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Small hydropower – prestudy and design of a plant on Poarta river, Romania

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Diplomarbeit
zur Erlangung des akademischen Grades
Diplom-Ingenieurin
an der Universität für Bodenkultur Wien

eingereicht von
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Wien, Dezember 2010

Acknowledgements

First of all, I want to thank Prof. Bernhard Pelikan for this unique opportunity to work on this international project. It was a true challenge and an interesting end of my study in Vienna. Danke!

Equally I want to thank Prof. Codruța Jaliu for her aid during my stay in Romania. Mulțumesc!

Without my dear parents I would not have been able to complete such an interesting study. I appreciate their support and help during some hard study times and their joy and participations in times of pleasure. Bedankt!

Special thanks to my dear twin sister Lisi, who endured some sad but enjoyed even more happy moods with me. Without you, it wouldn't be the same ☺.

And I want to thank my dear friends and colleagues, who made my study time so colourful and happy. This time of my life surely is a period I will keep in best memory. Thanks to all of you!

Abstract

The importance of renewable energies strongly manifested itself in European legislation in recent years. The European Union's energy policy aims implement a percentage of energy that has to be produced out of renewable resources. In this thesis a feasibility study for a small hydropower plant in the political district of Braşov, Romania, is performed.

After the Poarta creek leaves the Bucegi National park, it flows beside the Poarta village. The plant is designed as a diversion power plant.

The results of this thesis are as follows:

The intake area is designed as a Tyrolean Weir, as the Poarta creek comes down from the mountains and still carries a lot of bed load. With a spillway the obligatory water dotation is performed. The retrieved water is transported into a settling basin to let the captured sediments sink. At the end it falls into an intake chamber and enters the penstock, which is made out of steel with a dimension of 800 mm and is embedded under the road that leads through Poarta village until it reaches the powerhouse.

Combining the head of 155 m and the water amount of 0.8 m³/s a Pelton turbine is selected. After passing the turbine, the water is led back into the river bed.

The construction costs are based on the Austrian price level and amount to roughly five million Euro. The avail calculation results in about 400,000 Euro per year.

The calculated energy production amounts to 5.100 MWh per year. By this, approximately 1160 households can be supplied.

Kurzzusammenfassung

Die Wichtigkeit der Energiegewinnung aus sogenannten erneuerbaren Energien ist allgemein bekannt und wurde in der europäischen Gesetzgebung implementiert. Die Staaten der Europäischen Union verpflichten sich einen Prozentsatz der elektrischen Energie aus diesen Quellen zu gewinnen. In Hinblick hierauf wurden für diese Diplomarbeit Vorstudie und Entwurf eines Kleinwasserkraftwerks im politischen Bezirk Braşov, Rumänien, erstellt.

Der Poarta Bach verlässt den Bucegi Nationalpark und fließt neben der Ortschaft Poarta. Das Kraftwerk wird als Ausleitungskraftwerk geplant.

Die Ergebnisse dieser Arbeit lauten wie folgt:

Die Entnahme des Wassers aus dem Bachbett erfolgt mittels eines Tirolerwehres, da der Bach aus dem Gebirge kommt und noch viel Geschiebe mitführt. Das entnommene Wasser wird in einen Sandfang geleitet um die restlichen Sedimente absinken zu lassen. Am Ende fällt es in eine Entnahmekammer, von wo es in die Druckleitung eingespeist wird. Diese besteht aus einem Stahlrohr mit einem Durchmesser von 800 mm und wird unter der Straße, die durch die Ortschaft führt, eingegraben verlegt bis sie das Krafthaus erreicht.

Mit einer Fallhöhe von 155 m und einem Ausbaudurchfluss von 0,8 m^3/s wird eine Peltonturbine gewählt. Nachdem das Wasser abgearbeitet wurde, wird es zurück ins Bachbett geleitet.

