VARIABLE ELEVATION HYDRO POWER STATIONS OF ZHINVALI HYDRO POWER STATION

(Business plan)

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In accordance with the suggested technology, on the water reservoirs of the hydroelectric power station will be used hydro energy of feeding water, which is lost on existing hydroelectric power station in the period, when there is a fluctuation of level of water from maximum to minimum and back in the water reservoir. It means in the months of emptying (autumn-winter) and filling (spring) of water reservoir.

Innovational hydroelectric power station with variable mark carries out diversion flow from intake unit, located near the feeding water inflow in the water reservoir. Then, by the diversion water conduit, water goes to pressure reservoir in the minimum explanation range of the water reservoir. From the reservoir, a turbine pipeline will be directly connected to the hydraulic unit, which in turn will be mounted on the platform, floating in the water reservoir. Hydroelectric power station with the variable mark will be operated on the variable head. In case of pressure intake system, a device of head reservoir won't be needed any more.

Innovational technology is patented and for nowadays it is not carried out.

Generation, produced on the hydroelectric power station with the variable mark is based on ecologically clean energy carrier. Also major portion of generated el. power (~66%) coincides with the period of deficit of el. power in the energy system of the country and correspondingly occurs an introduction of capacities in the energy system by means of heat stations.

Cost of produced el. power on hydroelectric power station with the variable mark will be less energy, than on traditional hydroelectric power station.

Adoption of suggested technology in Georgia is possible on the following water reservoirs of hydroelectric power station: Jinvali, Inguri, Sioni and in perspective – Khudoni, Namakhvani etc.

Key words: *hydro power station (HPS), elevation, variable elevation HPS, derivation, floating platform.*

1. Project Information

There is no similar project worldwide (see V. Jamarjashili. patent 3735 Georgia 2004.03.18). This is Hydro Power Station (HPS) with variable elevation hydro units.

Innovative technology enables electrical energy generation by utilizing the potential energy of river, which usually is lost when it is flowing in to the reservoir of existing regulation HPS. The mentioned is presented when water level of reservoir is lower than the normal under flood level (NUFL) during reservoirs water release and fill-up periods. In accordance with mentioned, it is obvious that the scope of usage of this project is hydro accumulation power stations as well.

At the same time, it should be underlined that unlike any other traditional type hydro power stations the HPS with Variable Elevation Hydro Units generates its major portion of electrical energy during Autumn-Winter period, 70 % of annual production, by time when due to the lack of water at Georgian (and mountain hydro energy countries) traditional hydro power stations the sharp decrease (3-4 times) of electrical energy production is presented.

With utilization of the Variable Elevation HPS (VE HPS), the countries which in conditions of traditional schematics actually fully developed water energy resources (Norway, Swiss and etc) will gain real opportunity of additional (ecologically clean) electrical energy production.

Variable Elevation (VE) HPS consists (Please see drawing #1-3): the existing reservoir 1 and on the surface of end point of the minimum level H_{min} spread the floating platform 2 with hydro unit 3 placed on it; the headworks 8 located on highest or upper elevation of maximum level H_{max}; the connected one or more derivation piping 7 (tunnel or open channel); the head reservoir 6 and water supplier, which consists turbine piping 4 and its supporting construction 5. At that one side of the turbine piping 4 via flexible reducer is connected with inlet of turbine (turbines) of unit 3, and by another to outlet of head reservoir 6.

VE HPS operates as follows: since the water level of existing HP station reservoir is lower than elevation - H_0 ($H_{min}<H_0<H_{max}$) from the headworks 8, water flow via derivation piping 7 (tunnel or open channel) is supplied to head reservoir 6, and via turbine piping 4 to hydro unit 3. Water supplier (4, 5) construction (it is considered to equip this construction with flexible bellows corresponding to turbine piping) enables uninterrupted water supply to hydro unit 3 and correspondingly generation of electrical energy in conditions of actual water level Hi ($H_{min} \le Hi \le H_0$) variation in reservoir.

2. Variable Elevation Hydro Power Stations of Zhinvali Reservoir

Proposed project considers implementation of two VE HP stations at reservoir of existing HPS of Zhinvali. For operational average conditions of Zhinvali HPS, the potential energy losses (during reservoir water release and fill-up periods) of reservoir inflow rivers, or complete energy to be used equals to 73.35 million KWhrs (please see table #1).

