6	Hydrological Data (number of years)	Year	20
1.7	Year of the average multi annual discharge	Year	1989/90
1.8	Catchment area	km ²	92.00
1.9	High water flow	m ³ /sec	1.50
1.10	Average water flow	m ³ /sec	1.18
1.11	Low water flow	m ³ /sec	0.57
1.12	Rated water discharge	m ³ /sec	1.70
1.13	Maximum gross head	m	133.00
1.14	Minimum gross head	m	169.00
	Reservoir		
1.15	Full supply level (FSL)	masl	2000.00
1.16	Minimum Operation level (MOL)	masl	1976.00
1.17	Total volume at FSL	mln. m ³	8.00
1.18	Active reservoir level	mln. m ³	5.60
	Dam		
1.19	Type		Rock fill
1.20	Crest Elevation	masl	2003.00
	Spillway		
1.21	Type		Surface
1.22	Crest Elevation	masl	2000.10
	Water intake		
1.23	Sill elevation	masl	1974.70
1.24	Stop log type and number		Butterfly valve
1.25	Quantity	unit	1
	Sluice or bottom spillway		
1.26	Type and number		Bottom
1.27	Quantity	unit	1
	Diversion		
1.28	Type of diversion		Conduit
1.29	Dimensions (w; l) or (d; l)	m	0.8; 5610
	Stilling basin or shaft		
1.30	Dimensions (w x l xh) or (d xh)	m	1.0; 44.0
	Powerhouse		
1.31	Type		Above-ground
1.32	Dimensions (w x h x l)	m	12x18x24
1.33	Elevation of tailrace outlet sill	masl	1870.00
	Tailrace		
1.34	Type		Covered channel
1.35	Dimensions (w x h)	m	1.5x1.5
1.36	Elevation of outlet sill	masl	1867.50
	Turbines/Generators		

No.	Characteristics	Unit	Index
1	2	3	4
1.37	Turbine Type and number		F. HL 904-WJ-71; 2
1.38	Rated discharge	m ³ /sec	0.85
1.39	Rated output	MW	1.04
1.40	Maximum output	MW	1.15
1.41	Generator Type		SFW1250-6/1430
1.42	Generator nominal output	MW	1.00
1.43	Generator nominal output	rpm	1019
	Transformers		
1.44	Type		Three-phase
1.45	Number	unit	2
1.46	Nominal power	MVA	1.1
1.47	Transformer dimensions (l x w x h)	m	4,5x3,15x4,9
II	Economic - Financial Parameters		
2.1	Costing	mln. USD	4.00
2.2	Duration of the construction	Year	2.00
2.3	Investment per 1 kW	Thousand USD	2.00
2.4	Investment per 1 kW/h	USD	0.27
2.5	Revenue per USD spent (Average price new HPP - 4,8 cents)	USD	0.48
2.6	Estimated carbon credit generation	T.	5.3
III	Social and Environmental Parameters		
	Special environmental requirements		
3.1	Social Impact		Additional workplace; Development of infrastructure
3.2	Ecological risks		Medium
	Transmission lines		
3.3	Parameters	kV	132
3.4	Distance to inter connection point	km	3.50
	Infrastructure		
3.5	Existing roads		Paved, Earth
3.6	Roads to be constructed	km	3.50

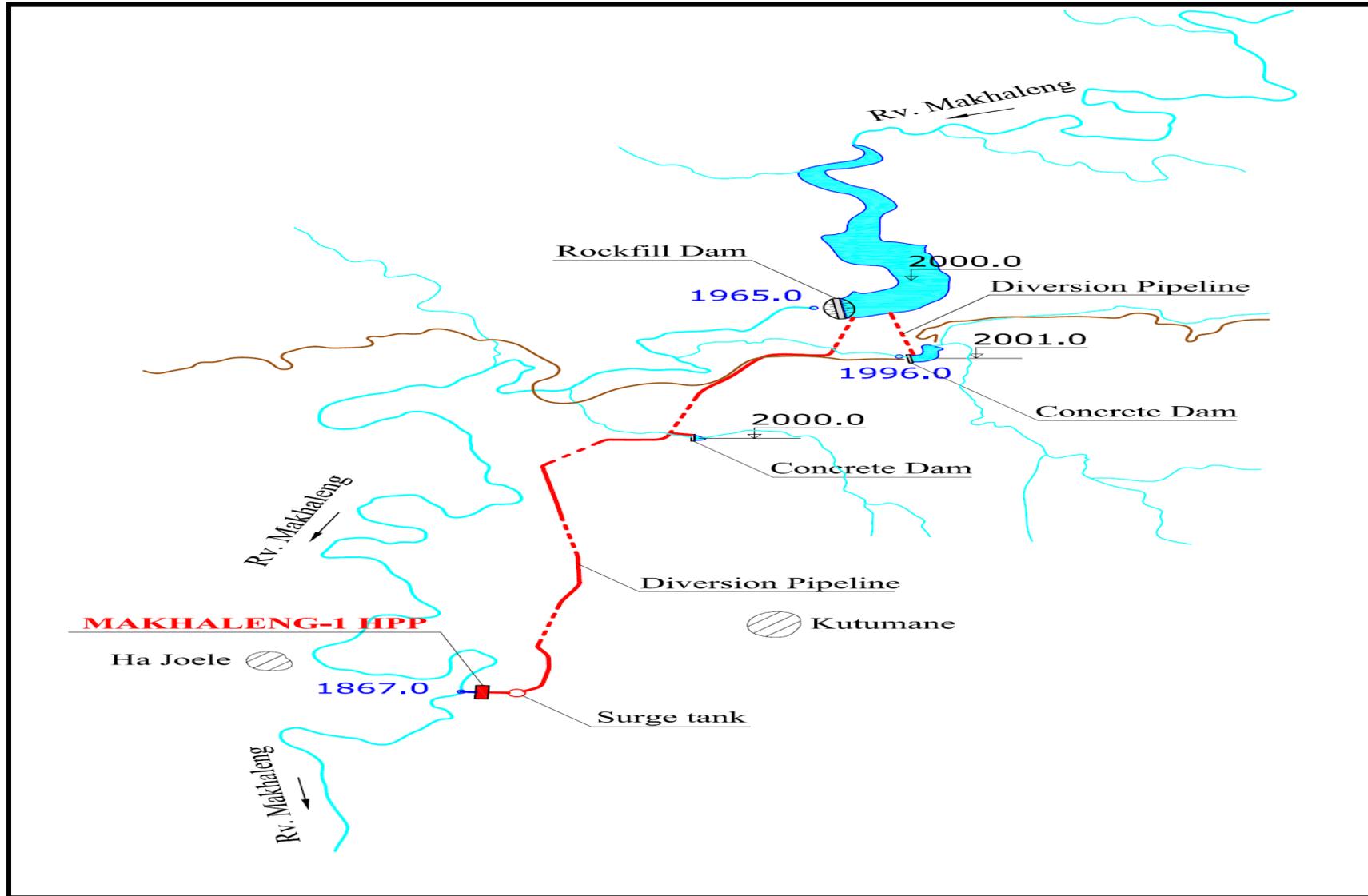
1.8 **Generation**



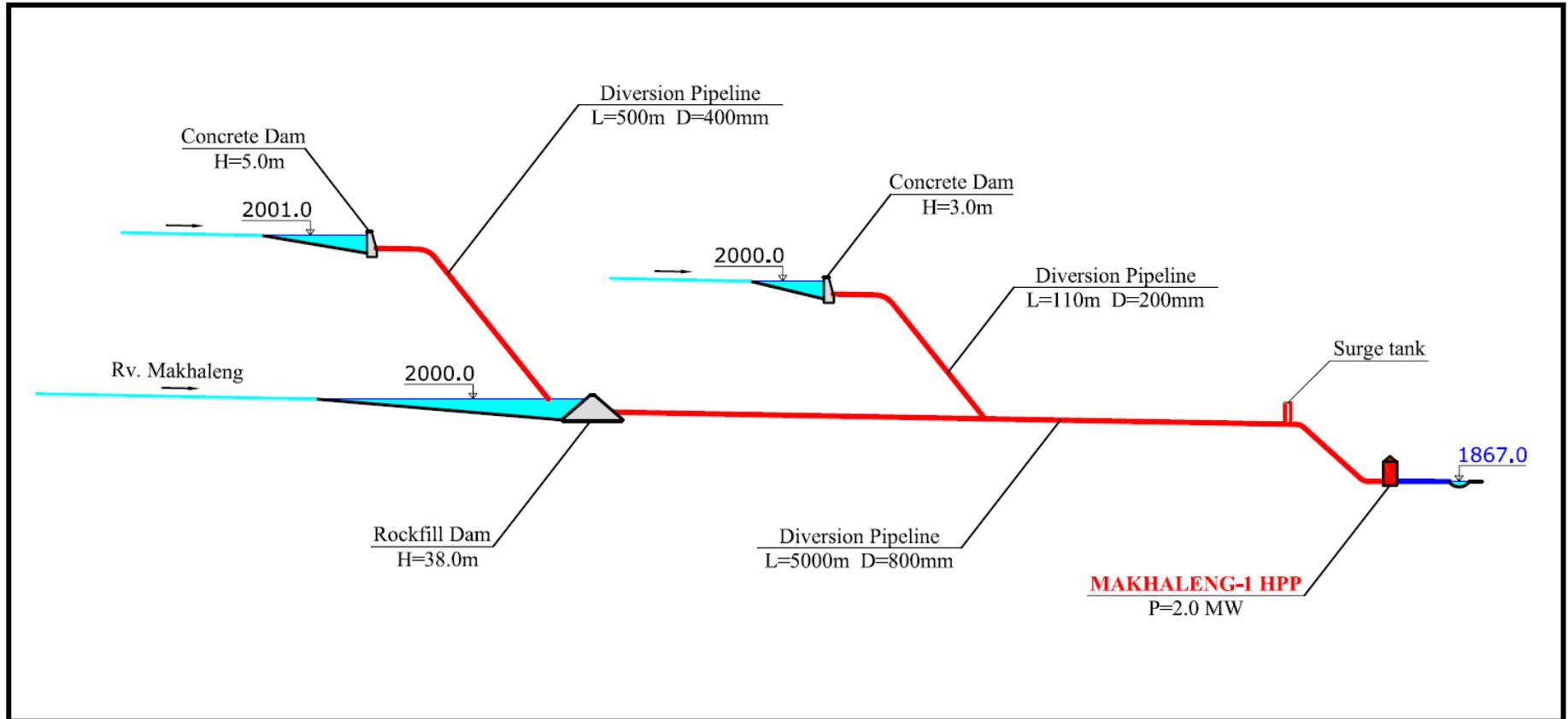
1.9 Topographic map



1.10 Plan



1.11 Longitudinal section



LESOTHO POWER GENERATION MASTER PLAN

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APPENDIX 1.1.4

MAKHALENG 2 HPP

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1. MAKHALENG 2 HPP

1.1 Brief description of the site

Two head units, diversion pressure pipeline, surge tank, turbine conduit, powerhouse, tailrace tunnel.

Head unit on the river Makhaleng conveys concrete dam, height – 3.0m, reinforced concrete water intake, spillway and silt basin with sluice. Diversion is 1.0m diameter pressure pipeline, length – 5.3km.

Head unit on the river Lekoloheng conveys concrete dam, height – 5.0m, reinforced concrete water intake, and silt basin with sluice. Diversion is 0.63m diameter pressure tunnel, length – 3.0 km.

Reinforced concrete surge tank is located at the end of diversion, dimensions - 4.0 x 15.0m, height – 4.0m. Turbine conduit is 1.0m diameter metal pipe. Powerhouse dimensions - 12.0x24.0m, height – 18.0m. Tailrace covered channel is rectangular reinforced concrete construction, dimensions – 2.0x2.0m, length – 50.0m.

1.2 Location

1.2.1 Location map



1.2.2 **Site Location**

- Maseru, Ha Sakia; and
- GPS coordinates for the main structures.

No.	Name of Structure	Coordinates	
		X	Y
1	Dam on the river Makhaleng	27.882435	-29.460318
2	Dam on the river Likolobeng	27.903610	-29.501846
3	Powerhouse	27.878764	-29.500586

1.2.3 **Name of the River**

- Makhaleng.

1.2.4 **Site Hyperlink (See appendix 2)**

- [Mk2 Dam on the river Likolobeng.kmz](#)
- [Mk2 Dam on the river Makhaleng.kmz](#)
- [Mk2 Makhaleng 2 Powerhouse.kmz](#)

1.3 **Type of HPP**

- Run-off-the-river.

1.4 **Existing site access**

- Earth Road: Approximately 0.5 km; and
- Distance from the paved road: 9.0 km.

1.5 **Nearest connection point with national or regional grid: 9.0 km; 132 kV**

1.6 **List of Literature used for this study:**

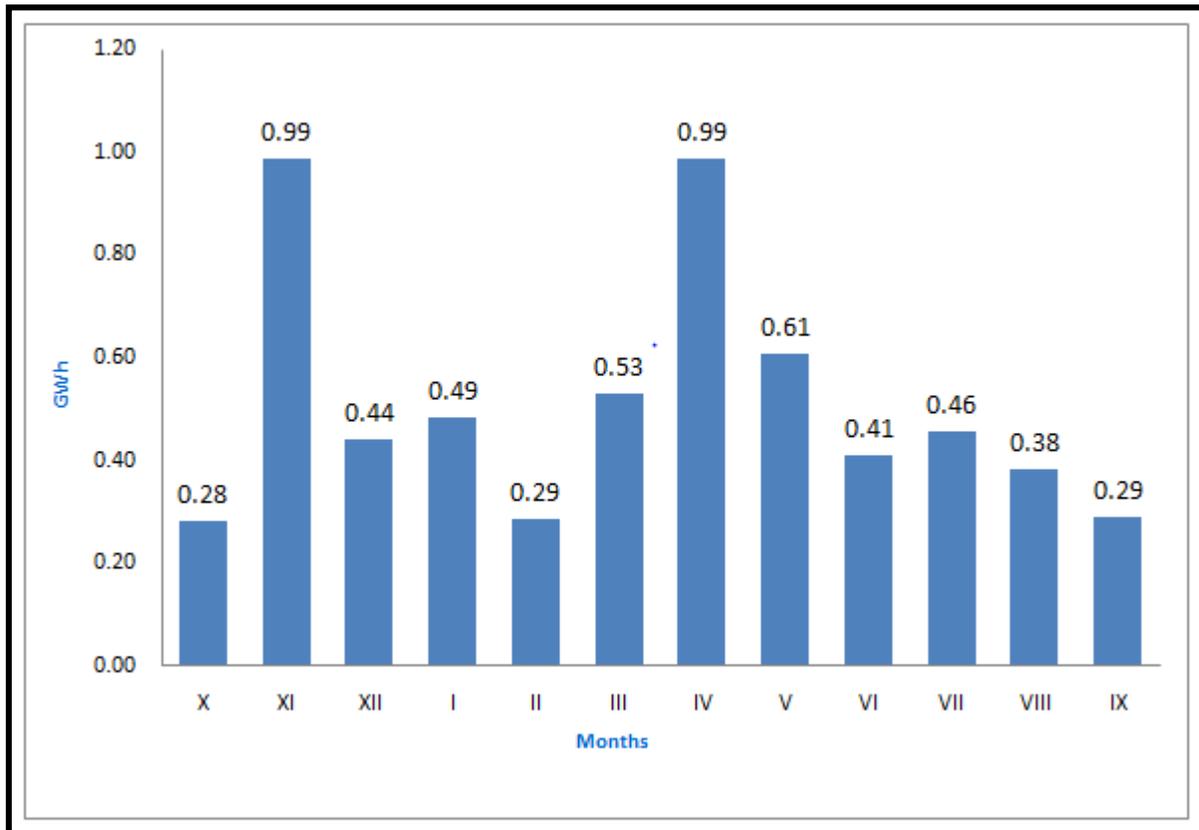
- Topographic Map - 1:50000 scale;
- Geologic Map - 1:25000 and 1:50000 scale;
- Map of hydrological and meteorological stations;
- Multiannual data of meteorological stations (temperature, humidity, wind, evaporation, precipitation);
- Scheme of High and low voltage grid, detailed technical parameters;
- Map of main communications;
- Water Resources Management, Policies and Strategies, Final Report; and
- WASM 90 Modeling Parameters.

1.7 Key Characteristics

No.	Characteristics	Unit	Index
1	2	3	4
I	Technical Parameters		
1.1	Installed Capacity	MW	1.40
1.2	Average Annual output	GWh	6.15
1.3	Capacity usage ratio/Efficiency	%	50.15
1.4	Type of regulation		Run-off-the-river
1.5	Scheme of energetic usage potential		Full
	Hydrology		
1.6	Hydrological Data (number of years)	Year	20
1.7	Year of the average multi annual discharge	Year	1989/90
1.8	Catchment area	Km ²	90.60
1.9	High water flow	m ³ /sec	2.48
1.10	Average water flow	m ³ /sec	2.17
1.11	Low water flow	m ³ /sec	1.12
1.12	Rated water discharge	m ³ /sec	4.00
1.13	Maximum gross head	m	42.00
1.14	Minimum gross head	m	–
	Reservoir		
1.15	Full supply level (FSL)	masl	1867.00
1.16	Minimum Operation level (MOL)	masl	Unnecessary
1.17	Total volume at FSL	mln. m ³	Unnecessary
1.18	Active reservoir level	mln. m ³	Unnecessary
	Dam		
1.19	Type		Tyrol
1.20	Crest Elevation	masl	1866.60
	Spillway		
1.21	Type		Surface
1.22	Crest Elevation	masl	Unnecessary
	Water intake		
1.23	Sill elevation	masl	1864.20
1.24	Stop log type and number		Butterfly valve
1.25	Quantity	unit	1
	Sluice or bottom spillway		
1.26	Type and number		Bottom
1.27	Quantity	unit	1
	Diversion		
1.28	Type of diversion		Conduit
1.29	Dimensions (w; l) or (d; l)	m	0.63; 3006. 1.0; 5300
	Stilling basin or shaft		
1.30	Dimensions (w x l xh) or (d xh)	m	4x15x3.5
	Powerhouse		
1.31	Type		Above-ground
1.32	Dimensions (w x h x l)	m	12x18x24
1.33	Elevation of tailrace outlet sill	masl	1827.50
	Tailrace		
1.34	Type		Covered channel
1.35	Dimensions (w x h)	m	2.0x2.0

No.	Characteristics	Unit	Index
1	2	3	4
1.36	Elevation of outlet sill	masl	1823.50
	Turbines/Generators		
1.37	Turbine Type and number		F. MLA 215-LJ-84; 2
1.38	Rated discharge	m ³ /sec	2.00
1.39	Rated output	MW	0.73
1.40	Maximum output	MW	0.81
1.41	Generator Type		SF800-10/2150
1.42	Generator nominal output	MW	0.70
1.43	Generator nominal output	rpm	600
	Transformers		
1.44	Type		Three-phase
1.45	Number	unit	2
1.46	Nominal power	MVA	0.8
1.47	Transformer dimensions (l x w x h)	m	4,5x3,15x4,9
II	Economic - Financial Parameters		
2.1	Costing	mln. USD	3.20
2.2	Duration of the construction	Year	2.00
2.3	Investment per 1 kW	Thousand USD	2.29
2.4	Investment per 1 kW/h	USD	0.52
2.5	Revenue per USD spent (Average price new HPP - 4,8 cents)	USD	0.46
2.6	Estimated carbon credit generation	T.	2.2
III	Social and Environmental Parameters		
	Special environmental requirements		
3.1	Social Impact		Additional workplace; Development of infrastructure
3.2	Ecological risks		Medium
	Transmission lines		
3.3	Parameters	kV	132
3.4	Distance to inter connection point	km	9.00
	Infrastructure		
3.5	Existing roads		Paved, Earth
3.6	Roads to be constructed	km	10.50