Die Kalkulation der Errichtungskosten geschieht auf österreichischem Preisniveau und beläuft sich auf etwa fünf Millionen Euro. Die Erlösrechnung wird auf etwa 400.000 Euro pro Jahr geschätzt.

Mit dem gewählten Ausbaudurchfluss und der vorhandenen Fallhöhe liefert die Ermittlung der elektrischen Arbeit etwa 5.100 MWh, womit zirka 1160 Haushalte mit Strom versorgt werden können.

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1. Introduction / Einleitung

Hydropower. It means more than turning on the lights and listening to the radio just because water is following gravity. Hydropower belongs to the so called renewable energy sources and helps – apart from reducing the dependence on fossil fuel – to lower CO_2-emissions. Not only in Austria but in the whole world this topic has gained more and more relevance in the recent years.

Although there is no international unified definition on small hydropower, most European countries accept the threshold of 10 megawatt of installed electrical power to separate it from large-scale hydropower. This limit was set by UNIPEDE (International union of producers and distributors of electricity) in 1982 (Müller, 1991).

After a study by the ESHA (European Small Hydropower Association) in the year 2004, a total capacity of 10,000 MW was installed at 14,000 small hydro power plants in the EU-15 countries. They provide an annual output of 40,000 GWh. In the new member states (EU-10) 2,800 facilities produce a total capacity of 820 MW and 2,300 GWh per year. Italy leads with 21%, followed by France (17%) and Spain (16%) the total capacity of small hydropower of the EU-25 countries. In the sector of renewable energies, hydropower contributes 80% of electrical energy and 19% of total electricity production (Kleinwasserkraft Österreich, 2008)

In Romania, hydropower contributes 30% of the national electricity generation capacity. The country has more than 400 large dams, and two of them belong to the largest hydropower plant along the Danube. Together with Serbia, Romania built up the Iron Gate Dams I and II at their mutual border. Here the river breaks through the Carpathian Mountains and forms the Djerdap gorge. At this point the average flow rate of the Danube is 5,500 m³/sec, and the river drops a total of over 34 metres. The capacity of the hydropower facilities is 2,532 MW, and annual production amounts up to 13,140 GWh. The produced energy is shared equally by these two countries (ICPDR, 2010).

The hydropower market in Romania is highly developed. As it is Romania's most important renewable energy source, a lot has been invested into hydropower in the last decade (REECO, 2009). The renewable energy sources target to be achieved is 11% of total energy in 2010, electricity production from renewable energy sources is set to 33% of total electricity consumption in 2010. The share of electricity out of renewable sources to total electricity consumption has shrunken from 31.3% in 1997 to 29.87% in 2004 (European Commission, 2007).

Thus, on the one hand, there is the wish to use water as a source for power production and on the other hand, water is an important natural resource with different groups of interests. The use of water for the production of goods, irrigation, drinking water supply, recreation and nature can lead to heavy conflicts. The conflict is aggravated by the fact that it is not available at the same amounts at any time. Being a result of rainfall, it is connected to seasonal and yearly variations.

The aim of this thesis is to set up a pre feasibility study, if the construction and operation of a small-scale hydropower plant along the Poarta, Romania, is an economically profitable investment. The costs of establishing an intake building, a settling basin and a penstock leading the water down and a powerhouse with electro technical equipment are compared to the profit that is gained by selling the energy and boosting the local electricity supply market.

Einleitung

Wasserkraft. Es bedeutet mehr als einfach nur das Licht aufzudrehen oder das Radio einzuschalten. Weil sie zu den sogenannten erneuerbaren Energien zählt, hilft sie CO_2-Emissionen zu verringern und die Abhängigkeit von fossilen Brennstoffen zu reduzieren. Nicht nur in Österreich sondern in der ganzen Welt ist dieses Thema zu besonderer Bedeutung aufgestiegen.