There are two rivers flowing into the Zhinvali reservoir – Tetri Aragvi and Pshavi Aragvi. Hydrological data and relief conditions of which are practically the same. That is why energy indices of both VE HP stations are identical.

In line with the project of VE HP stations, the water off-takes are considered to be implemented on rivers of Terti Aragvi and Pshavis Aragvi, at places where the rivers are joining the reservoir, at an elevation of 810 m. Each water off-take node consists: movable dam, side (bank) water intakes and sedimentation basins. At that, both dams will under flood the rivers at an elevation of 813 m. The water from sedimentation basins via open channels will flow among corresponding banks to a proper head ponds, which will be installed in line with section line of platform (barge), located on the surface of end of the minimum level (768-770) spread of reservoir. At that an elevation of head

ponds equals to 813 m – $\Delta h_i \approx 3$ m (where Δh_i is pressure losses of water flow through corresponding water open channels). From the head ponds the water via special water supplier construction will be directed to platforms (barges), swimming on the surface of existing reservoir, on the platforms where the hydro nodes with all necessary mechanical equipments will be installed. In reservoir normal under flood level elevation (NUFL) equals to 810 meters, and minimum under flood level elevation is 768 meters, so water head average maximum value for VE HP stations equals to 42 meters.

For both VE HPS the calculated water flow is 20 m³ per second. The lengths of open channels are 4.3 and 3.7 kilometers. VE HPS hydro units, during reservoir water release and fill-up periods, due to variation of pressures in wide ranges (from 1 meter to 42 meter and visa versa) are chosen as follows: each VE HPS consist one turbine of Frenzies type, with power capacity of 7 MW and one propeller type turbine, which operates when head is lower than 15 meters, with power of 3 MW. Thus total maximal working power of both VE HP stations is 14 MW, and annual electrical energy generation is equal to 43.8 million KWhrs (tabl. 1)

3. Project Purpose and Attractive Points

The Project purpose is the construction of small power capacity two VE HP stations to obtain ecologically clean, renewable electrical energy, with comparative low financial costs; this is conditioned with possibility of implementation of penstock diversion by open channel. The utilized water fully returns to reservoir and is not affecting the operations of acting Zhivnali HPS. Most scope (66 %) of electrical energy will be generated during those months of year when the country energy system is shortfall.

The positive side of the project also represents the placement of VE HP stations within the ranges of acting Zhinvali facilities; this simplifies provision of technical services for the project units, executed by assistance of highly qualified staff of Zhinvali HPS.

There is no need for high voltage power transmission lines, because the voltage from terminals of VE HPS generators will be transmitted at 5-7 km distance to existing substation of acting Zhinvali HPS, which has proper spare.

The tariff (0. 06 USD or 8. 40 Tetri per KWhrs) of electrical energy generated by VE HP stations is less than existing consumption rate.

In future, in Georgia, admission of season tariffs will additionally increase economical performance of the VE HPS during Autumn-Winter period.

It is also important, that Zhinvali HPS reservoir is at 60 km away from industrial conglomerate of Tbilisi-Rustavi cities, this is facilitating circumstance for construction of VE HP stations.

Furthermore, as known, it is excluded to install landing stage on regulation reservoirs, due to sharp varying of reservoir levels. Utilization of pontoon of VE HPS and equip of the HPS water supplier with elevators, the mentioned problem will be solved easily. As a result, possibility to survey water area of the reservoir with power accumulator boats can be additional profit source, for tourism intensive development conditions, in Georgia.

4. Social – Ecological benefits and construction period

At first the local population will be involved in construction of variable elevation (VE) hydro power stations (HPS), and next in operations team as a site service staff. Construction will be implemented on non-populated and economy useless areas. Generated energy will substitute electrical energy generated on thermal power stations with corresponding quantity.

In spite of mountain relief, the construction conditions are still useful: there are roads at headwork point; trace of derivation channels follows roads of existing soil. Construction period of variable level HP stations (fabrication of floating means with energy unit installation) is determined out as one year.