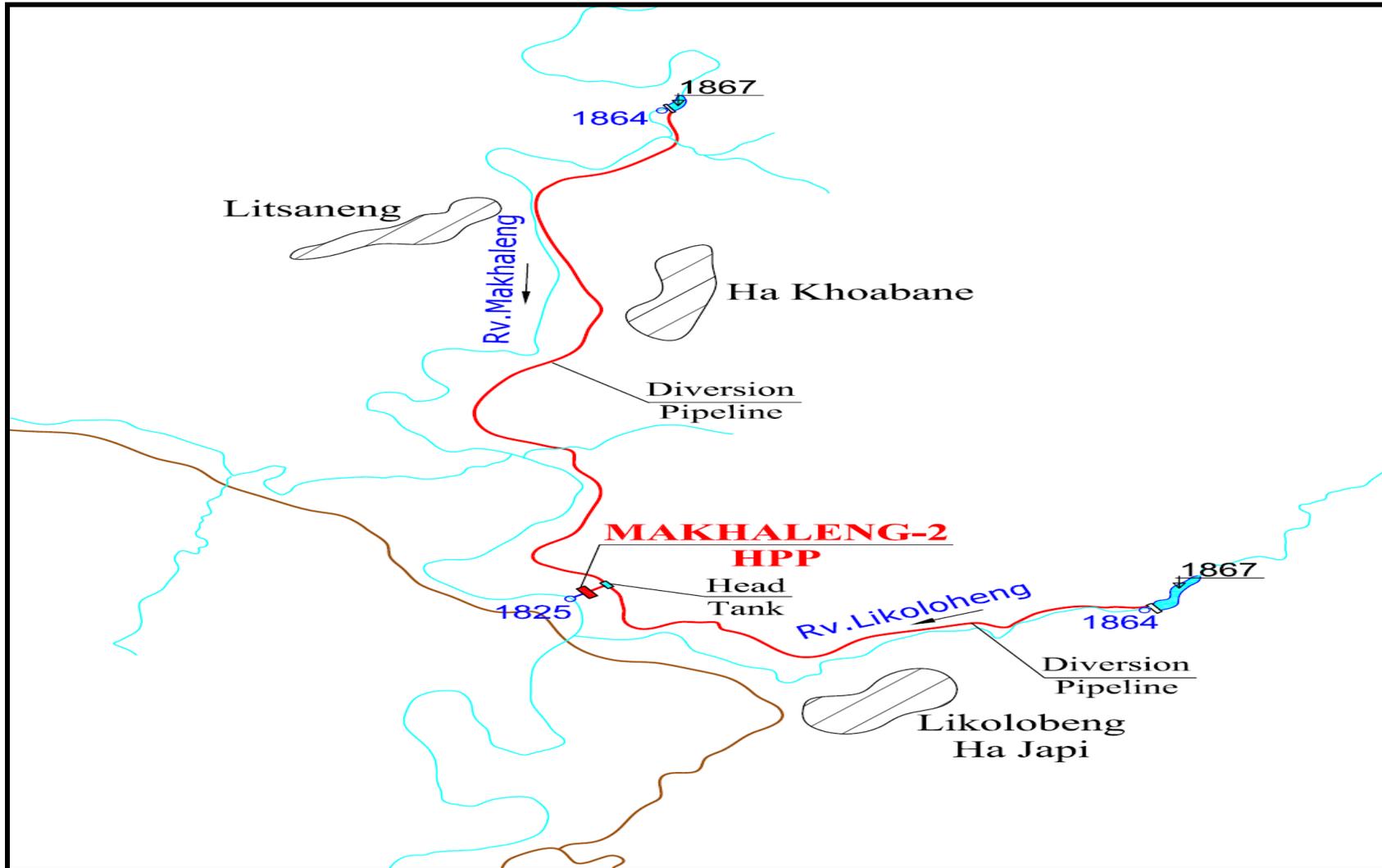
1.8 Generation



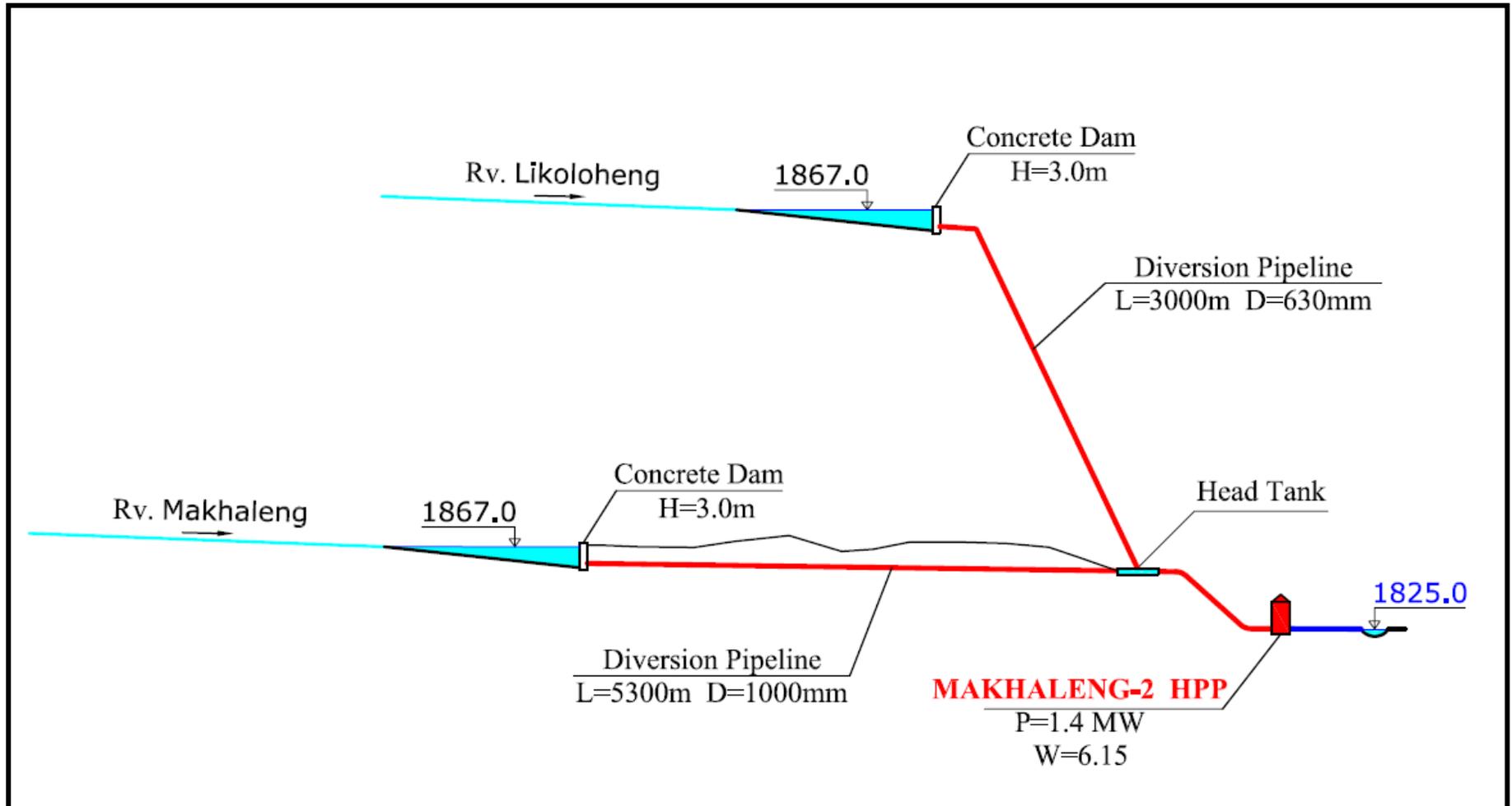
1.9 Topographic map



1.10 Plan



1.11 Longitudinal section



LESOTHO POWER GENERATION MASTER PLAN

PROJECT # LEC/GEN/1-2009

FINAL MILESTONES REPORT

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APPENDIX 1.1.5

MAKHALENG 3 HPP

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1.2.3	<i>Name of the river</i>	<i>99</i>
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1.4	Existing site access.....	99
1.5	Nearest connection point with national or regional grid.....	99
1.6	List of literature used for this study:	99
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1.11	Longitudinal section.....	105

1. MAKHALENG 3 HPP

1.1 Brief description of the site

Four head units, diversion pressure tunnel, surge tank, turbine conduit, powerhouse, tailrace channel.

Head unit on the river Makhaleng conveys concrete dam, height – 5.0m, reinforced concrete water intake, and silt basin with sluice. Diversion is 2.0m diameter pressure tunnel, length – 8.3km.

Head unit on the river Leghilighili conveys concrete dam, height – 5.0m, reinforced concrete water intake, and silt basin with sluice. Diversion is 2.0m diameter pressure tunnel, length – 1.7 km.

Head unit on the river Likotopong conveys concrete dam, height – 5.0m, reinforced concrete water intake, and silt basin with sluice. Diversion is 2.0m diameter pressure tunnel, length – 3.65 km.

Head unit on the river Mosenya-Senya conveys concrete dam, height – 5.0m, reinforced concrete water intake, and silt basin with sluice. Diversion is 2.0m diameter pressure tunnel, length – 2.6 km.

Reinforced concrete surge tank is located at the end of diversion, diameter - 4.0m. Turbine conduit is 1.4m diameter metal pipe with concrete layer. Powerhouse dimensions - 12.0x24.0m, height – 18.0m. Tailrace covered channel is rectangular reinforced concrete construction, dimensions – 2.0x2.5m, length – 100.0m.

1.2.2 **Site location**

- Maseru, Majoaneng; and
- GPS coordinates for the main structures.

No.	Name of Structure	Coordinates	
		X	Y
1	Dam on the river Makhaleng	27.878084	-29.504398
2	Dam on the river Leghilighili	27.909055	-29.581419
3	Dam on the river Ngope-Khubelo	27.912053	-29.597275
4	Dam on the river Mosenya-senya	27.887908	-29.618443
5	Powerhouse	27.863071	-29.622528

1.2.3 **Name of the river**

- Makhaleng.

1.2.4 **Site hyperlink (See appendix 2)**

- [Mk3 Dam on the river Makhaleng.kmz](#)
- [Mk3 Dam on the river Mosenya-senya.kmz](#)
- [Mk3 Dam on the river Ngope-Khubelo.kmz](#)
- [Mk3Dam on the river Leghiliqhili.kmz](#)
- [Mk3 Makhaleng 3 Powerhouse.kmz](#)

1.3 **Type of HPP**

- Run-off-the-river.

1.4 **Existing site access**

- Earth Road: approximately 0.8 km; and
- Distance from the paved road: 2.8 km.

1.5 **Nearest connection point with national or regional grid**

- Distance: 15.0 km; and
- Existing Grid Voltage level: 132 kV.

1.6 **List of literature used for this study:**

- Topographic Map - 1:50000 scale;
- Geologic Map - 1:25000 and 1:50000 scale;
- Map of hydrological and meteorological stations;

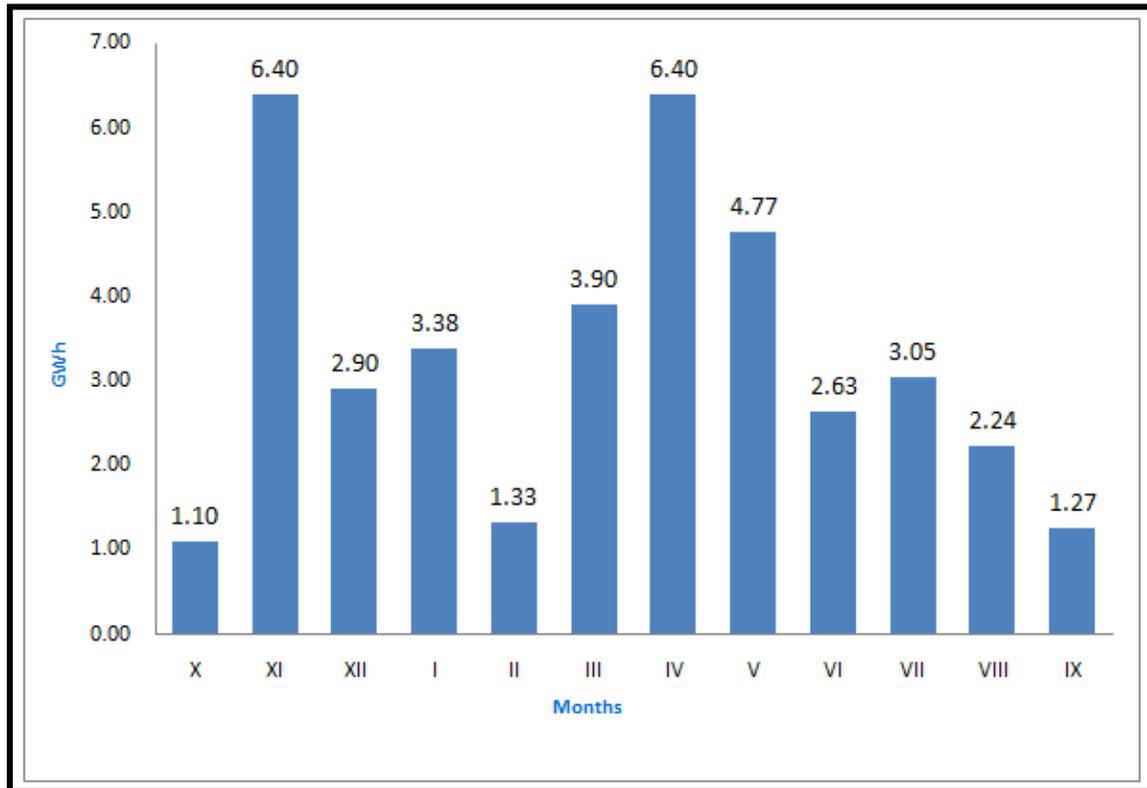
- Multiannual data of meteorological stations (temperature, humidity, wind, evaporation, precipitation);
- Scheme of High and low voltage grid, detailed technical parameters;
- Map of main communications;
- Water Resources Management, Policies and Strategies, Final Report; and
- WASM 90 Modeling Parameters.

1.7 Key characteristics

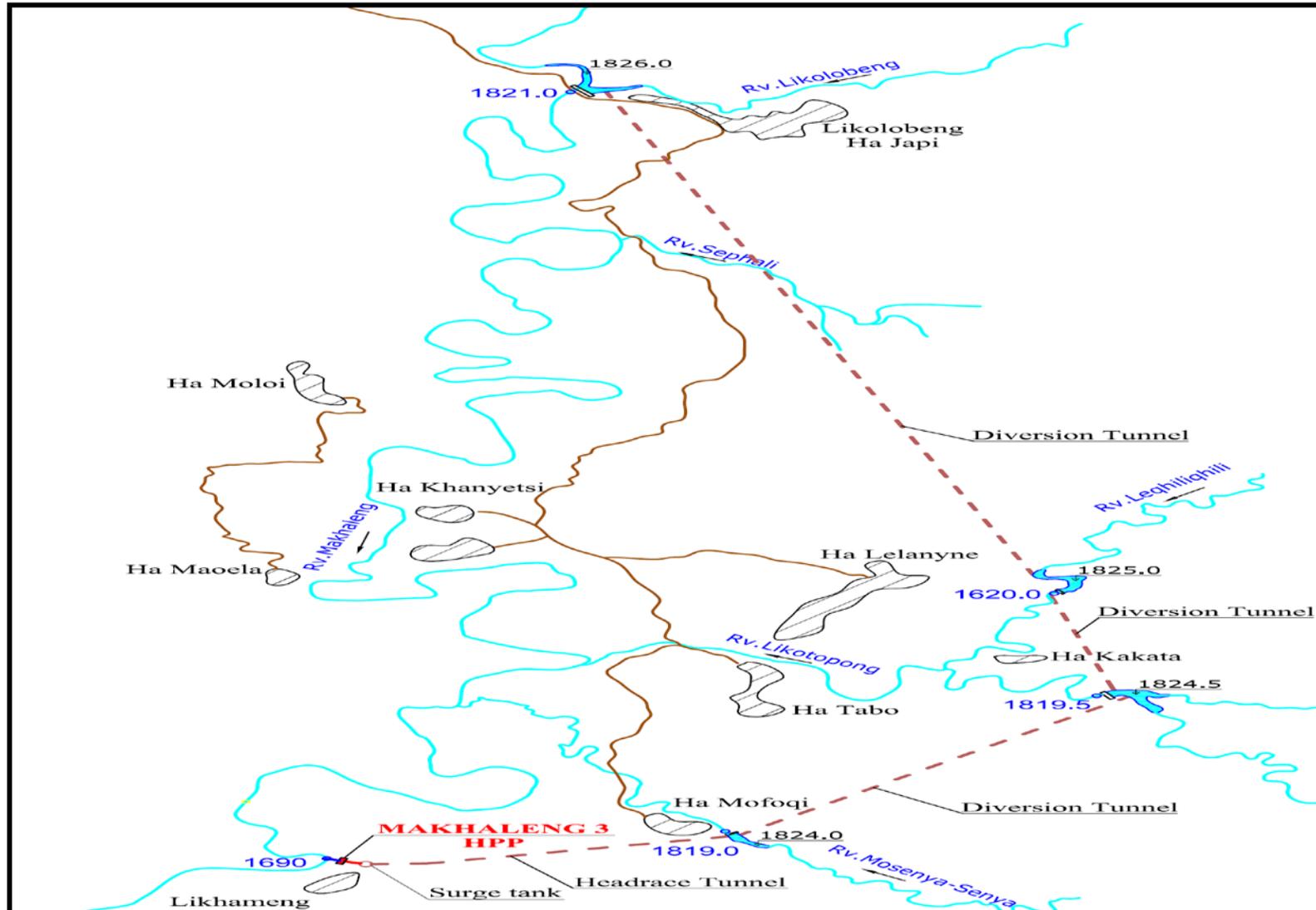
#	Characteristics	Unit	Index
1	2	3	4
I	Technical Parameters		
1.1	Installed Capacity	MW	8.90
1.2	Average Annual output	GWh	39.40
1.3	Capacity usage ratio/Efficiency	%	50.54
1.4	Type of regulation		Run-off-the-river
1.5	Scheme of energetic usage potential		Full
	Hydrology		
1.6	Hydrological Data (number of years)	Year	20
1.7	Year of the average multi annual discharge	Year	1989/90
1.8	Catchment area	km ²	313.00
1.9	High water flow	m ³ /sec	5.13
1.10	Average water flow	m ³ /sec	4.73
1.11	Low water flow	m ³ /sec	1.93
1.12	Rated water discharge	m ³ /sec	8.00
1.13	Maximum gross head	m	134.00
1.14	Minimum gross head	m	–
	Reservoir		
1.15	Full supply level (FSL)	masl	1826.00
1.16	Minimum Operation level (MOL)	masl	Unnecessary
1.17	Total volume at FSL	mln. m ³	Unnecessary
1.18	Active reservoir level	mln. m ³	Unnecessary
	Dam		
1.19	Type		Tyrol
1.20	Crest Elevation	masl	1825.60
	Spillway		
1.21	Type		Surface
1.22	Crest Elevation	masl	1826.10
	Water intake		
1.23	Sill elevation	masl	1821.00
1.24	Stop log type and number		Butterfly valve
1.25	Quantity	unit	1
	Sluice or bottom spillway		
1.26	Type and number		Bottom
1.27	Quantity	unit	1
	Diversion		
1.28	Type of diversion		Tunnel
1.29	Dimensions (w; l) or (d; l)	m	2.0; 16250
	Stilling basin or shaft		
1.30	Dimensions (w x l xh) or (d xh)	m	4.0; 13.0

#	Characteristics	Unit	Index
1	2	3	4
	Powerhouse		
1.31	Type		Above-ground
1.32	Dimensions (w x h x l)	m	12x18x24
1.33	Elevation of tailrace outlet sill	masl	1693.00
	Tailrace		
1.34	Type		Covered channel
1.35	Dimensions (w x h)	m	2.0x2.5
1.36	Elevation of outlet sill	masl	1688.50
	Turbines/Generators		
1.37	Turbine Type and number		F. MHD 46-WJ-84; 2
1.38	Rated discharge	m ³ /sec	4.00
1.39	Rated output	MW	4.61
1.40	Maximum output	MW	5.12
1.41	Generator Type		SFW5000-6/2150
1.42	Generator nominal output	MW	4.45
1.43	Generator nominal output	rpm	1000/1654
	Transformers		
1.44	Type		Three-phase
1.45	Number	unit	2
1.46	Nominal power	MVA	4.9
1.47	Transformer dimensions (l x w x h)	m	4,5x3,15x4,9
II	Economic - Financial Parameters		
2.1	Costing	mIn. USD	35.40
2.2	Duration of the construction	Year	3.50
2.3	Investment per 1 kW	Thousand USD	3.98
2.4	Investment per 1 kW/h	USD	0.90
2.5	Revenue per USD spent (Average price new HPP - 4,8 cents)	USD	0.09
2.6	Estimated carbon credit generation	T.	13.8
III	Social and Environmental Parameters		
	Special environmental requirements		
3.1	Social Impact		Additional workplace; Development of infrastructure
3.2	Ecological risks		Low
	Transmission lines		
3.3	Parameters	kV	132
3.4	Distance to inter connection point	km	15.00
	Infrastructure		
3.5	Existing roads		Paved, Earth
3.6	Roads to be constructed	km	0.80

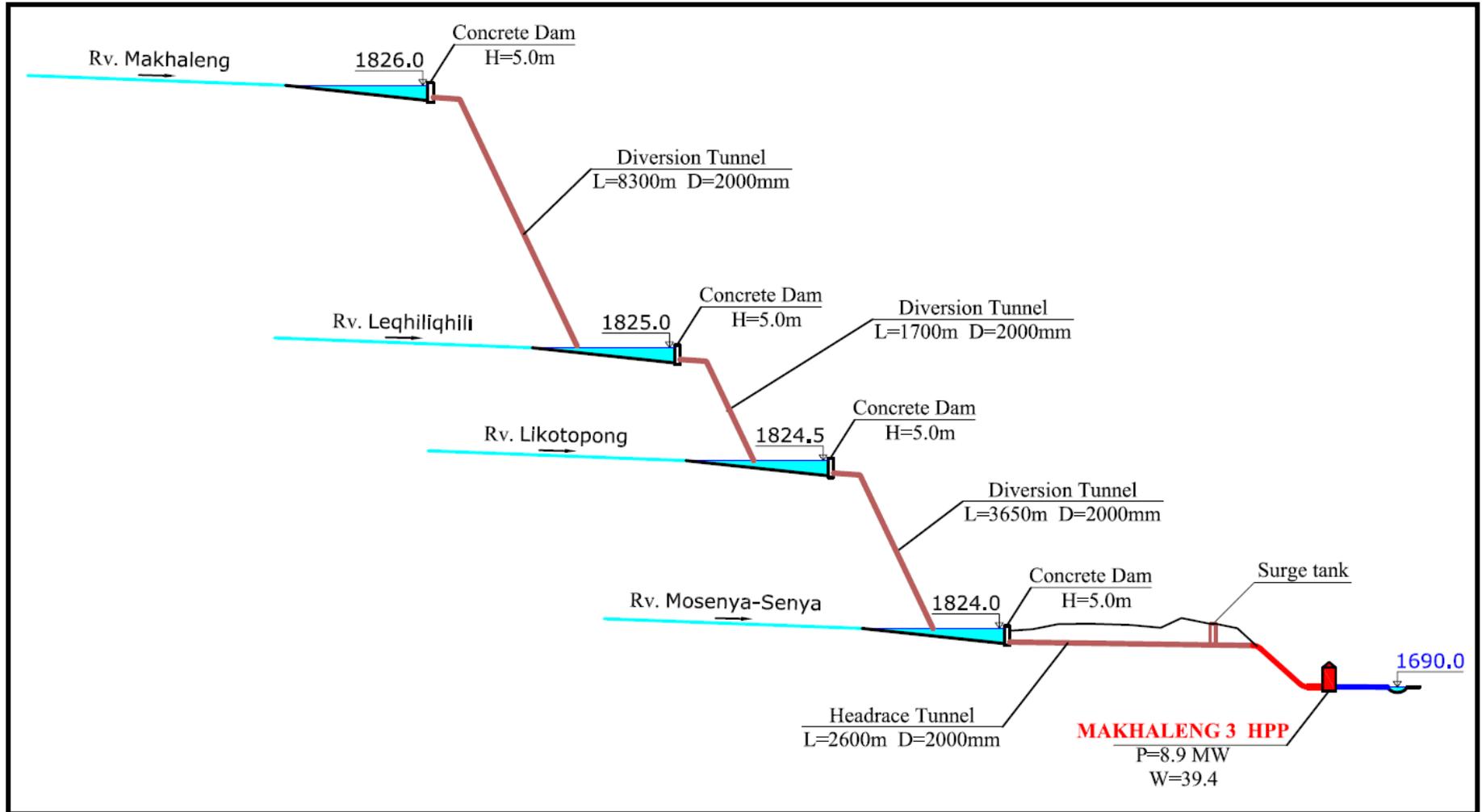
1.8 Generation



1.10 Plan



1.11 Longitudinal section



LESOTHO POWER GENERATION MASTER PLAN

PROJECT # LEC/GEN/1-2009

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HYDROPOWER GENERATION OPTION

APPENDIX 1.1.6

MAKHALENG 4 HPP

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1. MAKHALENG 4 HPP

1.1 Brief description of the site

Three head units, diversion pressure tunnel, surge tank, turbine conduit, powerhouse, tailrace channel.