Obwohl es keine international einheitliche Definition für Kleinwasserkraft gibt, akzeptiert die Mehrzahl an Staaten die Grenze von 10 Megawatt installierter elektrischer Leistung um sie von Großwasserkraft zu trennen. Dieser Grenzwert wurde 1982 von der UNIPEDE, der Internationalen Vereinigung von Erzeugern und Verteilern der Elektrizität, festgelegt (Müller, 1991).

Einer Studie des Europäischen Kleinwasserkraft Vereins ESHA zufolge war im Jahr 2004 eine Gesamtleistung von 10.000 MW auf 14.000 Kleinwasserkraftwerke im Raum der EU-15 Staaten installiert. Diese produzieren eine jährliche Arbeit von 40.000 GWh. In den neuen Mitgliedsländern (EU-10) erzeugen 2.800 Anlagen eine Gesamtleistung von 820 MW und 2.300 GWh pro Jahr. Italien führt mit 21%, gefolgt von Frankreich mit 17% und Spanien (16%) die Liste der Gesamtkapazität der Kleinwasserkraftwerke in den EU-25 Ländern an. Im Sektor der erneuerbaren

Energien liefert Wasserkraft etwa 80% der elektrischen Energie und im Bereich der Gesamtenergieproduktion sind es 19% (Kleinwasserkraft Österreich, 2008).

In Rumänien steuert Wasserkraft etwa 30% der nationalen Elektrizitätsproduktion bei. Das Land hat mehr als 400 Dämme, und zwei davon gehören zum größten Wasserkraftwerk, das entlang der Donau steht. Zusammen mit Serbien hat Rumänien die beiden Dämme *Eisernes Tor I und II* an der gemeinsamen Grenze errichtet. Hier bricht der Fluss durch die Karpaten und formt die Djerdapschlucht. An diesem Punkt beträgt der Durchfluss der Donau 5.500 m^3/s und die Höhendifferenz fällt um mehr 34 Meter. Die Anlagen liefern 2.532 MW, was einen jährlichen Energiegewinn von 13.140 GWh bedeutet, der zu gleichen Teilen zwischen den beiden Ländern aufgeteilt wird (ICPDR, 2010).

Der Wasserkraftmarkt in Rumänien ist gut entwickelt und im letzten Jahrzehnt wurde auch viel in ihn investiert, nachdem Wasserkraft auch die wichtigste erneuerbare Ressource ist (REECO, 2009). Für das Jahr 2010 wurde von der Europäischen Kommission ein Energieziel aus erneuerbaren Rohstoffen von 11% an der Gesamtenergieproduktion und 33% am Elektrizitätsverbrauch festgesetzt. Der erreichte Elektrizitätsanteil sank von 31,3% im Jahr 1997 auf 29,87% im Jahr 2004 (Europäische Kommission, 2007).

Nun existiert einerseits der Wunsch Wasser als Quelle für Energieproduktion zu nützen. Andererseits ist Wasser ein wichtiger natürlicher Rohstoff, der von vielen Interessensgruppen begehrt wird. In der Güterproduktion, Bewässerung, Trinkwasserversorgung, als Erholungsgebiet und in der Natur finden sich sehr gegensätzliche Nutzungswünsche, die auch zu heftigen Konflikten führen können. Hinzu kommt noch, dass Wasser nicht jederzeit und unbegrenzt zur Verfügung steht. Durch die Abhängigkeit des Wasserdargebots vom Niederschlag ist es saisonalen und jährlichen Schwankungen unterworfen.

Das Ziel dieser Arbeit ist es eine Vorstudie entlang des Baches Poarta in Rumänien zu erstellen. Es soll ermittelt werden, ob es eine ökonomisch sinnvolle Investition in ein Kleinwasserkraftwerk geben kann. Den Errichtungskosten mit einem Fassungsbauwerk, einem Entsander, einer Druckleitung und einem Krafthaus mit elektrotechnischer Ausstattung wird der Erlös aus der Energieproduktion gegenübergestellt. Die Energie wird in die lokale Elektrizitätsversorgung eingespeist.