Water Power Data

Table 1

Month	Average multi-years water flow, m³/sec	Water level lowering, m	Loss of potential energy of river, million KWhrs	Energy parameters of VE HPS		
				Water flow on VE HPS	Power Capacity	Generation Output
1	2	3	4	5	6	7
I	17.70	28.60	3.70	17.70	4.30	3.20
II	17.70	36.90	4.32	17.70	5.55	3.73
III	26.50	41.30	8.00	26.50	9.30	6.92
IV	62.30	38.70	17.03	40.00	13.16	9.79
V	98.00	28.30	20.24	40.00	9.76	7.26
VI	83.00	14.10	8.27	40.00	4.80	3.46
VII	59.00	5.10	2.19	40.00	1.73	1.29
VIII	41.50	3.70	1.12	40.00	1.26	0.94
IX	35.70	3.60	0.91	35.70	1.22	0.88
X	31.30	6.60	1.51	31.30	1.76	1.31
XI	25.60	13.50	2.87	25.60	2.94	2.12
XII	21.00	21.80	3.34	21.00	3.90	2.90
Average - 43.3			Total 73.35			Total 43.80

5. Profitability

Financial forecast data (see table 7) concludes the project profitability indices are as follows:

1. Total Investment	**13 600 000.0**	**USD**
2. Net Income	**2 628 000.0**	**USD**
3. Return Period	**5.2**	**Years**
4. Repayment Period	**6.0**	**Years**
5. Internal rate of Profitability	**19.2**	**%**

Project Parameters

Table 2

#	Parameters	Calculate Value
1	Head (m)	40
2	Water flow (m^3/sec)	2x20=40
3	Installed Power (MW)	2x7.0=14
4	Annual average energy generation, million KWhrs	43.8
5	Project summary costs (million USD)	13.6
6	Price of 1 KW power (USD per KW)	971
7	Price of 1 KWhr energy (USD per KWhrs)	0.311
8	Tariff (USD per KWhrs)	0.06

Note: Table includes summary indices of both VE HPS

Project Costs

Table 3

#	Work Scope	Cost, 10^3 USD
1	Project management	20.0
2	Project-research works	180.0
3	Movable dam	210.0
4	Water intake and sedimentation tanks	250.0
5	Derivation channel (of soil)	3,400.0
6	Head basin	160.0
7	Swimming mean (barge)	490.0
8	Penstock piping and supporting construction	40.0
9	Units in package	7,500.0
10	HV power transmission line	90.0
11	Unforeseen costs	1,300.0
	Summary investment	13,600.0

Operational Costs (Annual)

Table 4

#	Cost listing	Annual Costs, USD
1	Salary	71,400.0
2	Ongoing Maintenance	80,000.0
3	Unforeseen costs	26,600.0
4	Operations Costs (Annual)	178,000.0

Salary of Staff of Variable Elevation Hydro Power Station

Table 5

#	Position	Qty	Monthly Rate, USD	Staff Monthly Salary	Annual Salary, USD
1	Director	1	500.0	500.0	6,000.0
2	Engineer-Electrician	5	300.0	1,500.0	18,000.0
3	Engineer-Mechanical	5	300.0	1,500.0	18,000.0
4	Accountant	1	250.0	250.0	3,000.0
5	Assistant labor	4	150.0	600.0	7,200.0
6	Security	8	200.0	1,600.0	19,200.0
	Total	24	1,700.0	5,950.0	71,400.0

Debt Re-Payment Plan

Table 6

Re-Payment Dates	Credit Coverage	Amount of remaining credit	% of Credit	Annual Amount of Credit %-%	Annual Re-Payment Amount
30.06.10*		13600	544	-	
31.12.10		13600	544	1088	
30.06.11	680	12920	544	-	
31.12.11	680	12240	517	1061	2421
30.06.12	680	11560	490	-	
31.12.12	680	10880	462	1952	2312
30.06.13	680	10200	435	-	
31.12.13	680	9520	408	843	2203
30.06.14	680	8840	381	-	
31.12.14	680	8160	354	735	2095
30.06.15	680	7480	326	-	
31.12.15	680	6800	299	625	1925
30.06.16	680	6120	272	-	
31.12.16	680	5440	245	517	1877
30.06.17	680	4760	218	-	
31.12.17	680	4080	190	408	1768
30.06.18	680	3400	163	-	
31.12.18	680	2720	136	299	1659
30.06.19	680	2040	109	-	
31.12.19	680	1360	82	191	1551
30.06.20	680	680	54	-	
31.12.20	680	0	27	81	761