Head unit on the river Ntsupe conveys concrete dam, height – 12.0m, reinforced concrete water intake, and silt basin with sluice. Diversion is 0.4m diameter pressure metal pipe, length – 0.45km.

Head unit on the river Makhaleng conveys rock-fill earth dam, height – 38.0m, reinforced concrete water intake, and surface and bottom spillways. Diversion is 2.0m diameter pressure tunnel, length – 4.2km.

Head unit on the river Makhaleng conveys rock-fill earth dam, height – 58.0m, reinforced concrete water intake, and surface and bottom spillways. Diversion is 2.0m diameter pressure tunnel, length – 5.8km.

Reinforced concrete surge tank is located at the end of diversion, diameter - 4.0m. Turbine conduit is 1.8m diameter metal pipe. Powerhouse dimensions 12.0×24.0m, height – 18.0m. Tailrace covered channel is rectangular reinforced concrete construction, dimensions – 2.5×2.5m, length – 100.0m.

1.2 Location

1.2.1 Location map



1.2.2 **Site location**

- Maseru, Ha Ntleke; and
- GPS coordinates for the main structures.

No.	Name of Structure	Coordinates	
		X	Y
1	Dam on the river Makhaleng	27.759167	-29.704469
2	Dam on the river Makhalaneng	27.704173	-29.711627
3	Dam on the river Ntsupe	27.771053	-29.709446
5	Powerhouse	27.683601	-29.763382

1.2.3 **Name of the river**

- Makhaleng.

1.2.4 **Sites hyperlink (See appendix 2)**

- [Mk4 Dam on the river Makhalaneng.kmz](#)
- [Mk4 Dam on the river Makhaleng.kmz](#)
- [Mk4 Dam on the river Ntsupe.kmz](#)
- [Mk4 Mahaleng 4 Powerhouse.kmz](#)

1.3 **Type of HPP**

- Reservoir.

1.4 **Existing site access**

- Earth Road: approximately 2.2 km; and
- Distance from the paved road: 3.7 km.

1.5 **Nearest connection point with national or regional grid**

- Distance: 22.0 km; and
- Existing Grid Voltage level: 132 kV

1.6 **List of literature used for this study:**

- Topographic Map - 1:50000 scale;
- Geologic Map - 1:25000 and 1:50000 scale.;
- Map of hydrological and meteorological stations;
- Multiannual data of meteorological stations (temperature, humidity, wind, evaporation, precipitation);
- Scheme of High and low voltage grid, detailed technical parameters;
- Map of main communications;

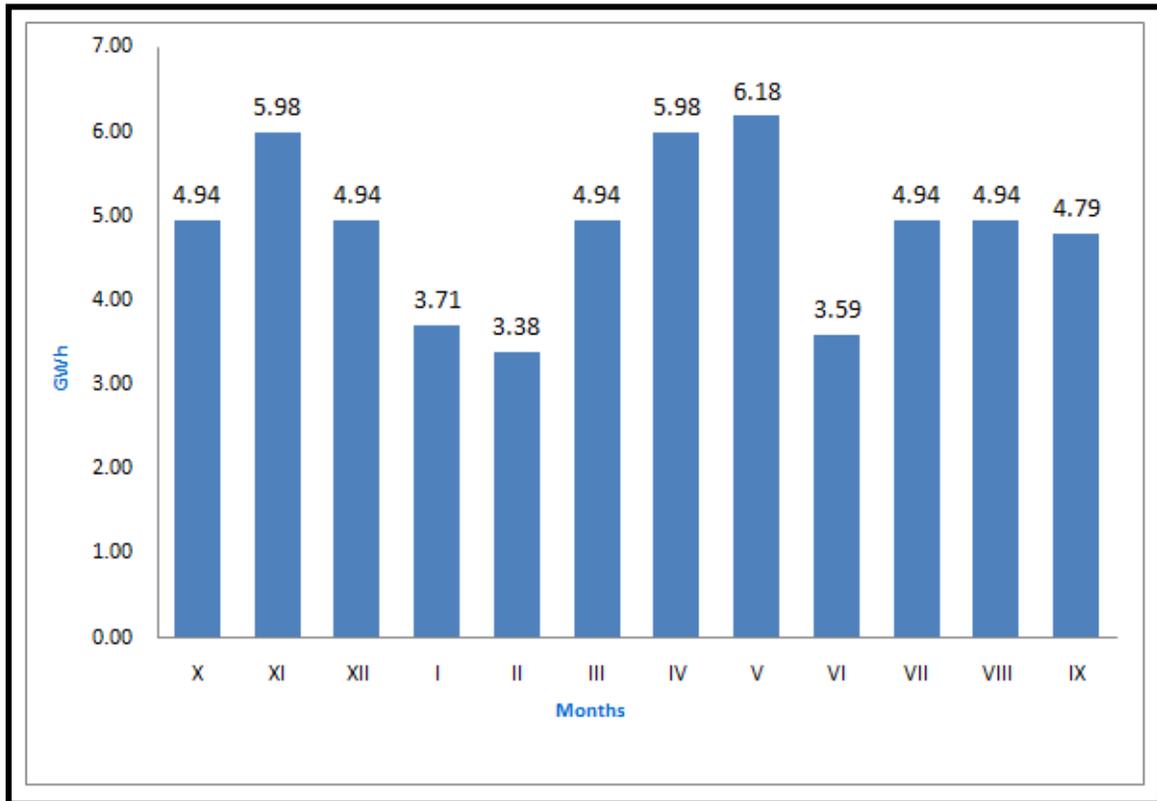
- Water Resources Management, Policies and Strategies, Final Report; and
- WASM 90 Modeling Parameters

1.7 Key characteristics

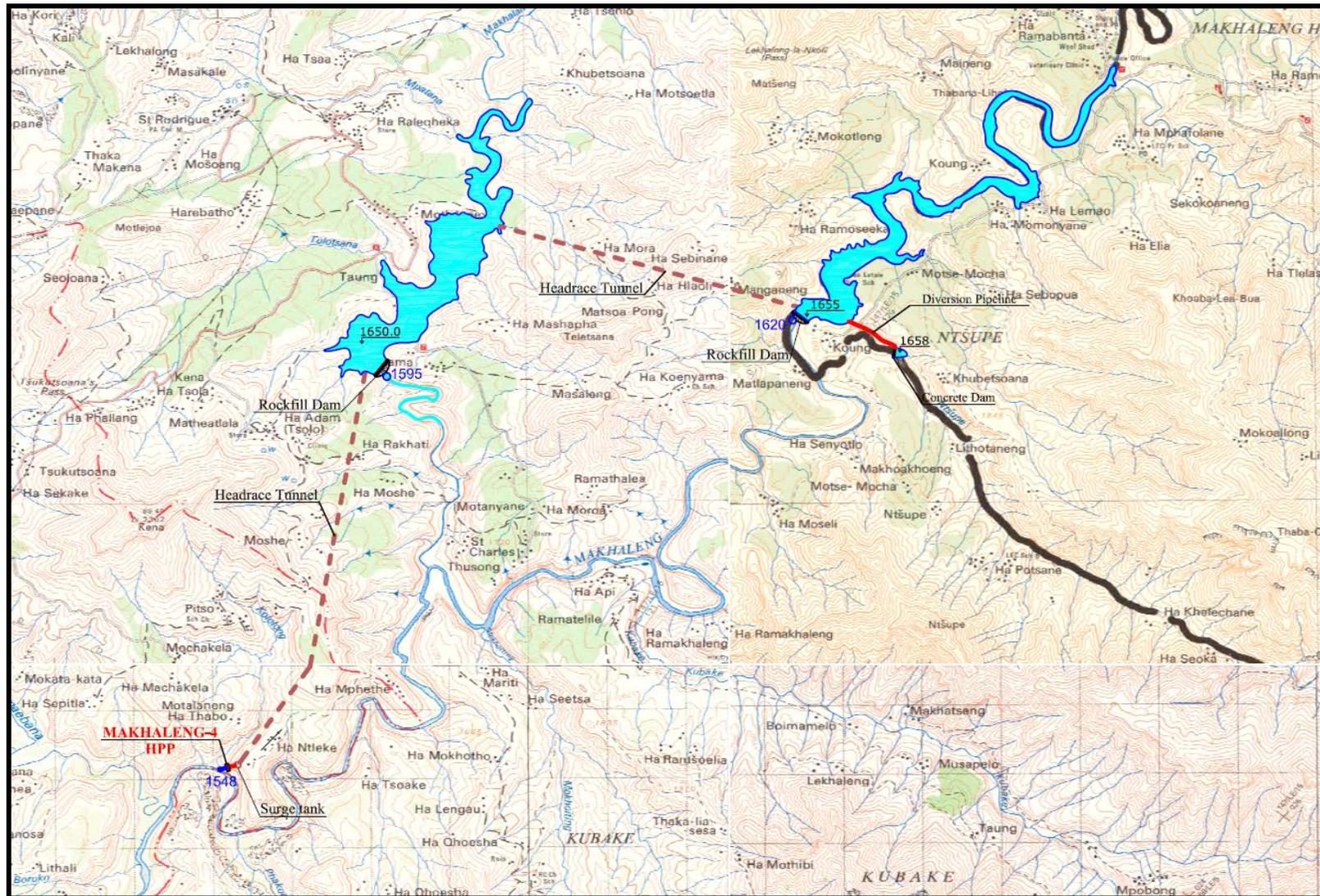
No.	Characteristics	Unit	Index
1	2	3	4
I	Technical Parameters		
1.1	Installed Capacity	MW	9.10
1.2	Average Annual output	GWh	58.30
1.3	Capacity usage ratio/Efficiency	%	73.13
1.4	Type of regulation		Reservoir
1.5	Scheme of energetic usage potential		Full
	Hydrology		
1.6	Hydrological Data (number of years)	Year	20
1.7	Year of the average multi annual discharge	Year	1989/90
1.8	Catchment area	km ²	991.20
1.9	High water flow	m ³ /sec	11.40
1.10	Average water flow	m ³ /sec	8.88
1.11	Low water flow	m ³ /sec	4.24
1.12	Rated water discharge	m ³ /sec	11.00
1.13	Maximum gross head	m	102.00
1.14	Minimum gross head	m	74.50
	Reservoir		
1.15	Full supply level (FSL)	masl	1650.00
1.16	Minimum Operation level (MOL)	masl	1622.50
1.17	Total volume at FSL	mln. m ³	83.00
1.18	Active reservoir level	mln. m ³	63.80
	Dam		
1.19	Type		Rock fill
1.20	Crest Elevation	masl	1653.00
	Spillway		
1.21	Type		Surface
1.22	Crest Elevation	masl	1650.10
	Water intake		
1.23	Sill elevation	masl	1620.00
1.24	Stop log type and number		Butterfly valve
1.25	Quantity	unit	1
	Sluice or bottom spillway		
1.26	Type and number		Bottom
1.27	Quantity	unit	1
	Diversion		
1.28	Type of diversion		Tunnel
1.29	Dimensions (w; l) or (d; l)	m	2.0; 10000
	Stilling basin or shaft		
1.30	Dimensions (w x l x h) or (d x h)	m	4.0; 51.0
	Powerhouse		
1.31	Type		Above-ground
1.32	Dimensions (w x h x l)	m	12x18x24
1.33	Elevation of tailrace outlet sill	masl	1551.00
	Tailrace		
1.34	Type		Covered channel

No.	Characteristics	Unit	Index
1	2	3	4
1.35	Dimensions (w x h)	m	2.5x2.5
1.36	Elevation of outlet sill	masl	1558.50
	Turbines/Generators		
1.37	Turbine Type and number		F. HLD 46-WJ-100; 2
1.38	Rated discharge	m ³ /sec	5.50
1.39	Rated output	MW	4.72
1.40	Maximum output	MW	5.24
1.41	Generator Type		SFW5000-10/2500
1.42	Generator nominal output	MW	4.55
1.43	Generator nominal output	rpm	600/1205
	Transformers		
1.44	Type		Three-phase
1.45	Number	unit	2
1.46	Nominal power	MVA	5.1
1.47	Transformer dimensions (l x w x h)	m	4,5x3,15x4,9
II	Economic - Financial Parameters		
2.1	Costing	mIn. USD	29.00
2.2	Duration of the construction	Year	3.50
2.3	Investment per 1 kW	Thousand USD	3.19
2.4	Investment per 1 kW/h	USD	0.50
2.5	Revenue per USD spent (Average price new HPP - 4,8 cents)	USD	0.14
2.6	Estimated carbon credit generation	T.	20.4
III	Social and Environmental Parameters		
	Special environmental requirements		
3.1	Social Impact		Additional workplace; Development of infrastructure
3.2	Ecological risks		Medium
	Transmission lines		
3.3	Parameters	kV	132
3.4	Distance to inter connection point	km	22.00
	Infrastructure		
3.5	Existing roads		Paved, Earth
3.6	Roads to be constructed	km	2.20

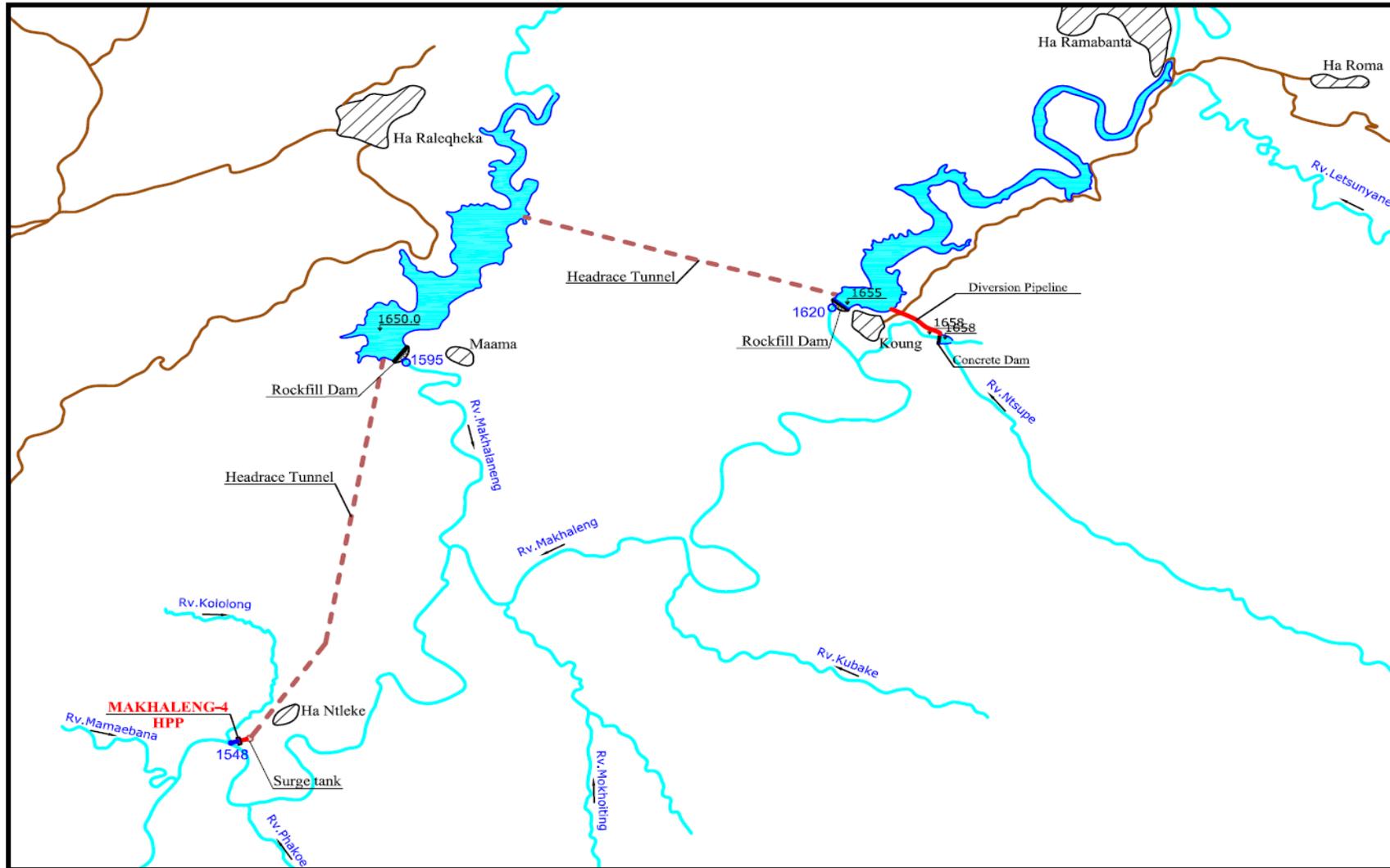
1.8 Generation



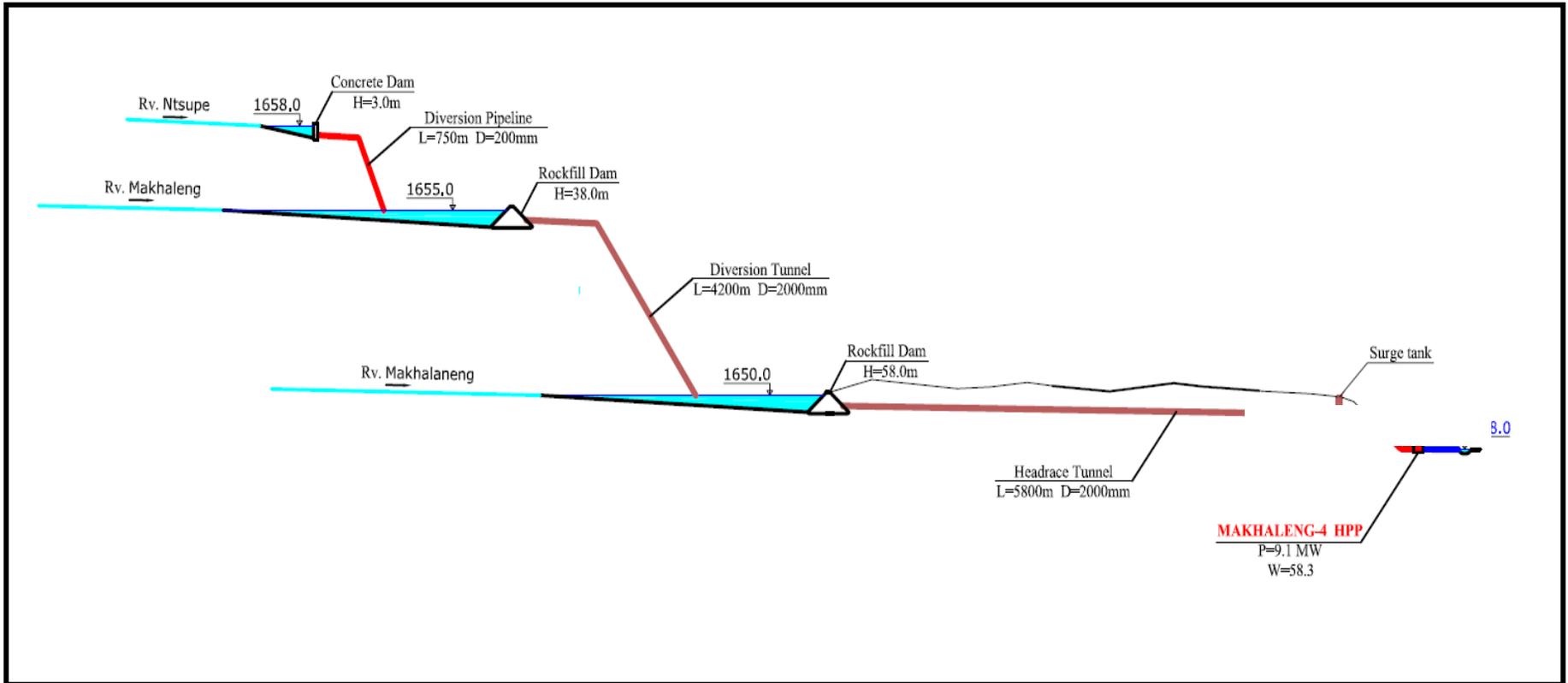
1.9 Topographic map



1.10 Plan



1.11 Longitudinal section



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APPENDIX 1.1.7

POLIHALE HPP

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1. POLIHALE HPP

1.1 Brief description of the site

Five head units, diversion pressure tunnel and pipeline, surge tank, turbine conduit, powerhouse, tailrace channel.