2. Description of the area

2.1 Geographic location

The region that is bounded by the mountain ring of the Southern and Western Carpathians and the Apuseni Mountains is called *Transylvania* or *Siebenbürgen*. The project area along the creek Poarta is located on the northern side of the Southern Carpathian and about 20 km in the southwest of the city Braşov, with its german name *Kronstadt*, as it belonged to the Austrian-Hungarian Empire until 1918.

Figure 1: Location of the project area (Wikipedia, 2009)

Catchment area:

The catchment area of the Poarta consists of two parts. The smaller one has an area of about 1.52 km² and is limited by Mt. Klinci (1375 m) in the southeast and by the other catchment area in the west. It is not relevant for the water amounts that are captured for producing energy, as its creek enters the Poarta only downstream.

The main part spreads out over an area of 11.76 km². On the eastside it is limited by the Bucegi Mountains with its summits at 2213.9 m and at 2277 m, followed by Mt. Gzura with 2288 m, which constitutes the southern border of the catchment area.

Extending westwards it is limited by Mt. Pântecele (1722 m) and Mt. Goza (1669 m). The size of catchment area is calculated from the intake area to the top of the mountains.

Intake area:

The water withdrawal is located shortly after the Poarta leaves the territory of Bucegi national park. At the height of 900 m the water is collected by a Tyrolean Weir. By this, there is no damming of the creek.

Penstock:

After passing a settling basin, the water enters the penstock. The pipe is buried and goes down on the right side of the riverbank following the road, which means using public property until it reaches road 73. On the last meters it is embedded on the right side of it and finally enters a fenced plateau, where it ends in the powerhouse. The total penstock will be dug in frost-free depth. The total length amounts to 4086 m.

Power house:

The power house is located on the south-east side of the bridge, which leads the main road 73 across the Poarta creek. It is situated on the slope which forms the left shore of the river. Here it has easy access to the electricity grid. Construction vehicles can stop at the area inside the fence and will not disturb public traffic. This is of high interest, as the road leads to the neighbouring Bran Castle which is a highly frequented touristic hotspot.