*** Note: Initial re-payment date will be corrected after project actual implementation**

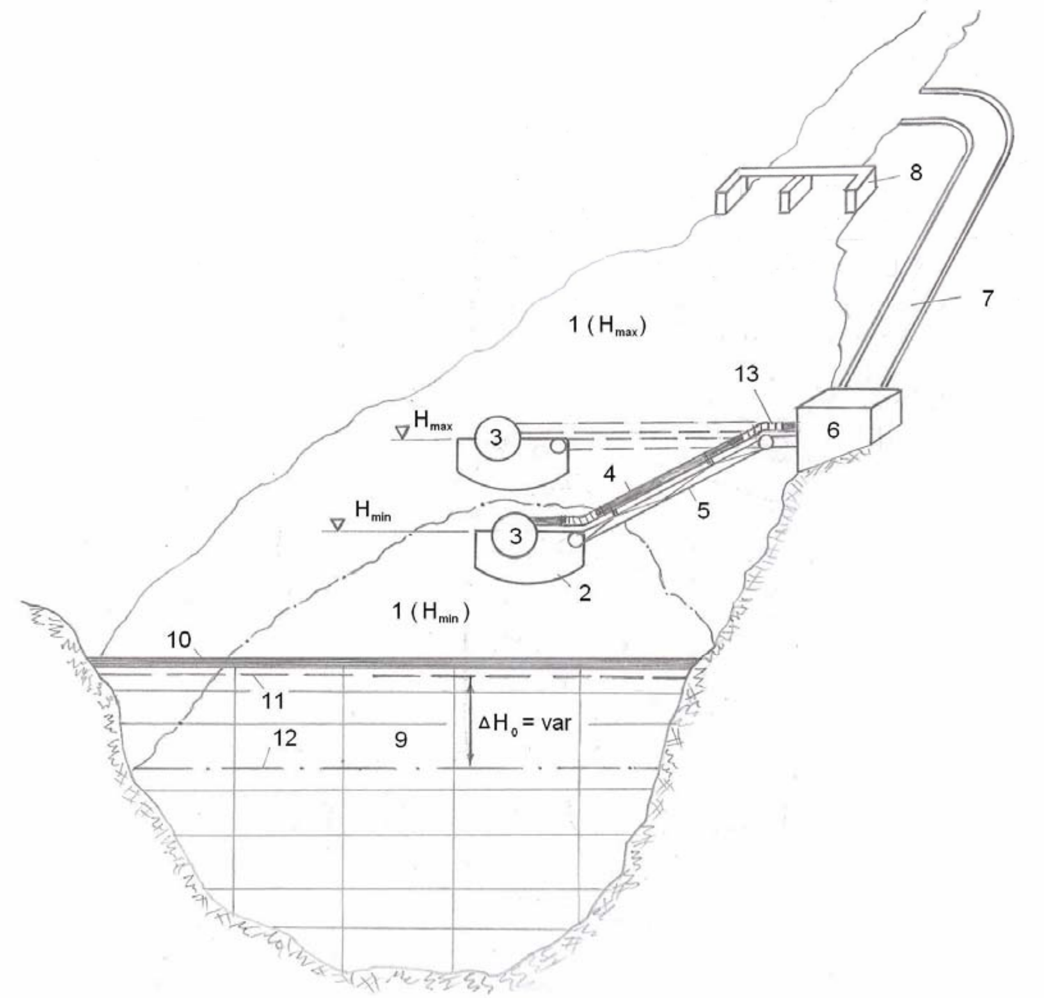
Financial Forecast

Table 7

Project Money Flow		YEARS											
		0	1	2	3	4	5	6	7	8	9	10	11
	Investment	13600											
	Investment for Depreciation	7000											
	Depreciation Period	10											
	Income	2628											
	Operational Costs	178											
A	Investment	13600											
B	Debt	13600											
C	Self-Capital	-											
E	Debt service	-		1360	1360	1360	1360	1360	1360	1360	1360	1360	1360
F	%-% of Debt	-	1088	979.2	870.4	761.6	652.8	544	435.2	326.4	217.6	108.8	0
G	Common Income		2628	2628	2628	2628	2628	2628	2628	2628	2628	2628	2628
H	Operational Costs		178	178	178	178	178	178	178	178	178	178	178