Head unit on the river Moremoholo conveys rock-fill earth dam, height – 32.0m, reinforced concrete water intake, surface and bottom spillways. Diversion is represented by pressure tunnel, diameter – 2.0m, length – 4.9km.

Head unit on the river Bafali conveys rock-fill earth dam, height – 29.0m, reinforced concrete water intake, surface and bottom spillways. Diversion is represented by pressure tunnel, diameter – 2.0m, length – 2.75km.

Head unit on the river Bafatsana conveys rock-fill earth dam, height – 23.0m, reinforced concrete water intake, surface and bottom spillways. Diversion is represented by pressure tunnel, diameter – 2.0m, length – 3.75km.

Head unit on the river Mokhotlong right tributary conveys concrete dam, height – 3.0m, reinforced concrete water intake, spillway and silt basin with sluice. Diversion is represented by metal pipe, diameter – 0.4m, length – 0.33km.

Head unit on the river Mokhotlong conveys rock-fill earth dam, height – 83.0m, reinforced concrete water intake, surface and bottom spillways. Diversion is represented by pressure tunnel, diameter – 2.0m, length – 12.5km.

Reinforced concrete surge tank is located at the end of diversion, diameter – 4.0m. Turbine conduit is 1.4m diameter metal pipe. Powerhouse dimensions – 12.0 x 24.0m, height – 18.0m. Tailrace covered channel is reinforced concrete rectangular construction, dimensions – 2.5 x 2.5m, length – 170.0m.

1.2 Location

1.2.1 Location map



1.2.2 Site location

- Mokhotlong, Polihale; and

- GPS coordinates for the main structures.

No.	Name of Structure	Coordinates	
		X	Y
1	Dam on the river Moremoholo	29.130918	-29.163013
2	Dam on the river Bafali	29.144024	-29.209171
3	Dam on the river Bafatsana	29.145533	-29.233805
4	Dam on the river Mokhotlong	29.189664	-29.310370
5	Dam on the river Mokhotlong right tributary	29.191905	-29.303117
6	Powerhouse	29.087780	-29.264696

1.2.3 *Name of the river*

- Mokhotlong.

1.2.4 *Site hyperlink (See appendix 2)*

- [Po Dam on the river Bafali.kmz](#)
- [Po Dam on the river Bafatsana.kmz](#)
- [Po Dam on the river Mokhotlong right tributary.kmz](#)
- [Po Dam on the river Moremoholo.kmz](#)
- [Po Polihale Powerhouse.kmz](#)

1.3 *Type of HPP*

- Reservoir.

1.4 *Existing site access*

- Earth Road: Approximately 4.6 km; and
- Distance from the paved road: 0.5 km.

1.5 *Nearest connection point with national or regional grid*

- Distance: 10.0 km; and
- Existing Grid Voltage level: 33 kV.

1.6 *List of literature used for this study:*

- Topographic Map - 1:50000 scale;
- Geologic Map - 1:25000 and 1:50000 scale;
- Map of hydrological and meteorological stations;
- Multiannual data of meteorological stations (temperature, humidity, wind, evaporation, precipitation);
- Scheme of High and low voltage grid, detailed technical parameters;
- Map of main communications;
- Water Resources Management, Policies and Strategies, Final Report; and

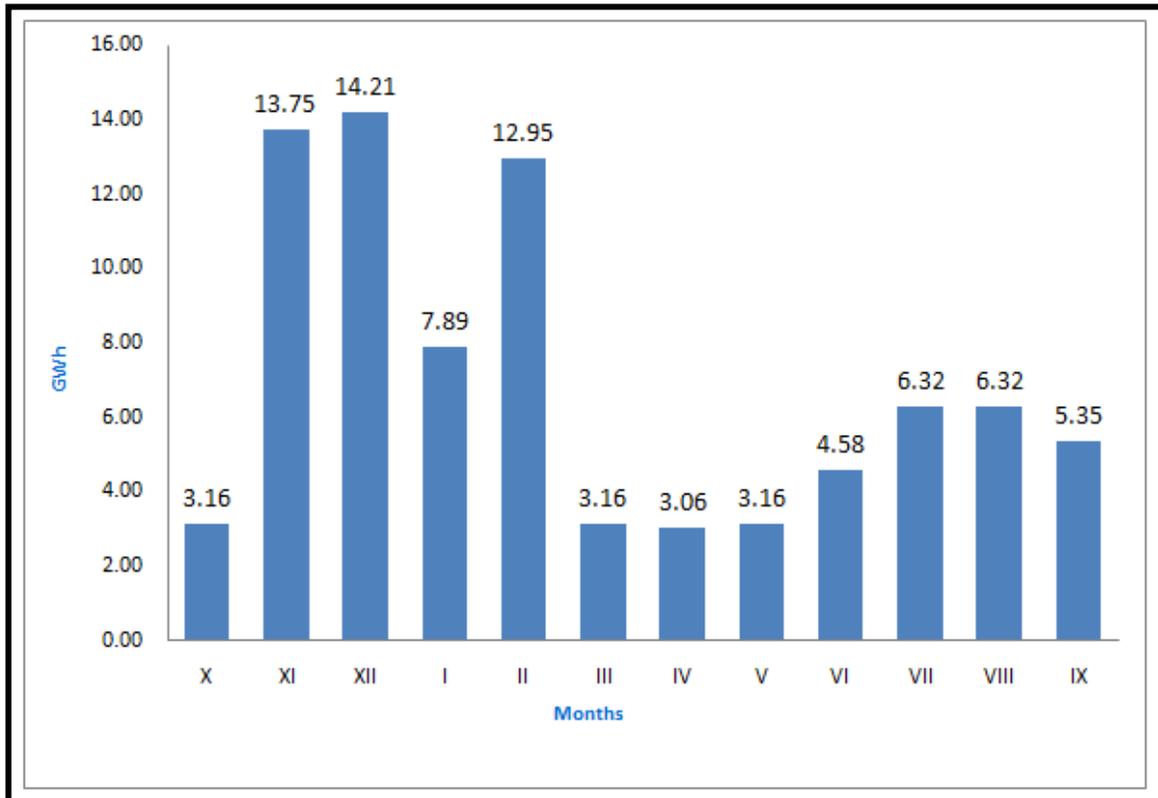
➤ WASM 90 Modeling Parameters.

1.7 Key Characteristics

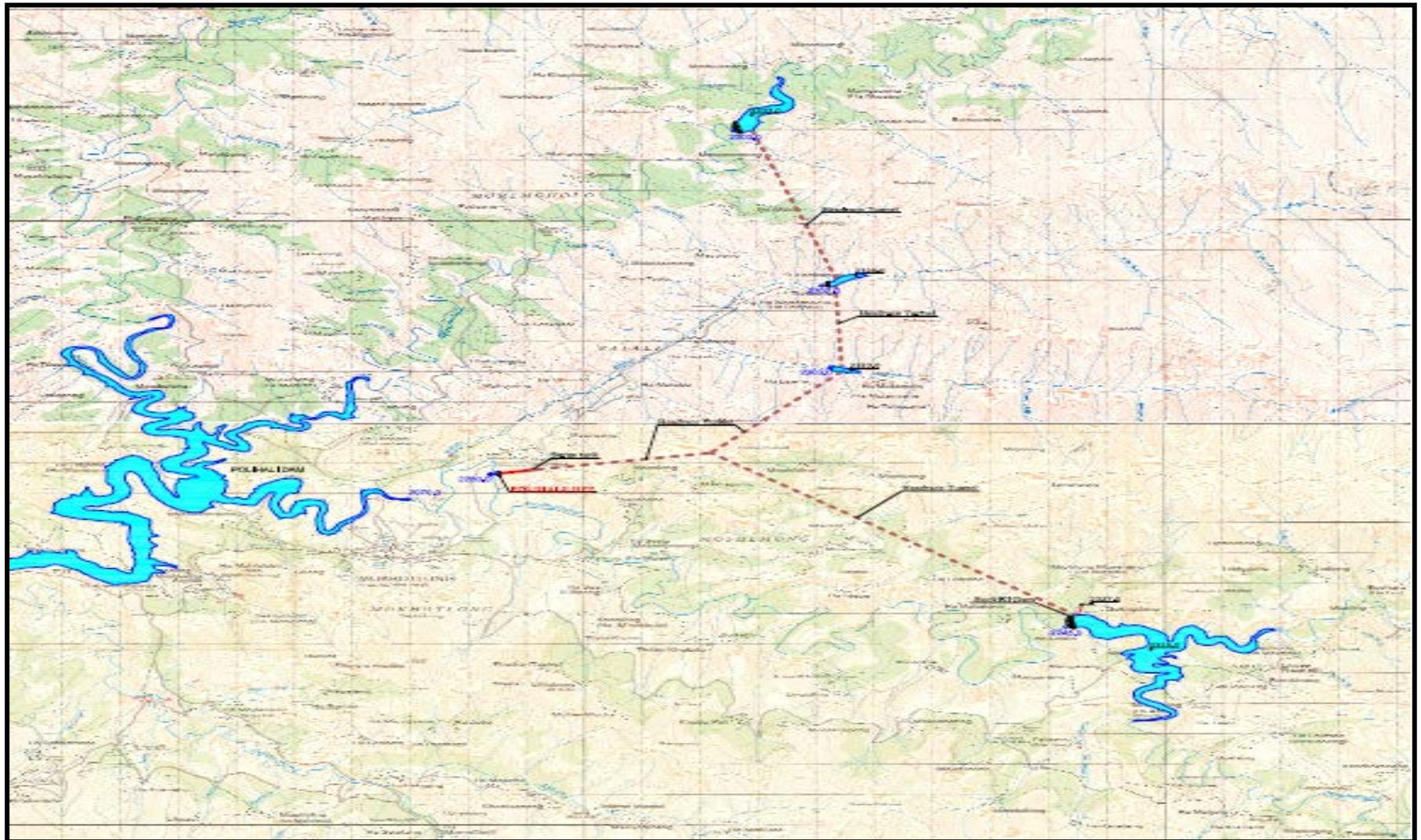
No.	Characteristics	Unit	Index
1	2	3	4
I	Technical Parameters		
1.1	Installed Capacity	MW	19.30
1.2	Average Annual output	GWh	83.89
1.3	Capacity usage ratio/Efficiency	%	49.62
1.4	Type of regulation		Reservoir
1.5	Scheme of energetic usage potential		N/A
	Hydrology		
1.6	Hydrological Data (number of years)	Year	46
1.7	Year of the average multi annual discharge	Year	1985/86
1.8	Catchment area	km ²	940.60
1.9	High water flow	m ³ /sec	8.82
1.10	Average water flow	m ³ /sec	5.04
1.11	Low water flow	m ³ /sec	1.77
1.12	Rated water discharge	m ³ /sec	9.00
1.13	Maximum gross head	m	237.00
1.14	Minimum gross head	m	195.00
	Reservoir		
1.15	Full supply level (FSL)	masl	2325.00
1.16	Minimum Operation level (MOL)	masl	2275.00
1.17	Total volume at FSL	mln. m ³	90.80
1.18	Active reservoir level	mln. m ³	63.60
	Dam		
1.19	Type		Rock fill
1.20	Crest Elevation	masl	2328.00
	Spillway		
1.21	Type		Surface
1.22	Crest Elevation	masl	2325.10
	Water intake		
1.23	Sill elevation	masl	2272.50
1.24	Stop log type and number		Butterfly valve
1.25	Quantity	unit	1
	Sluice or bottom spillway		
1.26	Type and number		Bottom
1.27	Quantity	unit	1
	Diversion		
1.28	Type of diversion		Tunnel
1.29	Dimensions (w; l) or (d; l)	m	2.0; 12500
	Stilling basin or shaft		
1.30	Dimensions (w x l x h) or (d x h)	m	4.0; 97.0
	Powerhouse		
1.31	Type		Above-ground
1.32	Dimensions (w x h x l)	m	12x18x24
1.33	Elevation of tailrace outlet sill	masl	2083.00
	Tailrace		
1.34	Type		Channel

No.	Characteristics	Unit	Index
1	2	3	4
1.35	Dimensions (w x h)	m	2.5x2.5
1.36	Elevation of outlet sill	masl	2078.50
	Turbines/Generators		
1.37	Turbine Type and number		F. HL 100-LJ-120; 2
1.38	Rated discharge	m ³ /sec	4.50
1.39	Rated output	MW	10.00
1.40	Maximum output	MW	11.11
1.41	Generator Type		SF10-8/2600
1.42	Generator nominal output	MW	9.65
1.43	Generator nominal output	rpm	80
	Transformers		
1.44	Type		Three-phase
1.45	Number	unit	2
1.46	Nominal power	MVA	10.7
1.47	Transformer dimensions (l x w x h)	m	4,5x3,15x4,9
II	Economic - Financial Parameters		
2.1	Costing	mln. USD	101.00
2.2	Duration of the construction	Year	3.50
2.3	Investment per 1 kW	Thousand USD	5.23
2.4	Investment per 1 kW/h	USD	1.20
2.5	Revenue per USD spent (Average price new HPP - 4,8 cents)	USD	0.05
2.6	Estimated carbon credit generation	T.	29.4
III	Social and Environmental Parameters		
	Special environmental requirements		
3.1	Social Impact		Additional workplace; Development of infrastructure
3.2	Ecological risks		Medium
	Transmission lines		
3.3	Parameters	kV	33
3.4	Distance to inter connection point	km	10.00
	Infrastructure		
3.5	Existing roads		Paved, Earth
3.6	Roads to be constructed	km	4.60

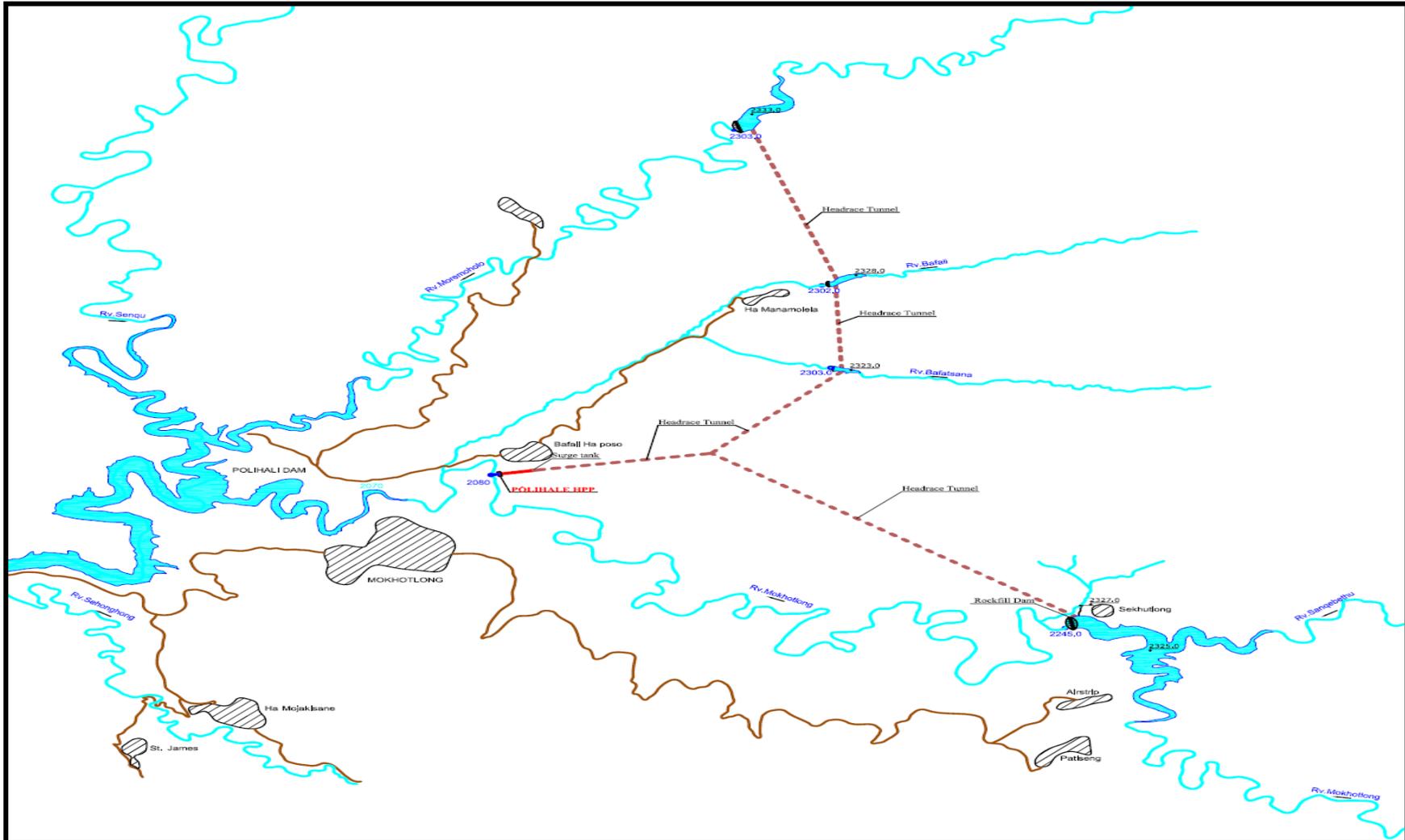
1.8 Generation



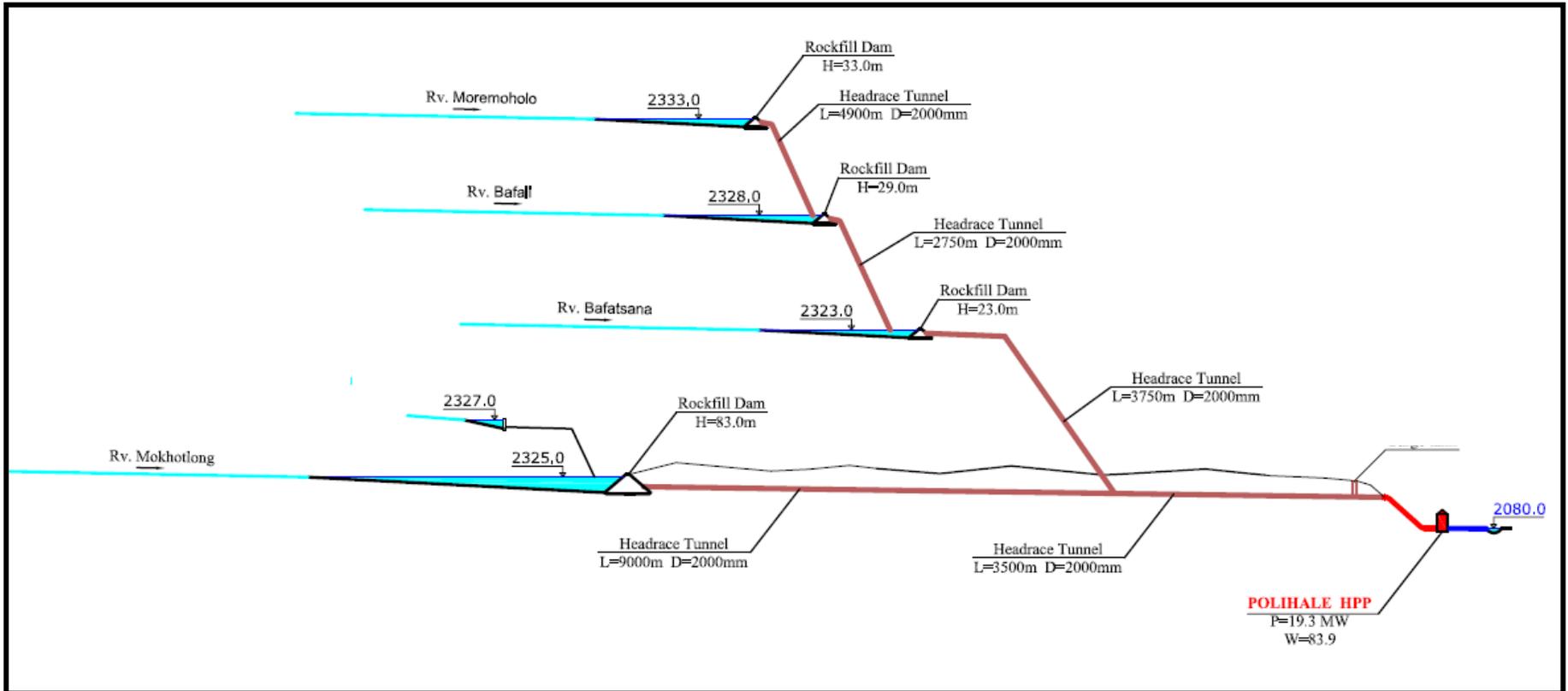
1.9 Topographic map



1.10 Plan



1.11 Longitudinal section



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APPENDIX 1.1.8

TSOELIKE HPP

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1. TSOELIKE HPP

1.1 Brief description of the site

Head Unit, diversion pressure tunnel, surge tank, turbine conduit, power-cavern, tailrace tunnel.