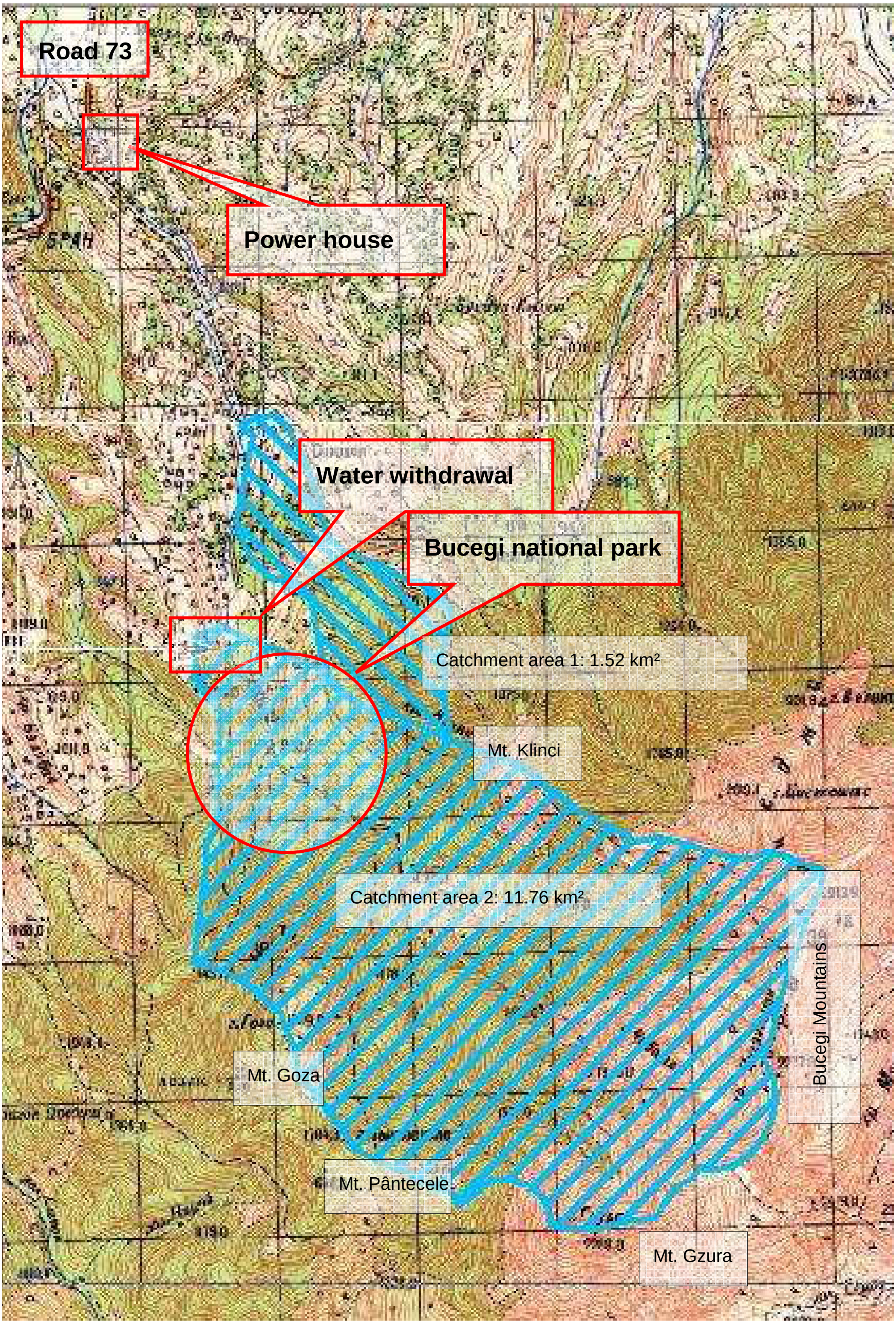

Figure 2: Catchment area and position of water withdrawal and power house (on basis of Generalhyj štab map, 1975)

Figure 3: Poarta River with position of Tyrolean Weir (red ellipse), looking upstream (own source)

Figure 4: Poarta River with position of Tyrolean Weir (red ellipse) looking upstream (own source)

Figure 5: Poarta River with position of Tyrolean Weir looking downstream (own source)

2.2 Political location

The project area belongs to the municipal Bran and the political district of Braşov.

2.3 Geology

Related to this thesis a geotechnical study was performed by S.C.Glob Consult Internațional S.R.L. with the following results.

From a geologic point of view, the studied area integrates itself in the orogeny of the Eastern Carpathians, from a geographic point of view in the corridor Rucar-Bran, belonging to the Southern Carpathians.

This lowland area corresponds to a vast tectonic depression oriented north-south, placed between the Bucegi Mountains in the east and Făgăraş Massive in the west. The last deposits took place at the end of the Cretaceous. Later, the uncovered relief passed into a new stage of erosion, parallel with the deepening of the valleys and the subside of the relief. In this corridor, the river Turcu and the other streams deepened their beds, because of the low level of the depression Tara Barsei. These streams fragmented the old cretaceous sediments, from which only a few parts remained. The surface deposits are the result of alteration, transport and deposit of the base rock. At the top they are formed by dusty sands with rare elements of gravel and deeper by bulky materials such as gravel with boulders and sand.