I	Net Income		2450	2450	2450	2450	2450	2450	2450	2450	2450	2450	2450
J	Depreciation		700	700	700	700	700	700	700	700	700	700	700
K	Income Tax		662	770.8	879.6	988.4	1097.2	1206	1314.8	1423.6	1532.4	1641.2	1750
L	Tax (15%)		99	116	132	148	165	181	197	214	230	246	263
N	Net Income		2,351	2,334	2,318	2,302	2,285	2,269	2,253	2,236	2,220	2,204	2,188
O	Net Money Flow		1,263	-5	88	180	273	365	458	550	643	735	828
P	Accumulating Money Flow		1,263	1,258	1,346	1,526	1,798	2,163	2,621	3,171	3,814	4,549	5,376

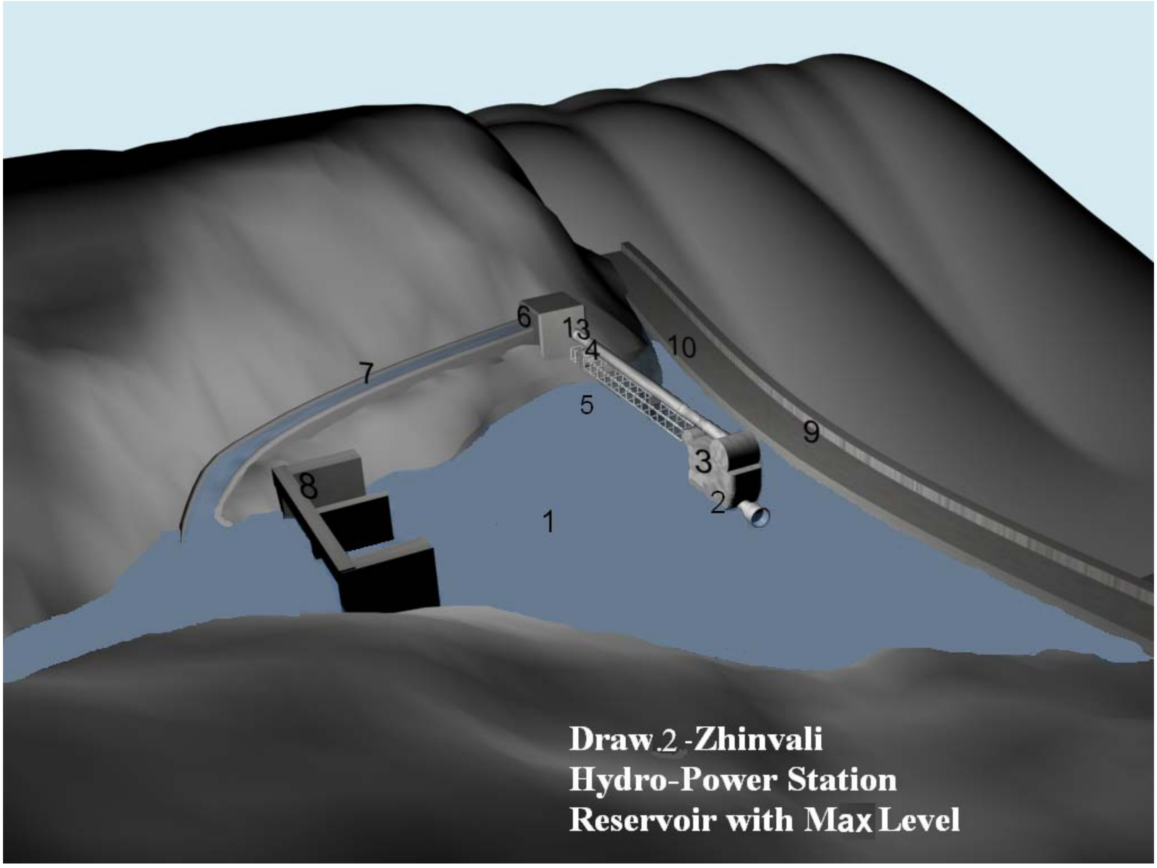
Note: **Investment will be returned in 8 years. Profitability factor is 5.6 years.**

6. Drawings



Draw. 1. Principal diagram of Hydropower Station with Variable Elevation Hydro Unit