Head unit conveys rock-fill earth dam, height – 108.0m, reinforced concrete water intake, surface and bottom spillways. Diversion is represented by 2.0m diameter pressure tunnel, length – 10.0km.

Reinforced concrete surge tank is located at the end of the diversion, diameter – 4.0m. Turbine conduit is 1.4m diameter metal pipe with concrete layer. Power cavern dimensions – 19.0 x 52.0m, height – 45.0m. Tailrace tunnel is trapezoidal reinforced concrete construction, dimensions – 2.5 x 2.5m, length – 450.0m.

1.2 Location

1.2.1 Location map



1.2.2 Site location

- Qacha'Snek, Ha Moalosi; and

- GPS coordinates for the main structures.

No.	Name of Structure	Coordinates	
		X	Y
1	Dam on the river Tsoelike	28.893968	-30.015248
2	Powerhouse	28.821433	-30.033732

1.2.3 **Name of the river**

- Tsoelike.

1.2.4 **Site hyperlink (See appendix 2)**

- [Ts Dam on the river Tsoelike.kmz](#)
- [Ts Tsoelike Powerhouse.kmz](#)

1.3 **Type of HPP**

- Reservoir.

1.4 **Existing site access**

- Earth Road: Approximately 1.4 km; and
- Distance from the paved road: 3.5 km.

1.5 **Nearest connection point with national or regional grid**

- Distance: 59.0 km;
- Existing Grid Voltage level: 33 kV up to Tahaba–Tseka;
- Distance: 15.0 km; and
- Existing Grid Voltage level: 15.0 km, 33 kV up to Qacha’Snek.

1.6 **List of literature used for this study:**

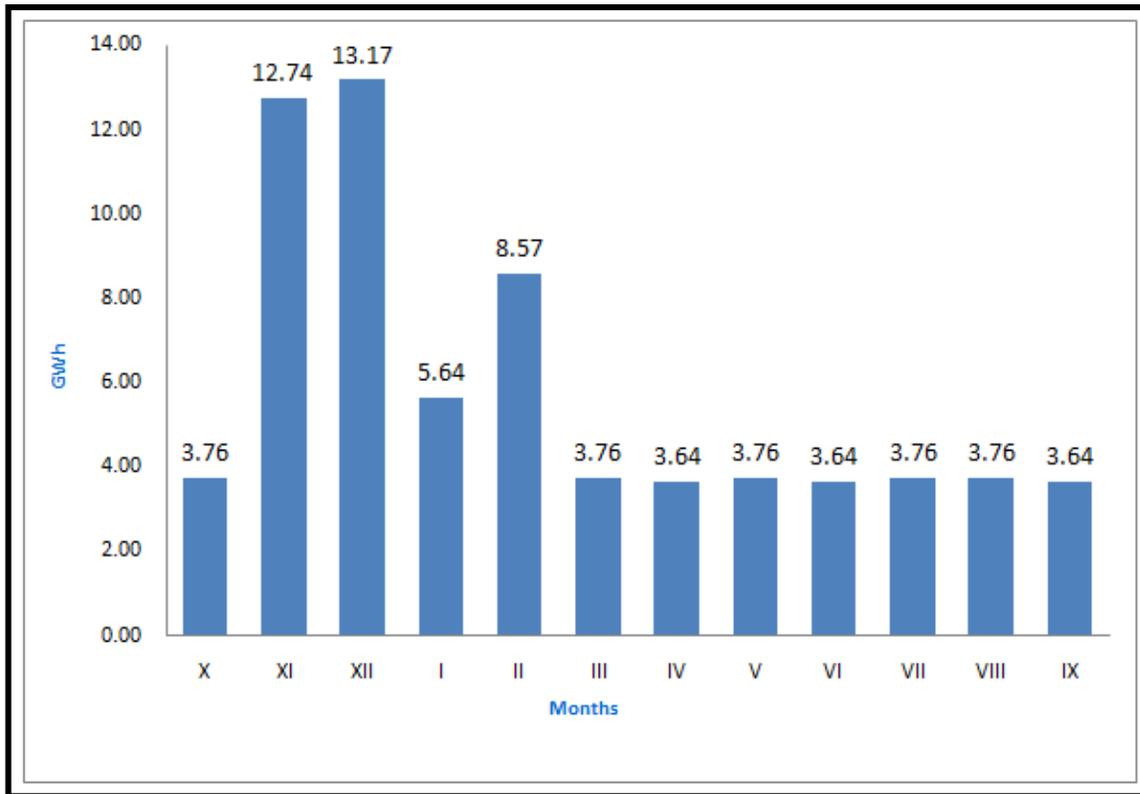
- Topographic Map - 1:50000 scale;
- Geologic Map - 1:25000 and 1:50000 scale;
- Map of hydrological and meteorological stations;
- Multiannual data of meteorological stations (temperature, humidity, wind, evaporation, precipitation);
- Scheme of High and low voltage grid, detailed technical parameters;
- Map of main communications;
- Water Resources Management, Policies and Strategies, Final Report; and
- WASM 90 Modeling Parameters.

1.7 **Key characteristics**

No.	Characteristics	Unit	Index
1	2	3	4
I	Technical Parameters		
1.1	Installed Capacity	MW	17.70
1.2	Average Annual output	GWh	69.80
1.3	Capacity usage ratio/Efficiency	%	45.02
1.4	Type of regulation		Reservoir
1.5	Scheme of energetic usage potential		N/A
	Hydrology		
1.6	Hydrological Data (number of years)	Year	46
1.7	Year of the average multi annual discharge	Year	1985/86
1.8	Catchment area	km ³	616.00
1.9	High water flow	m ² /sec	5.10
1.10	Average water flow	m ² /sec	3.51
1.11	Low water flow	m ² /sec	1.65
1.12	Rated water discharge	m ² /sec	7.00
1.13	Maximum gross head	m	302.00
1.14	Minimum gross head	m	237.00
	Reservoir		
1.15	Full supply level (FSL)	masl	2060.00
1.16	Minimum Operation level (MOL)	masl	1995.00
1.17	Total volume at FSL	mln. m ²	170.00
1.18	Active reservoir level	mln. m ²	155.00
	Dam		
1.19	Type		Rock fill
1.20	Crest Elevation	masl	2063.00
	Spillway		
1.21	Type		Surface
1.22	Crest Elevation	masl	2060.10
	Water intake		
1.23	Sill elevation	masl	1990.50
1.24	Stop log type and number		Butterfly valve
1.25	Quantity	unit	1
	Sluice or bottom spillway		
1.26	Type and number		Bottom
1.27	Quantity	unit	1
	Diversion		
1.28	Type of diversion		Tunnel
1.29	Dimensions (w; l) or (d; l)	m	2.0; 10000
	Stilling basin or shaft		
1.30	Dimensions (w x l x h) or (d x h)	m	4.0; 105.0
	Powerhouse		
1.31	Type		Underground
1.32	Dimensions (w x h x l)	m	19x45x52
1.33	Elevation of tailrace outlet sill	masl	1755.00
	Tailrace		
1.34	Type		Tunnel
1.35	Dimensions (w x h)	m	2.5x2.5
1.36	Elevation of outlet sill	masl	1756.50
	Turbines/Generators		
1.37	Turbine Type and number		P. CJA 237-L-145/3x16; 2
1.38	Rated discharge	m ² /sec	3.50

No.	Characteristics	Unit	Index
1	2	3	4
1.39	Rated output	MW	9.17
1.40	Maximum output	MW	10.19
1.41	Generator Type		SF10-12/2860
1.42	Generator nominal output	MW	8.85
1.43	Generator nominal output	rpm	500/849
	Transformers		
1.44	Type		Three-phase
1.45	Number	unit	2
1.46	Nominal power	MVA	9.8
1.47	Transformer dimensions (l x w x h)	m	4,5x3,15x4,9
II	Economic - Financial Parameters		
2.1	Costing	mln. USD	65.00
2.2	Duration of the construction	Year	3.50
2.3	Investment per 1 kW	Thousand USD	3.67
2.4	Investment per 1 kW/h	USD	0.93
2.5	Revenue per USD spent (Average price new HPP - 4,8 cents)	USD	0.07
2.6	Estimated carbon credit generation	T.	24.4
III	Social and Environmental Parameters		
	Special environmental requirements		
3.1	Social Impact		Additional workplace; Development of infrastructure
3.2	Ecological risks		Medium
	Transmission lines		
3.3	Parameters	kV	33
3.4	Distance to inter connection point	km	15.00
	Infrastructure		
3.5	Existing roads		Paved, Earth
3.6	Roads to be constructed	km	1.40

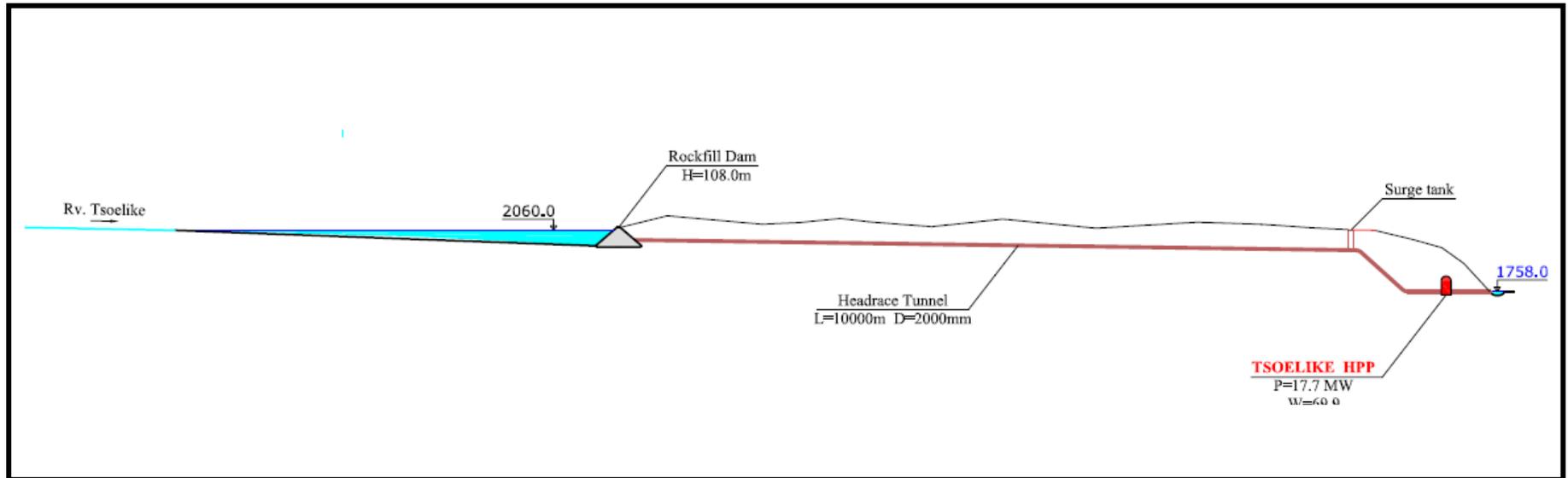
1.8 Generation



1.10 Plan



1.11 Longitudinal section



LESOTHO POWER GENERATION MASTER PLAN

PROJECT # LEC/GEN/1-2009

FINAL MILESTONES REPORT

VOLUME 1 - PART 1.1

HYDROPOWER GENERATION OPTION

APPENDIX 1.1.9

KHUBELU HPP

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1.4	Existing site access.....	142
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1.8	Generation.....	145
1.9	Topographic map.....	146
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1. KHUBELU HPP

1.1 Brief description of the site

Five head units, diversion pressure tunnel and pipeline, surge tank, turbine conduit, powerhouse, tailrace channel.

Head unit on the river Senqu conveys rock-fill earth dam, height – 14.0m, reinforced concrete water intake, surface and bottom spillways. Diversion is represented by free flow pipeline, diameter – 2.0m, length – 7.1km.

Head unit on the river Khubelu conveys rock-fill earth dam, height – 63.0m, reinforced concrete water intake, surface and bottom spillways. Diversion is represented by pressure tunnel, diameter – 2.0m, length – 15.4km.

Head unit on the river Benteka conveys rock-fill earth dam, height – 13.0m, reinforced concrete water intake, surface and bottom spillways. Diversion is represented by pressure pipeline, diameter – 0.4m, length – 0.7km.

Head unit on the river Motseremeli right tributary conveys concrete dam, height – 13.0m, reinforced concrete water intake, spillway and silt basin with sluice. Diversion is represented by free flow tunnel, diameter – 2.0m, length – 3.5km.

Head unit on the river Mofolaneng conveys rock-fill earth dam, height – 7.0m, reinforced concrete water intake, surface and bottom spillways. Diversion is represented by pressure tunnel, diameter – 2.0m, length – 2.8km.

Reinforced concrete surge tank is located at the end of diversion, diameter – 4.0m. Turbine conduit is 1.4m diameter metal pipe. Powerhouse dimensions – 12.0 x 24.0m, height – 18.0m. Tailrace covered channel is reinforced concrete rectangular construction, dimensions – 2.5 x 2.5m, length – 160.0m.

1.2 Location

1.2.1 Location map



1.2.2 Site location

- Mokhotlong, Matebeng; and
- GPS coordinates for the main structures.

No.	Name of Structure	Coordinates	
		X	Y
1	Dam on the river Senqu	29.050414	-29.105465
2	Dam on the river Khubelu	28.988452	-29.086584
3	Dam on the river Mofolaneng	28.917839	-29.128259
4	Dam on the river Motseremeli	28.888598	-29.132793
5	Dam on the river Benteka	28.884097	-29.134982
6	Powerhouse	28.906691	-29.187620

1.2.3 Name of the river

- Khubelu.

1.2.4 Hyperlinks

- [Kb Dam on the river Benteka.kmz](#)
- [Kb Dam on the river Khubelu.kmz](#)
- [Kb Dam on the river Mofolaneng.kmz](#)
- [Kb Dam on the river Motseremeli.kmz](#)
- [Kb Dam on the river Senqu.kmz](#)
- [Kb Khumbelu Powerhouse.kmz](#)

1.3 Type of HPP

- Reservoir.

1.4 Existing site access

- Earth Road: approximately 3.0 km; and
- Distance from the paved road: 3.0 km.

1.5 Nearest connection point with national or regional grid: 21.0 km; 88 kV

1.6 List of literature used for this study:

- Topographic Map - 1:50000 scale;
- Geologic Map - 1:25000 and 1:50000 scale;
- Map of hydrological and meteorological stations;
- Multiannual data of meteorological stations (temperature, humidity, wind, evaporation, precipitation);

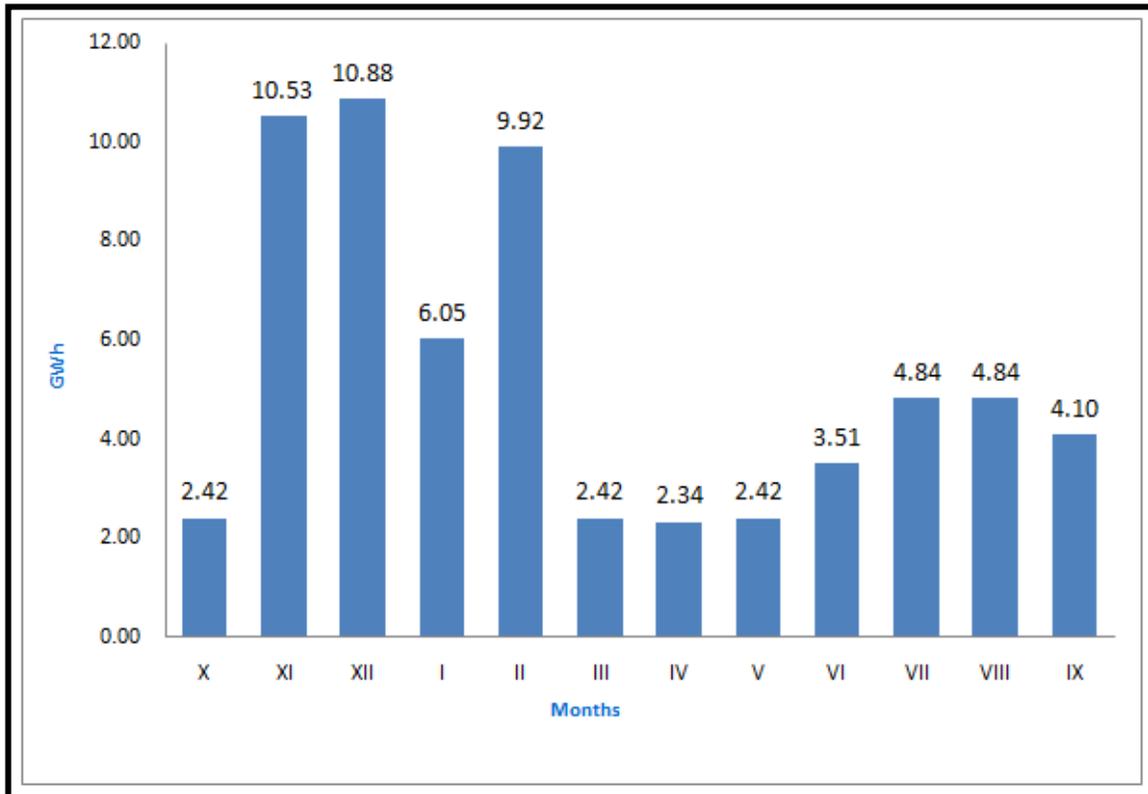
- Scheme of High and low voltage grid, detailed technical parameters;
- Map of main communications;
- Water Resources Management, Policies and Strategies, Final Report; and
- WASM 90 Modeling Parameters

1.7 Key characteristics

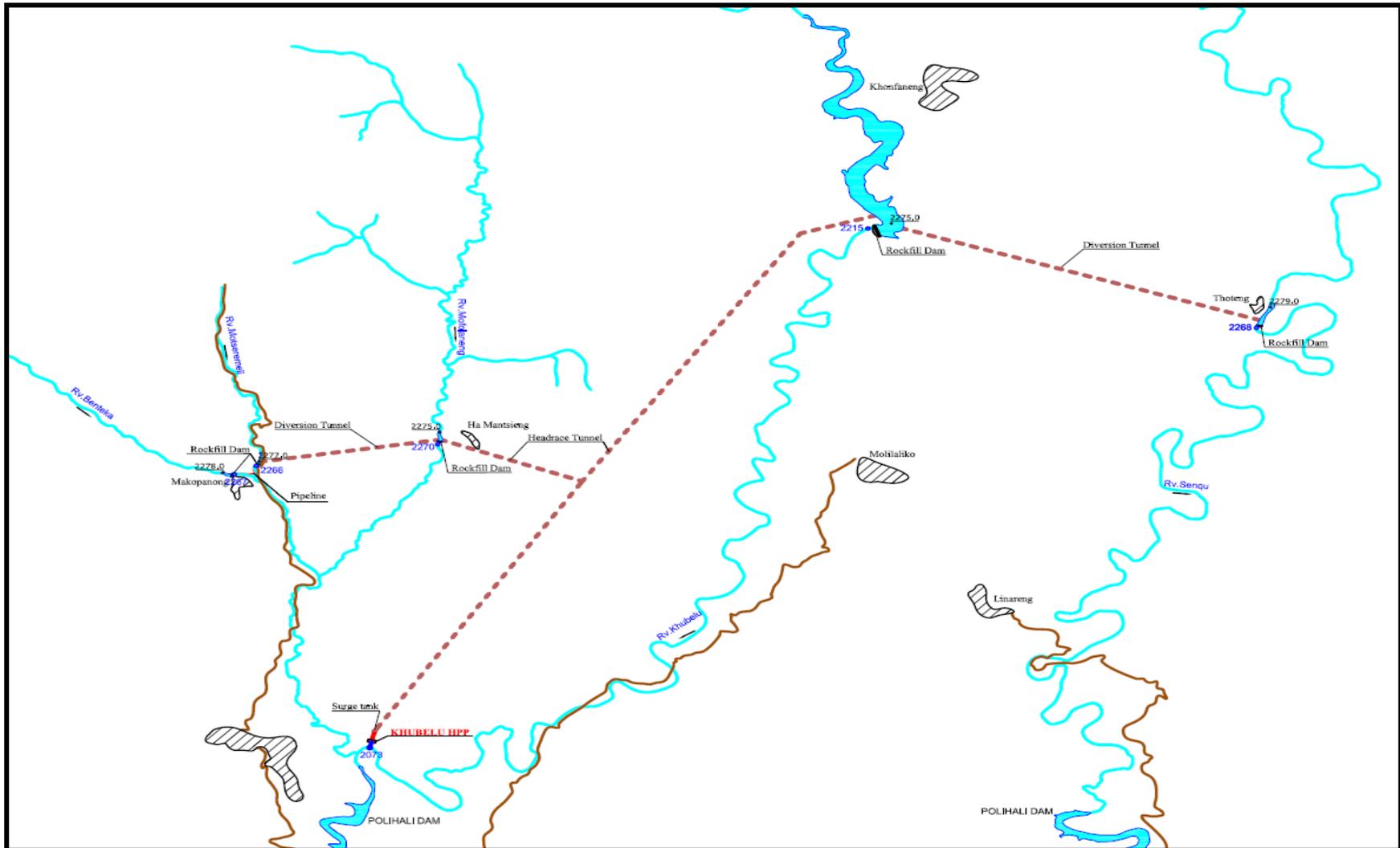
No.	Characteristics	Unit	Index
1	2	3	4
I	Technical Parameters		
1.1	Installed Capacity	MW	14.60
1.2	Average Annual output	GWh	64.26
1.3	Capacity usage ratio/Efficiency	%	50.24
1.4	Type of regulation		Reservoir
1.5	Scheme of energetic usage potential		N/A
	Hydrology		
1.6	Hydrological Data (number of years)	Year	46
1.7	Year of the average multi annual discharge	Year	1985/86
1.8	Catchment area	km ²	929.80
1.9	High water flow	m ³ /sec	8.82
1.10	Average water flow	m ³ /sec	5.06
1.11	Low water flow	m ³ /sec	1.77
1.12	Rated water discharge	m ³ /sec	9.00
1.13	Maximum gross head	m	202.00
1.14	Minimum gross head	m	165.00
	Reservoir		
1.15	Full supply level (FSL)	masl	2275.00
1.16	Minimum Operation level (MOL)	masl	2838.00
1.17	Total volume at FSL	mln. m ³	54.80
1.18	Active reservoir level	mln. m ³	38.40
	Dam		
1.19	Type		Rock fill
1.20	Crest Elevation	masl	2278.00
	Spillway		
1.21	Type		Surface
1.22	Crest Elevation	masl	2275.10
	Water intake		
1.23	Sill elevation	masl	2235.50
1.24	Stop log type and number		Butterfly valve
1.25	Quantity	unit	1
	Sluice or bottom spillway		
1.26	Type and number		Bottom
1.27	Quantity	unit	1
	Diversion		
1.28	Type of diversion		Tunnel
1.29	Dimensions (w; l) or (d; l)	m	2.0; 15400
	Stilling basin or shaft		
1.30	Dimensions (w x l x h) or (d x h)	m	4.0; 94.0
	Powerhouse		
1.31	Type		Above-ground