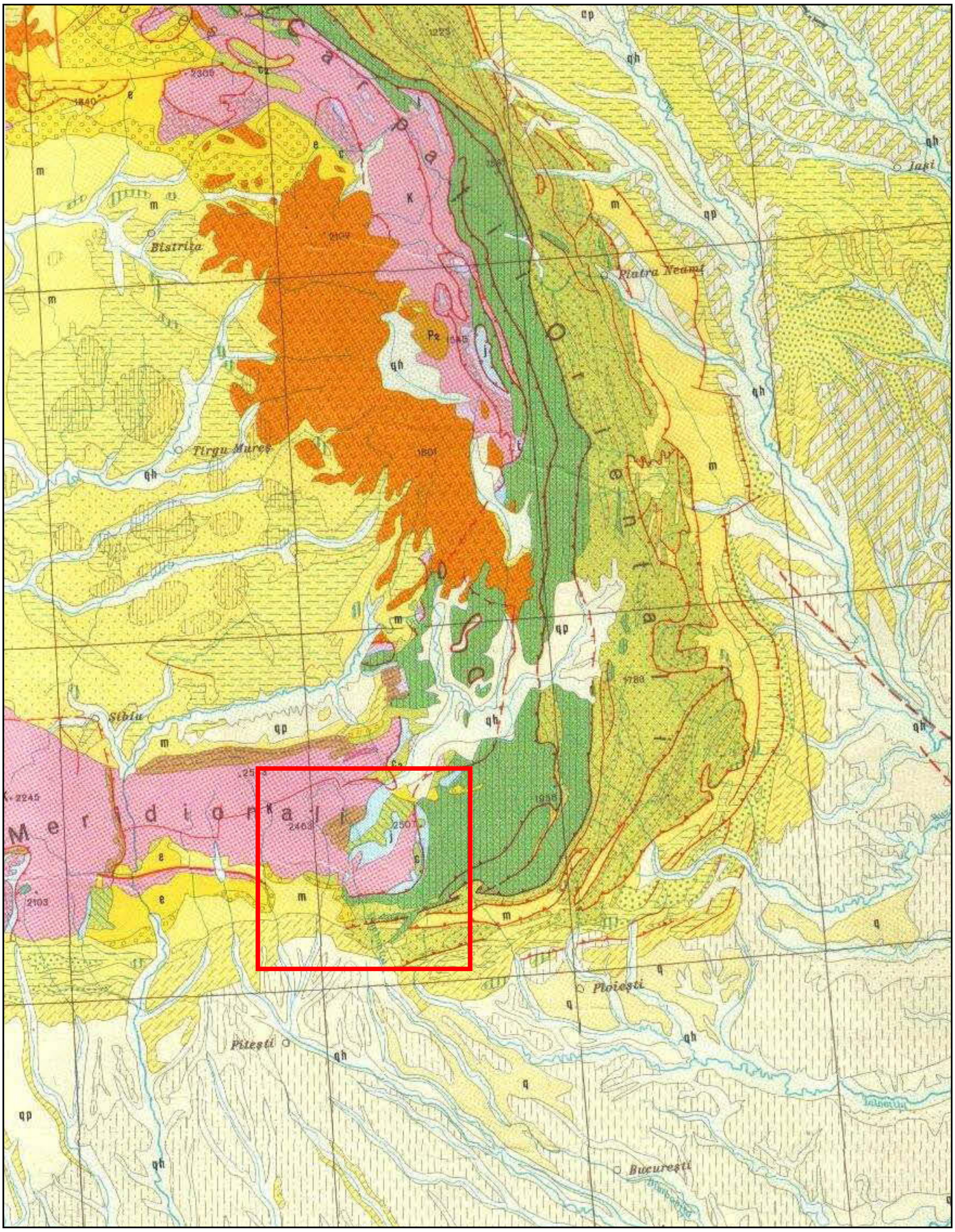

Figure 6: geological map showing the project area (BEV)

Era	Stone	Key	Era	Stone	Key
Tertiary (neogen)	Pont		Mesozoic (Cretaceous)	cretaceous undiff	c
	Sarmat			Gosau	
	Miozan	m		upper cretaceous-flysch	
	Eozan-flysch			Wildflysch	
Jurassic				lower cretaceous-flysch	
	Jurassic	j			
solidification stones and crystalline slade	old crystalline, undiff	K			

Figure 7: geological key for the project area (BEV, 1978)

2.3.1 Volume of the work done

For identifying the stratification S.C. Glob Consult carried out two dynamic penetrations and three surveys. The surveys were conducted on depths of 2 m. Direct observations in the field had been carried out on the path of the pipe, studying the abruptions encountered.