1 –Reservoir of existing hydropower station; 2 – Floating platform; 3 – Hydro unit; 4 – Turbine piping; 5 – Supporting construction of turbine piping; 6 – Head reservoir; 7 – Derivation open channel; 8 – Headworks of Hydropower Station with Variable Elevation Hydro Unit; 9 – Dam existing HP station; 10 - Crest point of the dam; 11 – Maximum level of reservoir – H_{max}; 12 – Minimum level of reservoir – H_{min}; 13 – Flexible adaptor - flexible bellows.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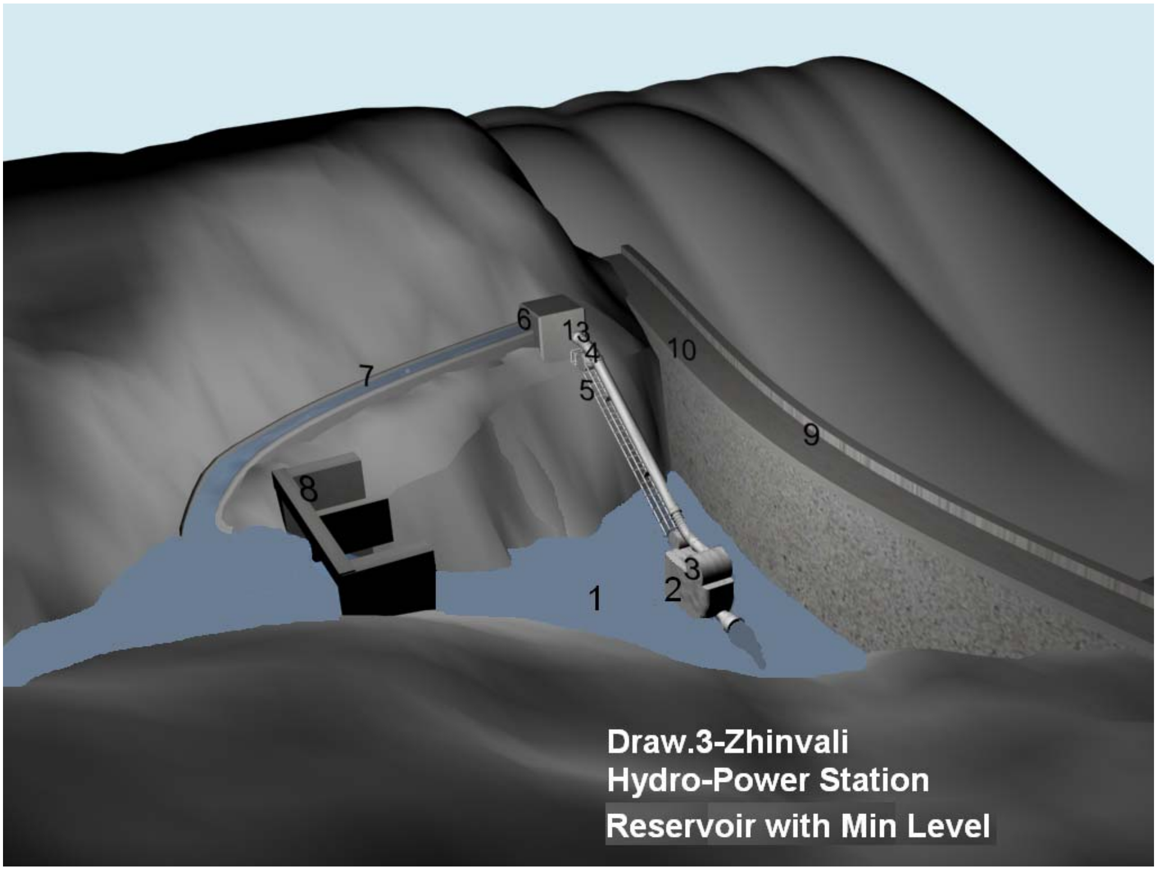
Draw.2 -Zhinvali
Hydro-Power Station
Reservoir with Max Level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Draw.3-Zhinvali
Hydro-Power Station
Reservoir with Min Level

7. Abbreviations

VE	**-**	**Variable Elevation**
HP	**-**	**Hydro-Power**
HPS	**-**	**Hydro-Power Station**
NUFL	**-**	**Normal Under Flood Level**

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