No.	Characteristics	Unit	Index
1	2	3	4
1.32	Dimensions (w x h x l)	m	12x18x24
1.33	Elevation of tailrace outlet sill	masl	2076.00
	Tailrace		
1.34	Type		Covered channel
1.35	Dimensions (w x h)	m	1.5x2.5
1.36	Elevation of outlet sill	masl	2071.50
	Turbines/Generators		
1.37	Turbine Type and number		F. HLD 54-LJ-120; 2
1.38	Rated discharge	m ³ /sec	4.50
1.39	Rated output	MW	7.56
1.40	Maximum output	MW	8.41
1.41	Generator Type		SF8000-8/2600
1.42	Generator nominal output	MW	7.30
1.43	Generator nominal output	rpm	750/1142
	Transformers		
1.44	Type		Three-phase
1.45	Number	unit	2
1.46	Nominal power	MVA	8.1
1.47	Transformer dimensions (l x w x h)	m	4,5x3,15x4,9
II	Economic - Financial Parameters		
2.1	Costing	mln. USD	58.00
2.2	Duration of the construction	Year	3.50
2.3	Investment per 1 kW	Thousand USD	3.97
2.4	Investment per 1 kW/h	USD	0.90
2.5	Revenue per USD spent (Average price new HPP - 4,8 cents)	USD	0.07
2.6	Estimated carbon credit generation	T.	22.5
III	Social and Environmental Parameters		
	Special environmental requirements		
3.1	Social Impact		Additional workplace; Development of infrastructure
3.2	Ecological risks		Medium
	Transmission lines		
3.3	Parameters	kV	88
3.4	Distance to inter connection point	km	21.00
	Infrastructure		
3.5	Existing roads		Paved, Earth
3.6	Roads to be constructed	km	3.00

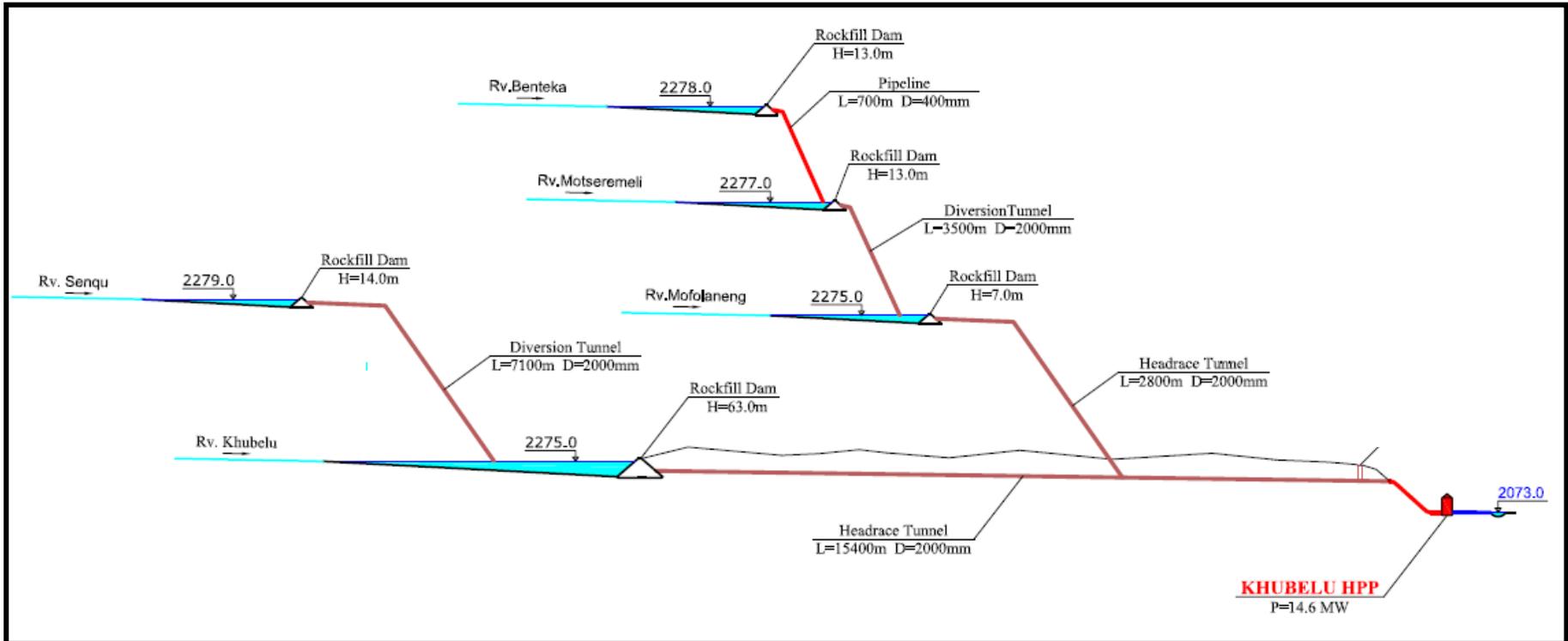
1.8 Generation



1.10 Plan



1.11 Longitudinal section



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APPENDIX 1.1.10

QUTHING 1 HPP

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1.2.2	<i>Site location</i>	<i>153</i>
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1. QUTHING 1 HPP

1.1 Brief description of the site

Two head units, diversion pressure tunnel and pipeline, turbine conduit, powerhouse, tailrace channel.

Head unit on the river Quthing conveys concrete dam with spillway, height – 24.0m, and reinforced concrete water intake. Diversion is 0.4m diameter pressure pipeline, length – 0.34km.

Head unit on the river Likhabaneng conveys concrete dam with spillway, height – 23.0m, and reinforced concrete water intake. Diversion is 2.0m diameter pressure pipeline, length – 0.8km.

Reinforced concrete surge tank is located at the end of diversion, diameter - 4.0m. Turbine conduit is 0.6m diameter metal pipe.

Powerhouse dimensions - 12.0×24.0m, height – 18.0m. Tailrace covered channel is rectangular reinforced concrete construction, dimensions – 1.0×1.0m, length – 50.0m.

1.2 Location

1.2.1 Location map



Base B01442 (B00980) 2-90

1.2.2 **Site location**

- Quthing, Ha Lethena; and
- GPS coordinates for the main structures.

No.	Name of Structure	Coordinates	
		X	Y
1	Dam on the river Quthing	28.143087	-30.361494
2	Dam on the river Likhabaneng	28.140305	-30.362541
3	Powerhouse	28.135510	-30.355021

1.2.3 **Name of the river**

- Quthing

1.2.4 **Hyperlink**

- a. [Q1 Dam on the river Likhabaneng.kmz](#)
- b. [Q1 Dam on the river Quthing.kmz](#)
- c. [Q1 Quthing 1 Powerhouse.kmz](#)

1.3 **Type of HPP**

- Reservoir

1.4 **Existing site access**

- Earth Road: approximately 5.0 km; and
- Distance from the paved road: 11.5 km.

1.5 **Nearest connection point with national or regional grid: 3.7 km; 11 kV**

1.6 **List of literature used for this study:**

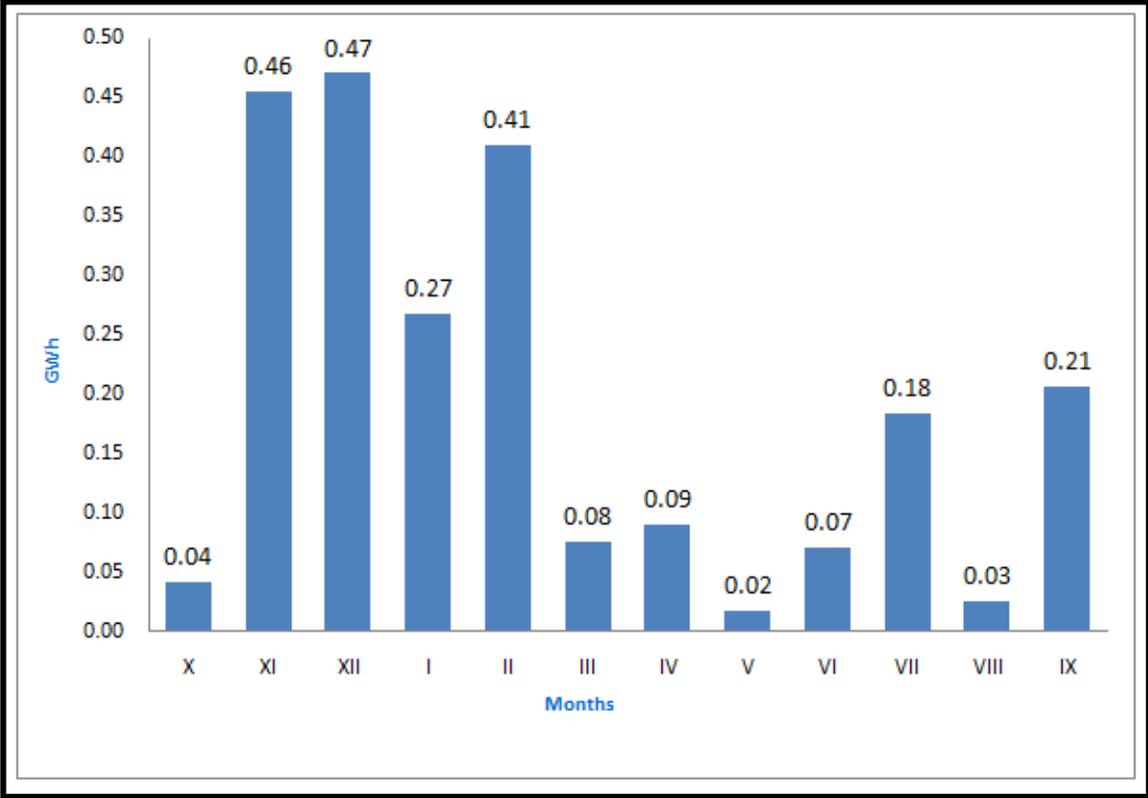
- Topographic Map - 1:50000 scale;
- Geologic Map - 1:25000 and 1:50000 scale;
- Map of hydrological and meteorological stations;
- Multiannual data of meteorological stations (temperature, humidity, wind, evaporation, precipitation);
- Scheme of High and low voltage grid, detailed technical parameters;
- Map of main communications;
- Water Resources Management, Policies and Strategies, Final Report; and
- WASM 90 Modeling Parameters.

1.7 Key characteristics

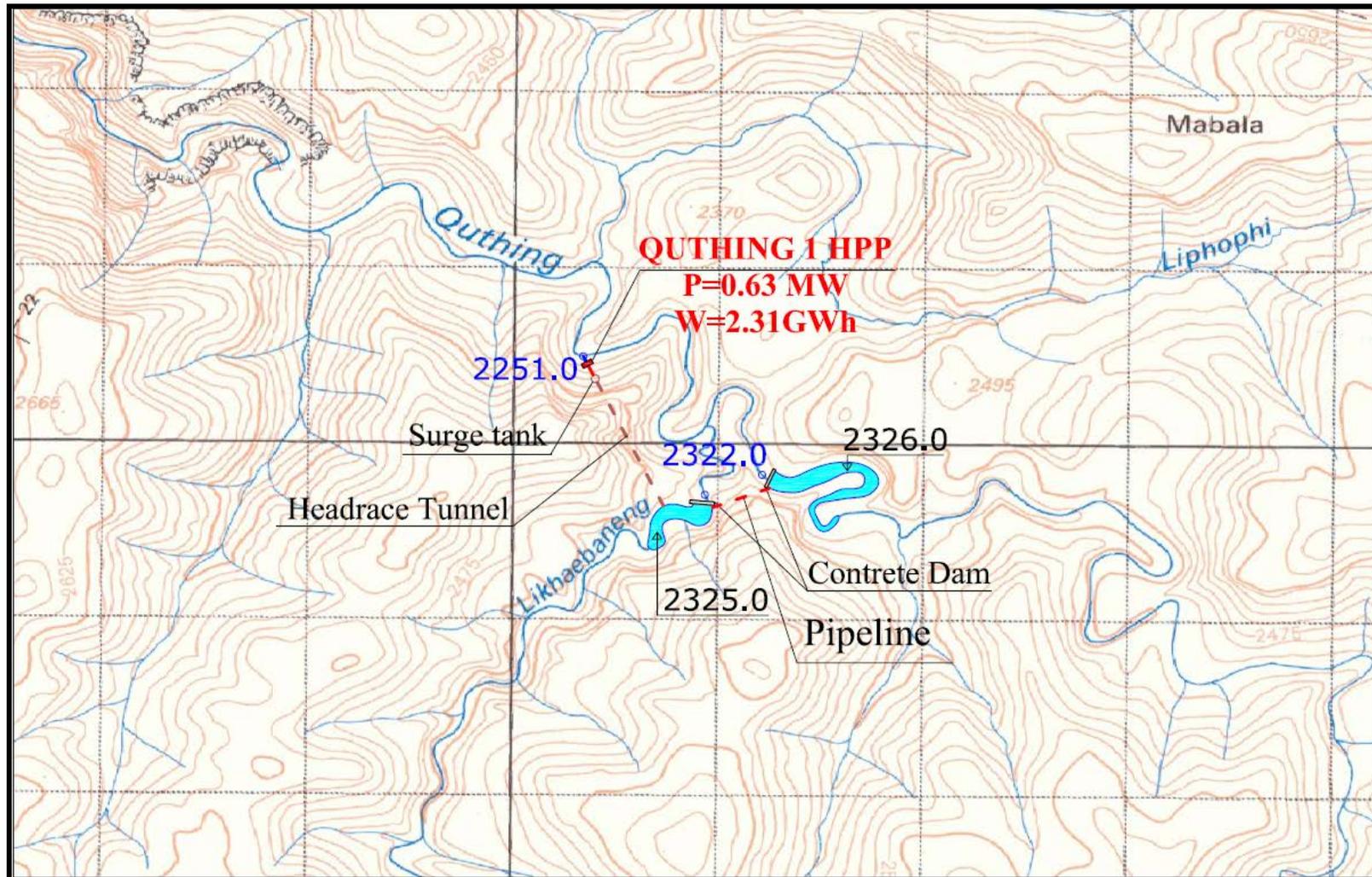
No.	Characteristics	Unit	Index
1	2	3	4
I	Technical Parameters		
1.1	Installed Capacity	MW	0.63
1.2	Average Annual output	GWh	2.31
1.3	Capacity usage ratio/Efficiency	%	41.86
1.4	Type of regulation		Reservoir
1.5	Scheme of energetic usage potential		N/A
	Hydrology		
1.6	Hydrological Data (number of years)	Year	45
1.7	Year of the average multi annual discharge	Year	1985/86
1.8	Catchment area	km ²	112.00
1.9	High water flow	m ³ /sec	0.93
1.10	Average water flow	m ³ /sec	0.64
1.11	Low water flow	m ³ /sec	0.30
1.12	Rated water discharge	m ³ /sec	1.00
1.13	Maximum gross head	m	74.00
1.14	Minimum gross head	m	62.00
	Reservoir		
1.15	Full supply level (FSL)	masl	2325.00
1.16	Minimum Operation level (MOL)	masl	2313.00
1.17	Total volume at FSL	mln. m ³	0.42
1.18	Active reservoir level	mln. m ³	0.29
	Dam		
1.19	Type		With spillway
1.20	Crest Elevation	masl	2325.00
	Spillway		
1.21	Type		Surface
1.22	Crest Elevation	masl	2325.00
	Water intake		
1.23	Sill elevation	masl	2310.00
1.24	Stop log type and number		Butterfly valve
1.25	Quantity	unit	1
	Sluice or bottom spillway		
1.26	Type and number		Bottom
1.27	Quantity	unit	3
	Diversion		
1.28	Type of diversion		Tunnel
1.29	Dimensions (w; l) or (d; l)	m	2.0; 800
	Stilling basin or shaft		
1.30	Dimensions (w x l x h) or (d x h)	m	4.0; 19.0
	Powerhouse		
1.31	Type		Above-ground
1.32	Dimensions (w x h x l)	m	12x18x24
1.33	Elevation of tailrace outlet sill	masl	2253.50
	Tailrace		
1.34	Type		Covered channel
1.35	Dimensions (w x h x l)	m	1.0x1.0
1.36	Elevation of outlet sill	masl	2249.50

No.	Characteristics	Unit	Index
1	2	3	4
	Turbines/Generators		
1.37	Turbine Type and number		F. HLD 54-WJ-50; 2
1.38	Rated discharge	m ³ /sec	0.50
1.39	Rated output	MW	0.33
1.40	Maximum output	MW	0.36
1.41	Generator Type		SFW320-6/740
1.42	Generator nominal output	MW	0.32
1.43	Generator nominal output	rpm	1088
	Transformers		
1.44	Type		Three-phase
1.45	Number	unit	2
1.46	Nominal power	MVA	0.4
1.47	Transformer dimensions (l x w x h)	m	4,5x3,15x4,9
II	Economic - Financial Parameters		
2.1	Costing	mln. USD	1.99
2.2	Duration of the construction	Year	2.00
2.3	Investment per 1 kW	Thousand USD	3.16
2.4	Investment per 1 kW/h	USD	0.86
2.5	Revenue per USD spent (Average price new HPP - 4,8 cents)	USD	0.65
2.6	Estimated carbon credit generation	T.	0.8
III	Social and Environmental Parameters		
	Special environmental requirements		
3.1	Social Impact		Additional workplace; Development of infrastructure
3.2	Ecological risks		Medium
	Transmission lines		
3.3	Parameters	kV	11
3.4	Distance to inter connection point	km	3.70
	Infrastructure		
3.5	Existing roads		Paved, Earth
3.6	Roads to be constructed	km	5.00

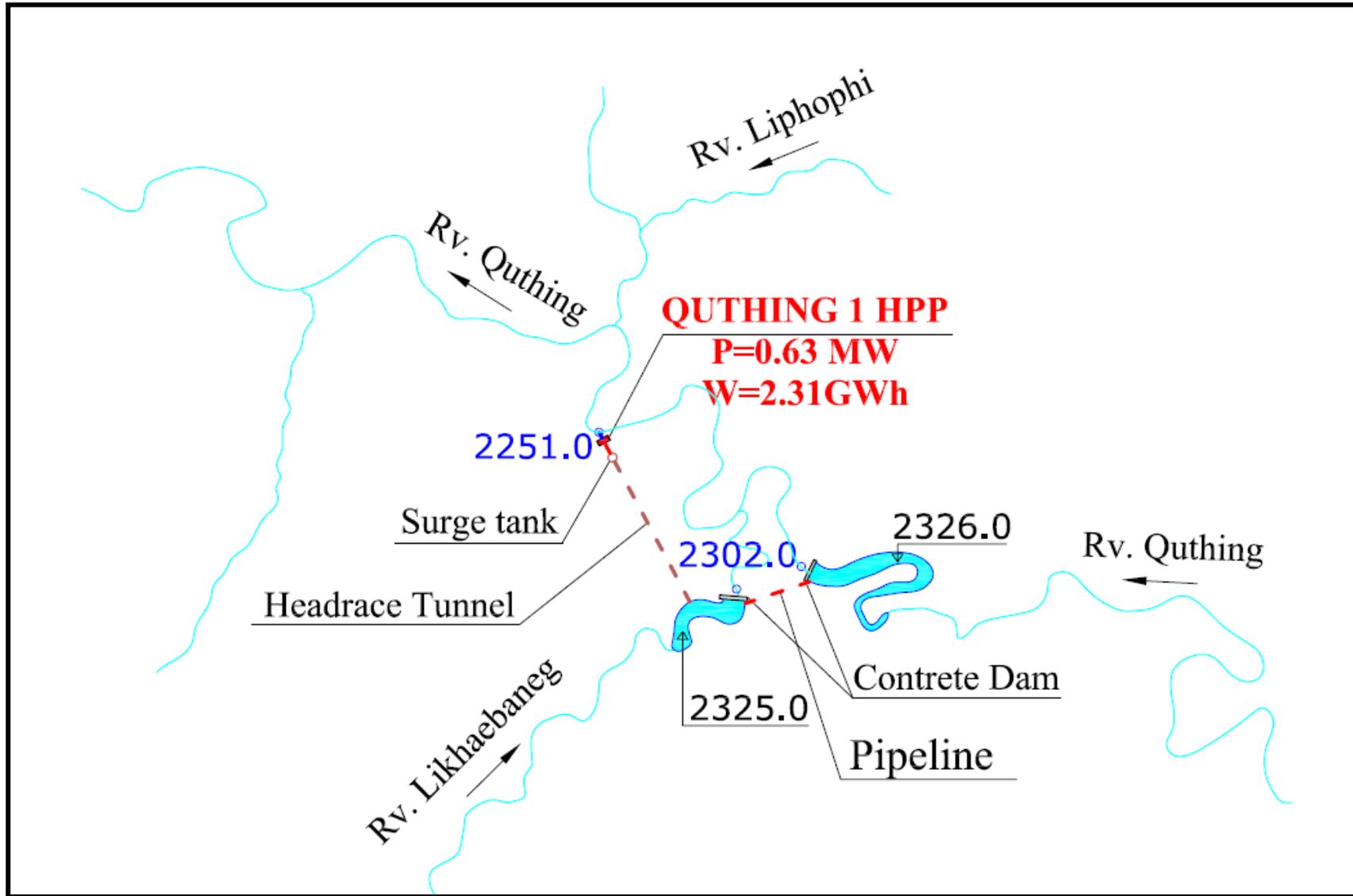
1.8 Generation



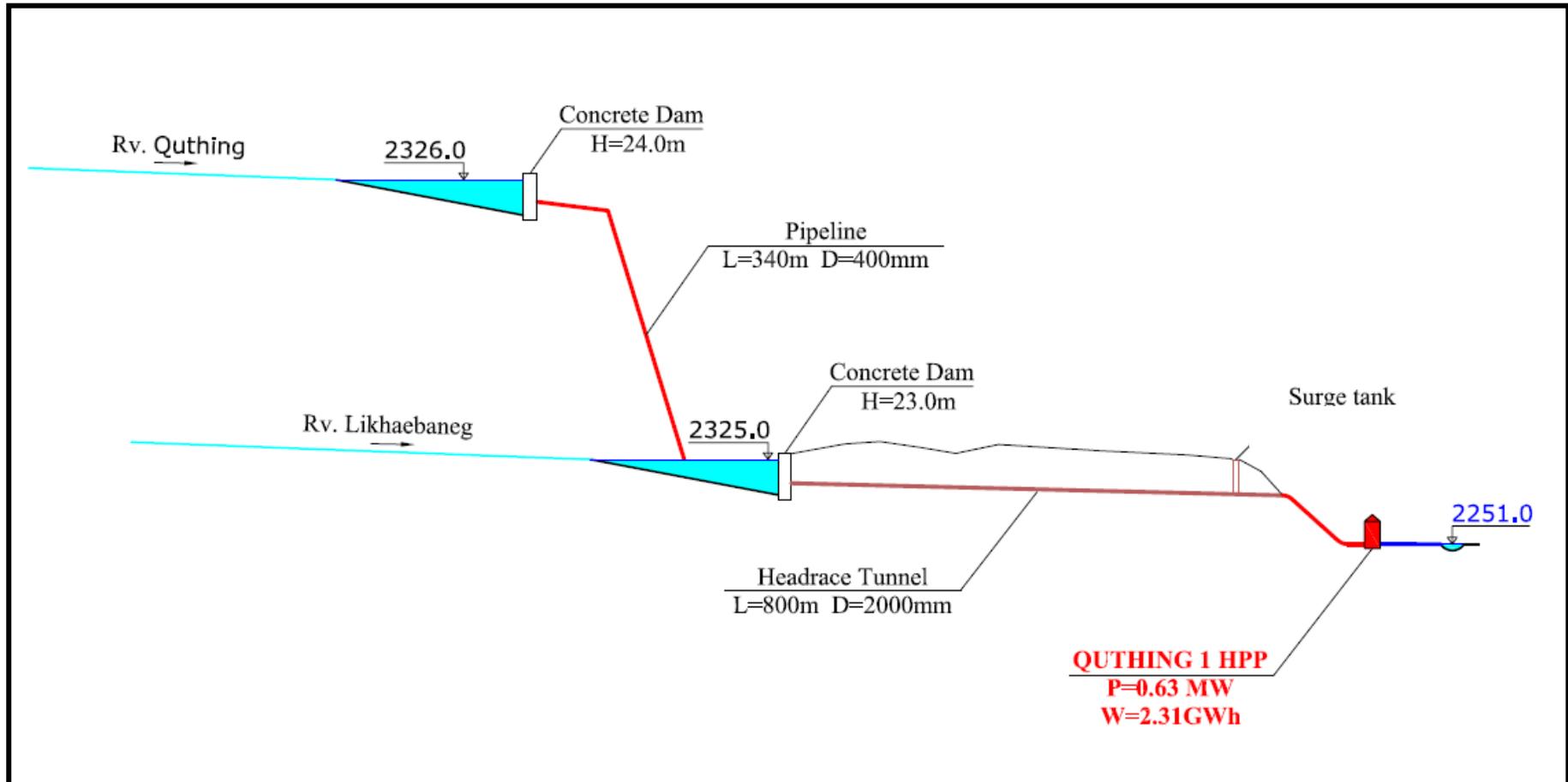
1.9 Topographic map



1.10 Plan



1.11 Longitudinal section



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QUTHING 2 HPP

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1. QUTHIG 2 HPP

1.1 Brief description of the site

Head unit, diversion pressure tunnel, turbine conduit, powerhouse, tailrace channel.

Head unit conveys concrete dam with spillway, height – 22.0m, and reinforced concrete water intake.

Diversion is 2.0m diameter pressure pipeline, length – 0.41km. Turbine conduit is 0.6m diameter metal pipe.

Powerhouse dimensions - 12.0×24.0m, height – 18.0m. Tailrace covered channel is rectangular reinforced concrete construction, dimensions – 1.2×1.2m, length – 75.0m.

1.2 Location

1.2.1 Location map



1.2.2 **Site location**

- Quthing, Ha Lethena; and
- GPS coordinates for the main structures.

No.	Name of Structure	Coordinates	
		X	Y
1	Dam on the river Quthing	28.122295	-30.346374
2	Powerhouse	28.118918	-30.345221

1.2.3 **Name of the river**

- Quthing

1.2.4 **Site hyperlink**

- [Q2 Dam on the river Quthing.kmz](#)
- [Q2 Quthing 2 Powerhouse.kmz](#)

1.3 **Type of HPP**

- Reservoir.

1.4 **Existing site access**

- Earth Road: Approximately 5.6 km; and
- Distance from the paved road: 7.5 km.

1.5 **Nearest connection point with national or regional grid**

- Distance: 4.5 km; and
- Existing Grid voltage level: 11 kV.

1.6 **List of literature used for this study:**

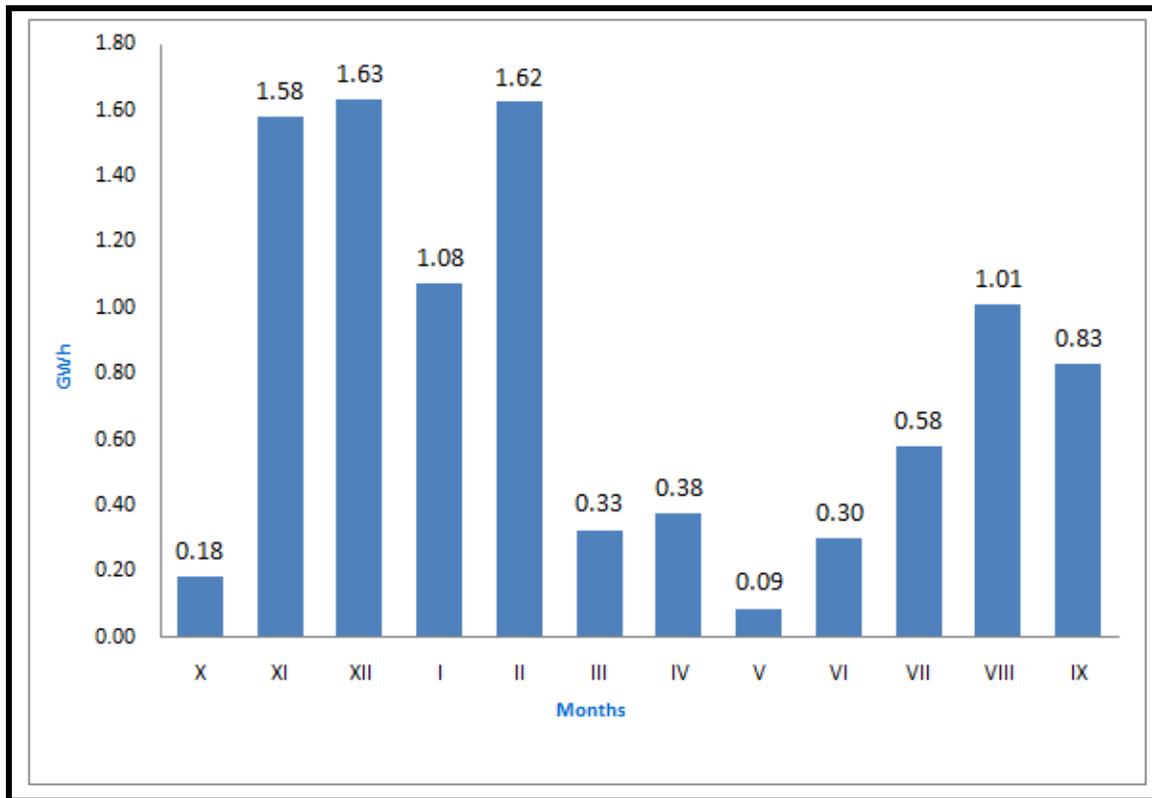
- Topographic Map - 1:50000 scale;
- Geologic Map - 1:25000 and 1:50000 scale;
- Map of hydrological and meteorological stations;
- Multiannual data of meteorological stations (temperature, humidity, wind, evaporation, precipitation);
- Scheme of High and low voltage grid, detailed technical parameters;
- Map of main communications;
- Water Resources Management, Policies and Strategies, Final Report; and
- WASM 90 Modeling Parameters.

1.7 Key characteristics

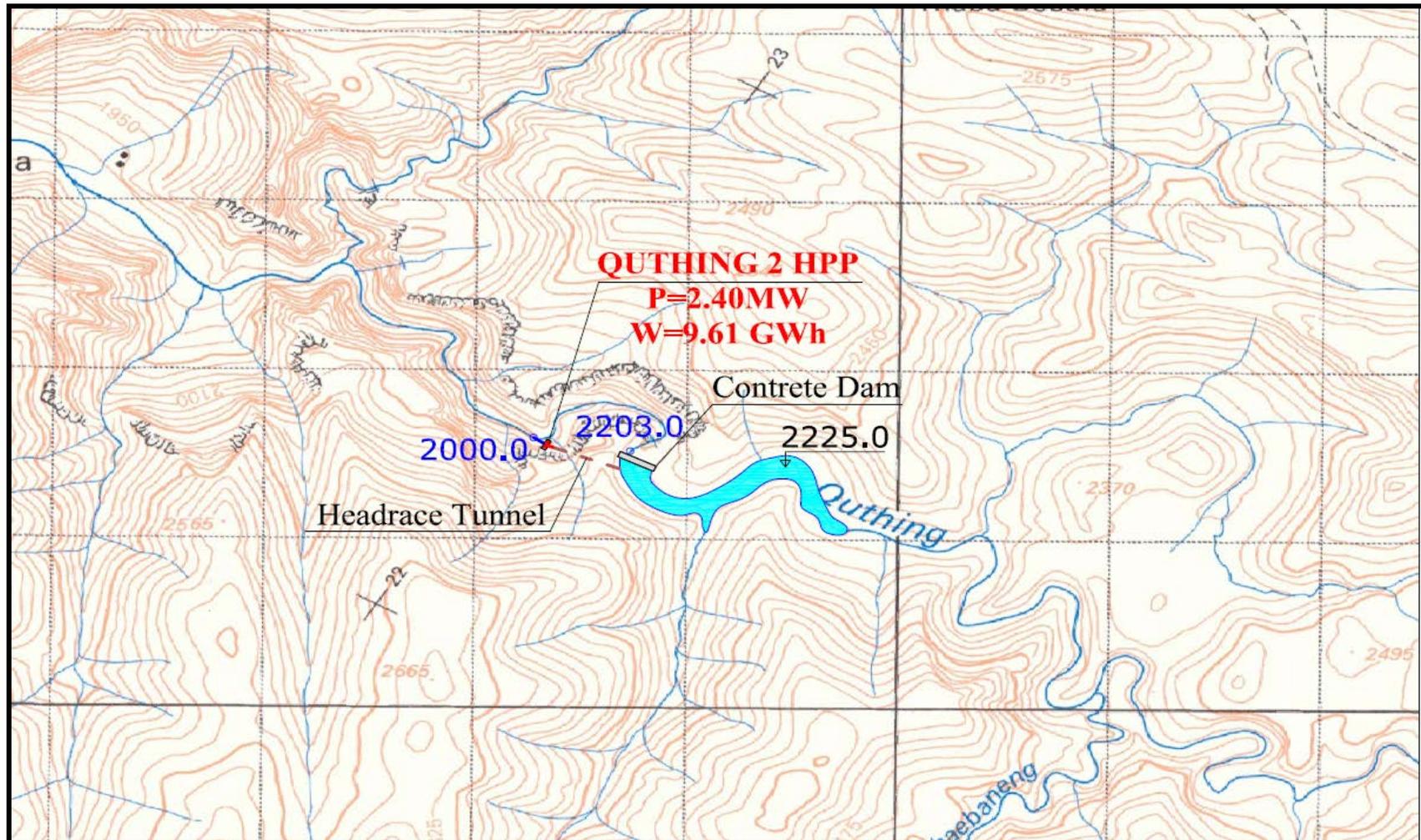
No.	Characteristics	Unit	Index
1	2	3	4
I	Technical Parameters		
1.1	Installed Capacity	MW	2.40
1.2	Average Annual output	GWh	9.61
1.3	Capacity usage ratio/Efficiency	%	45.71
1.4	Type of regulation		Reservoir
1.5	Scheme of energetic usage potential		N/A
	Hydrology		
1.6	Hydrological Data (number of years)	Year	45
1.7	Year of the average multi annual discharge	Year	1985/86
1.8	Catchment area	km ²	139.50
1.9	High water flow	m ³ /sec	1.15
1.10	Average water flow	m ³ /sec	0.80
1.11	Low water flow	m ³ /sec	0.36
1.12	Rated water discharge	m ³ /sec	1.20
1.13	Maximum gross head	m	225.00
1.14	Minimum gross head	m	213.00
	Reservoir		
1.15	Full supply level (FSL)	masl	2225.00
1.16	Minimum Operation level (MOL)	masl	2213.00
1.17	Total volume at FSL	mln. m ³	1.75
1.18	Active reservoir level	mln. m ³	1.23
	Dam		
1.19	Type		With spillway
1.20	Crest Elevation	masl	2225.00
	Spillway		
1.21	Type		Surface
1.22	Crest Elevation	masl	2225.00
	Water intake		
1.23	Sill elevation	masl	2210.00
1.24	Stop log type and number		Butterfly valve
1.25	Quantity	unit	1
	Sluice or bottom spillway		
1.26	Type and number		Bottom
1.27	Quantity	unit	3
	Diversion		
1.28	Type of diversion		Tunnel
1.29	Dimensions (w; l) or (d; l)	m	2.0; 410
	Stilling basin or shaft		
1.30	Dimensions (w x l x h) or (d x h)	m	N/A
	Powerhouse		
1.31	Type		Above-ground
1.32	Dimensions (w x h x l)	m	12x18x24
1.33	Elevation of tailrace outlet sill	masl	2002.50
	Tailrace		
1.34	Type		Covered channel
1.35	Dimensions (w x h)	m	1.2x1.2
1.36	Elevation of outlet sill	masl	1998.50

No.	Characteristics	Unit	Index
1	2	3	4
	Turbines/Generators		
1.37	Turbine Type and number		P. CJ 237-W-125/1x11; 2
1.38	Rated discharge	m ³ /sec	0.60
1.39	Rated output	MW	1.24
1.40	Maximum output	MW	1.38
1.41	Generator Type		SFW1250-12/1430
1.42	Generator nominal output	MW	1.20
1.43	Generator nominal output	rpm	502
	Transformers		
1.44	Type		Three-phase
1.45	Number	unit	2
1.46	Nominal power	MVA	1.3
1.47	Transformer dimensions (l x w x h)	m	4,5x3,15x4,9
II	Economic - Financial Parameters		
2.1	Costing	mln. USD	6.96
2.2	Duration of the construction	Year	2.00
2.3	Investment per 1 kW	Thousand USD	2.9
2.4	Investment per 1 kW/h	USD	0.72
2.5	Revenue per USD spent (Average price new HPP - 4,8 cents)	USD	0.24
2.6	Estimated carbon credit generation	T.	3.4
III	Social and Environmental Parameters		
	Special environmental requirements		
3.1	Social Impact		Additional workplace; Development of infrastructure
3.2	Ecological risks		Medium
	Transmission lines		
3.3	Parameters	kV	11
3.4	Distance to inter connection point	km	4.50
	Infrastructure		
3.5	Existing roads		Paved, Earth
3.6	Roads to be constructed	km	5.60

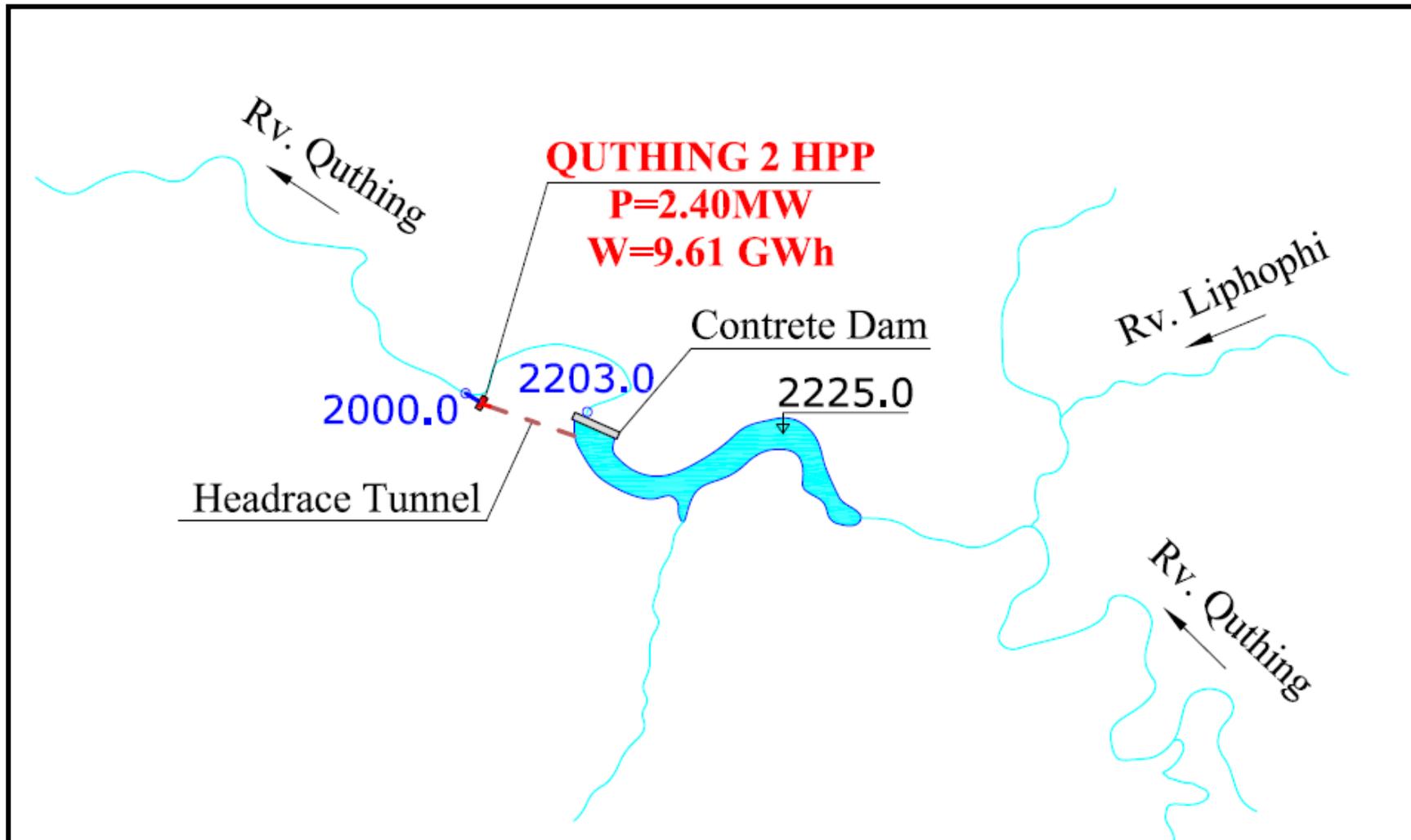
1.8 Generation



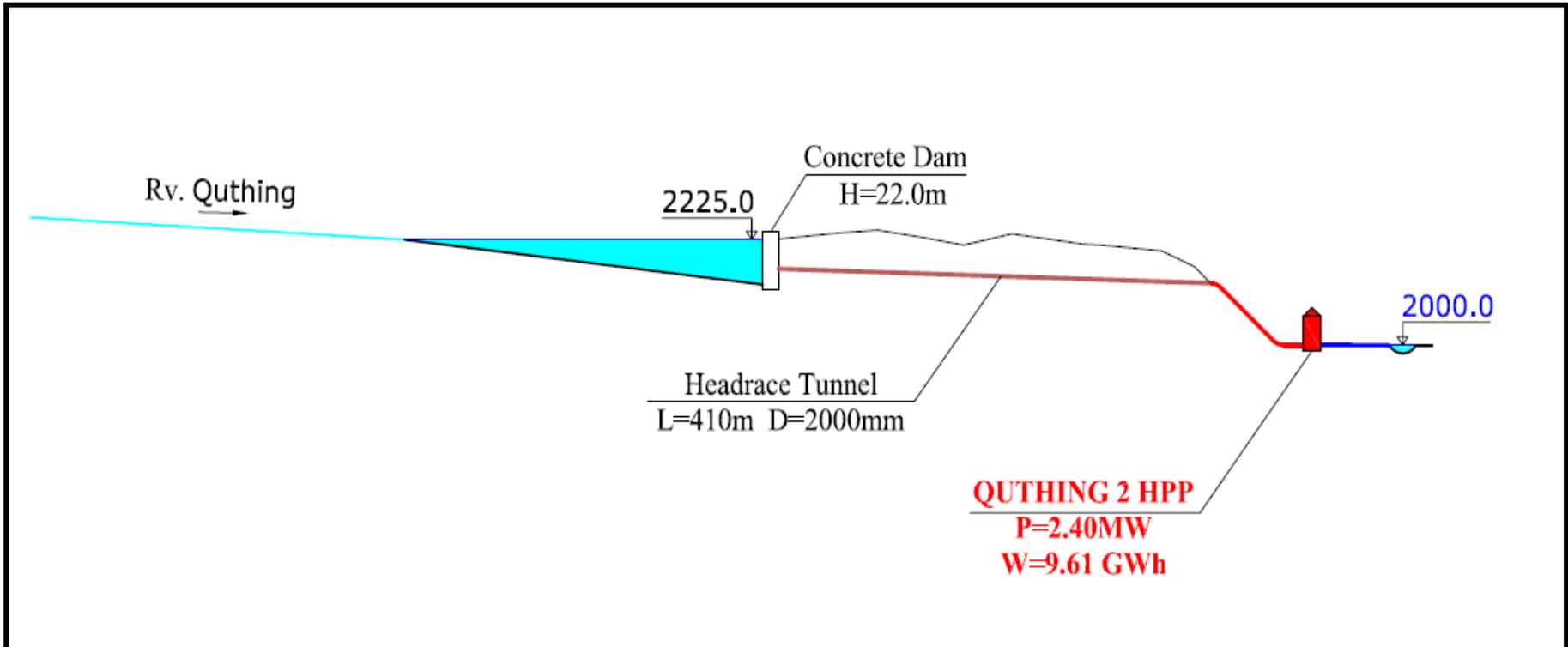
1.9 Topographic map



1.10 Plan



1.11 Longitudinal section



LESOTHO POWER GENERATION MASTER PLAN

PROJECT # LEC/GEN/1-2009

FINAL MILESTONES REPORT

VOLUME 1 - PART 1.1

HYDROPOWER GENERATION OPTION

APPENDIX 1.1.12

QUTHING 3 PSPP

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1. QUTHING 3 PSPP

1.1 Brief description of the site

Three head units, diversion pressure tunnel and pipeline, surge tank, turbine conduit, power-cavern, tailrace tunnel.

Head unit on the river Seforong conveys Concrete dam, height – 3.0m, and silt basin with sluice. Diversion is 0.4m diameter pressure pipeline, length – 2.25km.

Head unit on the river Quthing conveys rock-fill earth dam, height – 68.0m, and surface and bottom spillways. The reservoir holds water delivered from Quthing 3 PSP, when PSP is working in turbine regime, water is pumped from lower reservoir to the upper one.

Head unit on the river Quthing right tributary conveys rock-fill earth dam, height – 93.0m, reinforced concrete water intake, and surface and bottom spillways. Diversion is 9.5m diameter pressure tunnel, length – 2.3km.

Reinforced concrete surge tank is located at the end of diversion, diameter - 21.0m, followed by surge tank. From surge tank 6 thread underground turbine conduits, with diameter 4.0m come out. Turbine conduit is equipped with disk valves. Power-cavern dimensions - 30.0 × 220.0m, height – 45.0m. 6 tailrace tunnels (diameter – 4.0m) come out of the power cavern and connect to the surge tank, from which one tunnel, with the diameter 9.5m and length – 2300.0m, comes out.

The electric power will be connected through 765 kV transmission line to Bloemfontein existing 765 kV sub-station. Length of transmission line will be around 400.0 km.

1.2 Location

1.2.1 Location map



1.2.2 **Site location**

- Quthing, Ha Lethena; and
- GPS coordinates for the main structures.

No.	Name of Structure	Coordinates	
		X	Y
1	Dam on the river Letseng-la-letsie	28.122372	-30.322485
2	Dam on the river Quthing	28.076845	-30.322703
3	Powerhouse	28.096204	-30.324584

1.2.3 **Name of the river**

- Quthing.

1.2.4 **Site hyperlink**

- [Q3 Dam on the river Letseng-la-letsie.kmz](#)
- [Q3 Dam on the river Quthing.kmz](#)
- [Q3 Quithing 3 Powerhouse.kmz](#)

1.3 **Type of regulation**

- Reservoir.

1.4 **Existing site access**

- Earth Road: Approximately 8.4 km.
- Distance from the paved road: 3.0 km

1.5 **Nearest connection point with national or regional grid**

- Distance: No existing grid (South African Substation distance: 400.0 km); and
- Not existing grid (South African grid Existing level: 765 kV).

1.6 **List of literature used for this study:**

- Topographic Map - 1:50000 scale;
- Geologic Map - 1:25000 and 1:50000 scale;
- Map of hydrological and meteorological stations;
- Multiannual data of meteorological stations (temperature, humidity, wind, evaporation, precipitation);
- Scheme of High and low voltage grid, detailed technical parameters;
- Map of main communications;
- Water Resources Management, Policies and Strategies, Final Report;

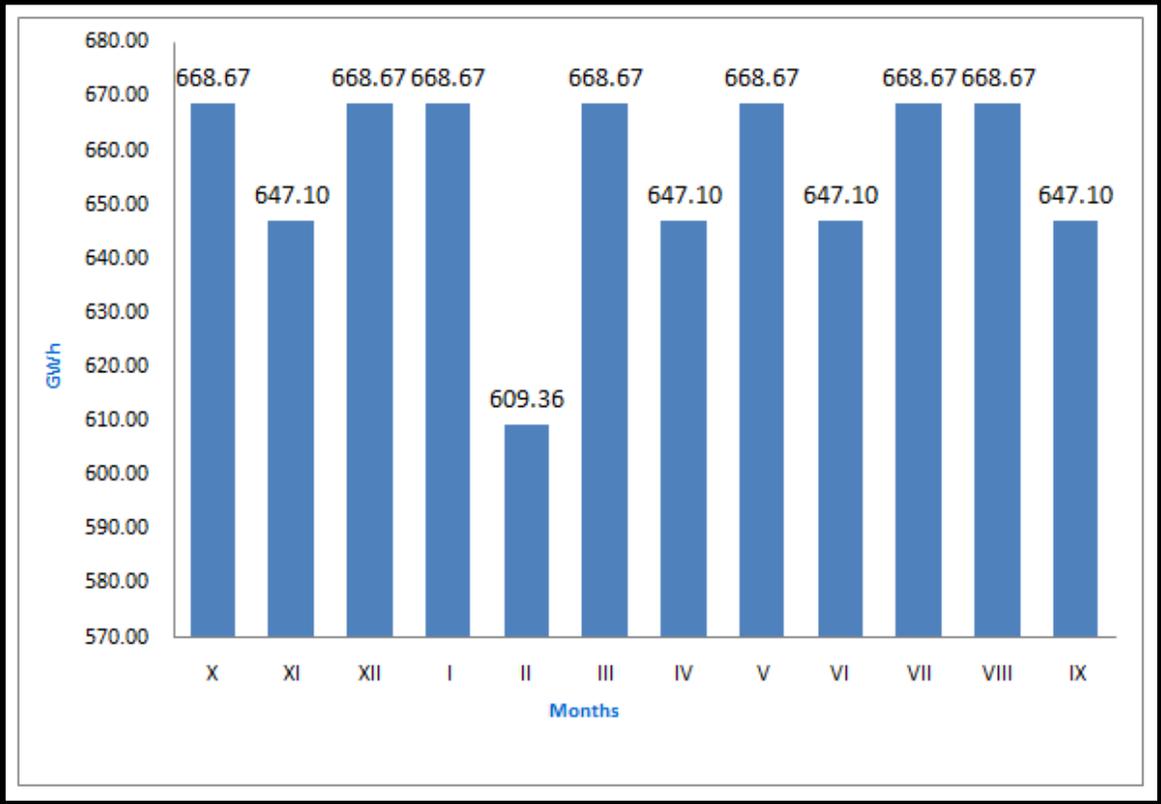
- WASM 90 Modeling Parameters; and
- Dimensions of the power cavern are agreed with the client.

1.7 Key characteristics

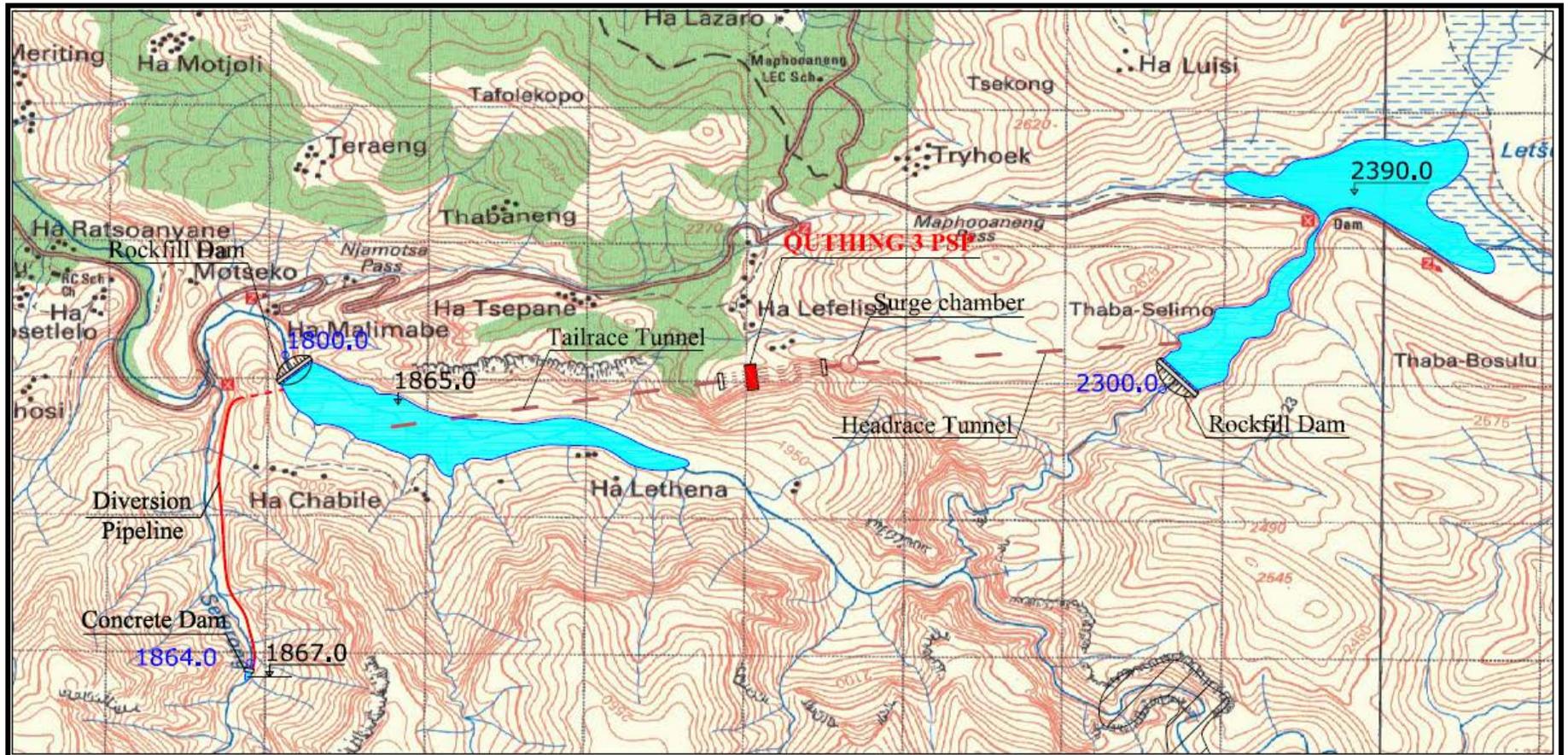
No.	Characteristics	Unit	Index
1	2	3	4
I	Technical Parameters		
1.1	Installed Capacity (Pumping/Generation)	MW	2160.0/1800.00
1.2	Average Annual output	GWh	7878.00
1.3	Capacity usage ratio/Efficiency	%	49.96
1.4	Type of regulation		Reservoir
1.5	Scheme of energetic usage potential		N/A
	Hydrology		
1.6	Hydrological Data (number of years)	Year	45
1.7	Year of the average multi annual discharge	Year	1985/86
1.8	Catchment area	km ²	268.70
1.9	High water flow	m ³ /sec	2.22
1.10	Average water flow	m ³ /sec	1.54
1.11	Low water flow	m ³ /sec	0.69
1.12	Rated water discharge	m ³ /sec	378.00
1.13	Maximum gross head	m	571.50
1.14	Minimum gross head	m	475.50
	Reservoir		
1.15	Full supply level (FSL)	masl	2390.00
1.16	Minimum Operation level (MOL)	masl	2340.50
1.17	Total volume at FSL	mln. m ³	44.50
1.18	Active reservoir level	mln. m ³	24.50
	Dam		
1.19	Type		Rock fill
1.20	Crest Elevation	masl	2393.00
	Spillway		
1.21	Type		Surface
1.22	Crest Elevation	masl	2390.10
	Water intake		
1.23	Sill elevation	masl	2330.50
1.24	Stop log type and number		Butterfly valve
1.25	Quantity	unit	1
	Sluice or bottom spillway		
1.26	Type and number		Bottom
1.27	Quantity	unit	1
	Diversion		
1.28	Type of diversion		Tunnel; Conduit
1.29	Dimensions (w; l) or (d; l)	m	9.5,2300; 0.4,2250
	Stilling basin or shaft		
1.30	Dimensions (w x l x h) or (d x h)	m	21.0; 65.0
	Powerhouse		
1.31	Type		Underground
1.32	Dimensions (w x h x l)	m	30x45x220
1.33	Elevation of tailrace outlet sill	masl	1798.50
	Tailrace		
1.34	Type		Tunnel

No.	Characteristics	Unit	Index
1	2	3	4
1.35	Dimensions (D)	m	9.50
1.36	Elevation of outlet sill	masl	1800.00
	Turbines/Generators		
1.37	Turbine Type and number		Francis, Vertical; 6
1.38	Rated discharge	m ³ /sec	63.00
1.39	Rated output	MW	310.88
1.40	Maximum output	MW	345.42
1.41	Generator Type		Three phase, Synchronic
1.42	Generator nominal output	MW	300.00
1.43	Generator nominal output	rpm	-
	Transformers		
1.44	Type		Three-phase
1.45	Number	unit	6
1.46	Nominal power	MVA	400.0
1.47	Transformer dimensions (l x w x h)	m	
II	Economic - Financial Parameters		
2.1	Costing	mln. USD	3240.00
2.2	Duration of the construction	Year	5.00
2.3	Investment per 1 kW	Thousand USD	1.8
2.4	Investment per 1 kW/h	USD	0.41
2.5	Revenue per USD spent (Average price new HPP - 4,8 cents)	USD	0.12
2.6	Estimated carbon credit generation	T.	2757.3
III	Social and Environmental Parameters		
	Special environmental requirements		
3.1	Social Impact		Additional workplace; Development of infrastructure
3.2	Ecological risks		Medium
	Transmission lines		
3.3	Parameters	kV	765
3.4	Distance to inter connection point	km	400.00
	Infrastructure		
3.5	Existing roads		Paved, Earth
3.6	Roads to be constructed	km	8.40

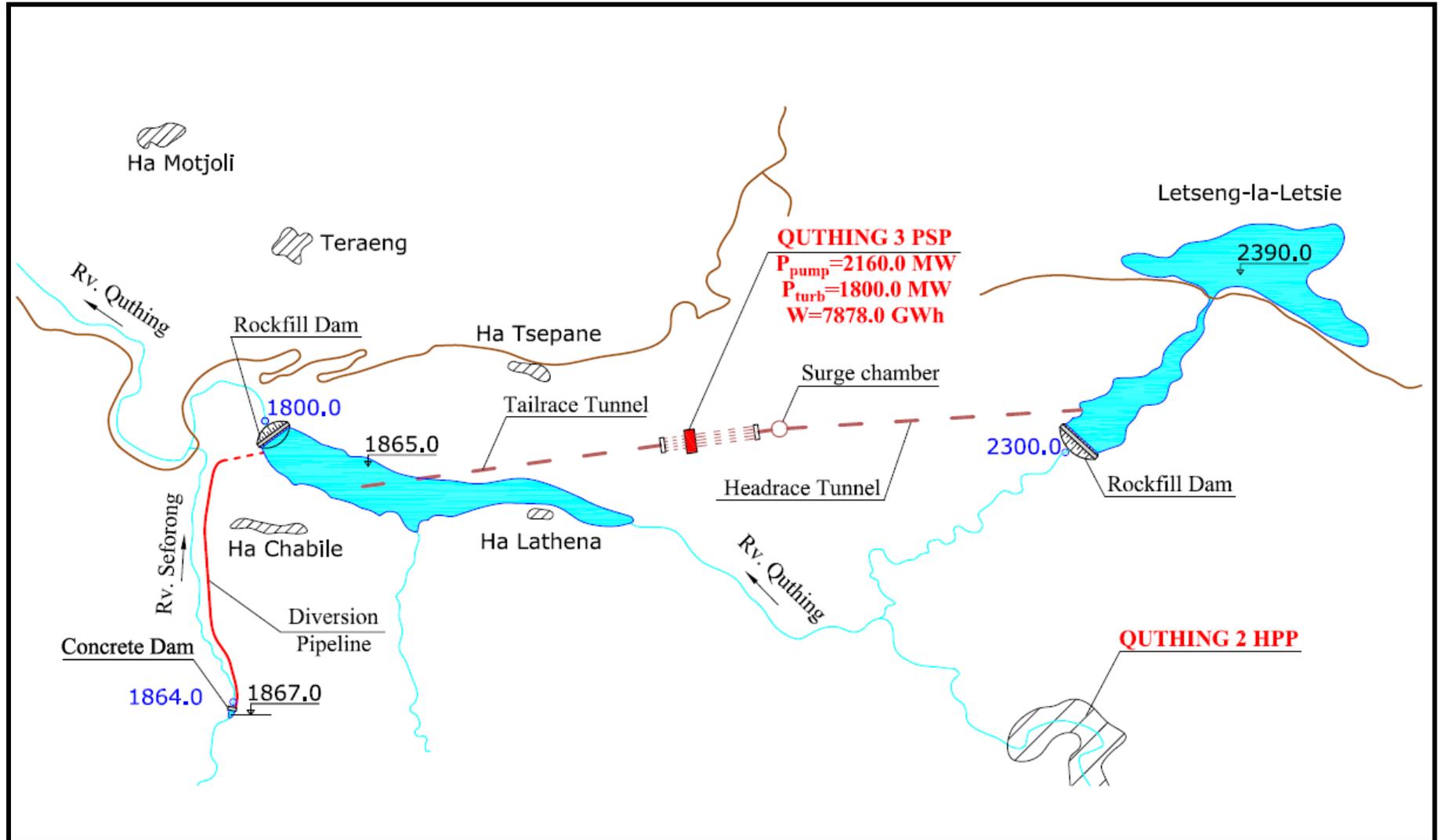
1.8 Generation



1.9 Topographic map



1.10 Plan



1.11 Longitudinal section