2.3.2 Materials and methods

The penetrations and surveys were conducted with the tool DM 30SA – Deep Drill. Furthermore, the other surveys done in the area were studied. The results were processed with the „WIN-DIN" program, offered by the tool manufacturer.

2.3.3 Terrain stratification

The stratification of the soil is:

- 0,00-0,30 vegetable earth
- 0,30-1,00 (1,10 m) brown dusty sand

Evaluating the terrain after TS standards regarding the hardness at manual digging:

Soil	Terrain
Vegetable earth	Light
Sandy dust, dusty sand, compacted	Middle

Soil	Terrain
vegetable earth, sand with gravel	
Gravel plus sand (till 150 mm)	Hard

2.3.4 Hydrologic-hydrogeologic data

The level of underground water is at depths greater than 2.00 meter.

From the known data, the underground waters do not have aggressive characteristics. For the present study underground waters were not collected.

At the depth of 1.00-1.30 the permeability coefficient is 10^{-4}m/sec.

2.3.5 Freezing depth

According to STAS 6054-77, a Romanian economical standard, the freezing depth is between 0.9 and 1.00 meter.

2.3.6 Conclusion

The vegetable earth and sand stratification mean light and middle terrain for digging the penstock. Furthermore the freezing depth lies not deep but between 0.9 and 1.0 m. Gravel and sand are stable materials for a high bearing strength. Combining these facts the conditions for digging and laying a pipe are good. In addition the groundwater level lies deeper than 2.00 m and should not interfere with the building process. The permeability coefficient of 10^{-4}m/sec means a very high permeability and a fast seep away of rain water.

3. Hydrology

3.1 Definition of terms

The Austrian norm ÖNORM B 2400 gives term definitions as follows:

Flow rate / Durchfluss Q: [m³/s] water volume that passes a profile during a determined time, divided by this time

Hydrograph / Ganglinie: graphic figure of the process from observed or calcutated values as function of time

Duration curve / Dauerlinie: graphic figure of timely equidistant, observed or calculated values in the order of their extent. In general the values are to be protracted with their extent decreasing along the timescale.

Flood / Hochwasser HQ: Water level or flow rate that exceeds a limit, which is to be defined.

Mean-flow conditions / Mittelwasser MQ: arithmetic mean of all daily mean values of water level or flow rate during a period, which is to be stated.

3.2 Rainfall

In the immediate catchment area, there are no rainfall registration devices. The station where the following data is used from is situated on the roof of the University of Braşov, about 25 km in the north-east.

The histogram of the monthly rainfall amount shows a maximum in the summer months and a minimum in winter time. For the time period of 1921 until 1970 the maximum is reached in June and reaches a value of 117 mm, the minimum is registered in February with 31.3 mm. The period between 1985 and 2004 shows the maximum with a value of 106.9 mm in June as well, whereas the minimum is recorded in January with 32.7 mm. It could not be evaluated, where the gap of 15 years results from.

Tab. 1: mean monthly rainfall amount values (Institutul Național de Hydrologie, 2004)

	1921-1970	1985-2004
	mm	mm
Jan	35,2	32,7
Feb	31,3	42,7
Mar	33,7	48,5
Apr	56,8	64,0
May	89,2	92,4
Jun	117,0	106,9
Jul	99,8	102,8
Aug	78,4	85,7
Sep	53,4	73,6
Oct	45,2	51,3
Nov	33,3	40,0
Dec	34,7	46,4
TOTAL	708,0	787,0

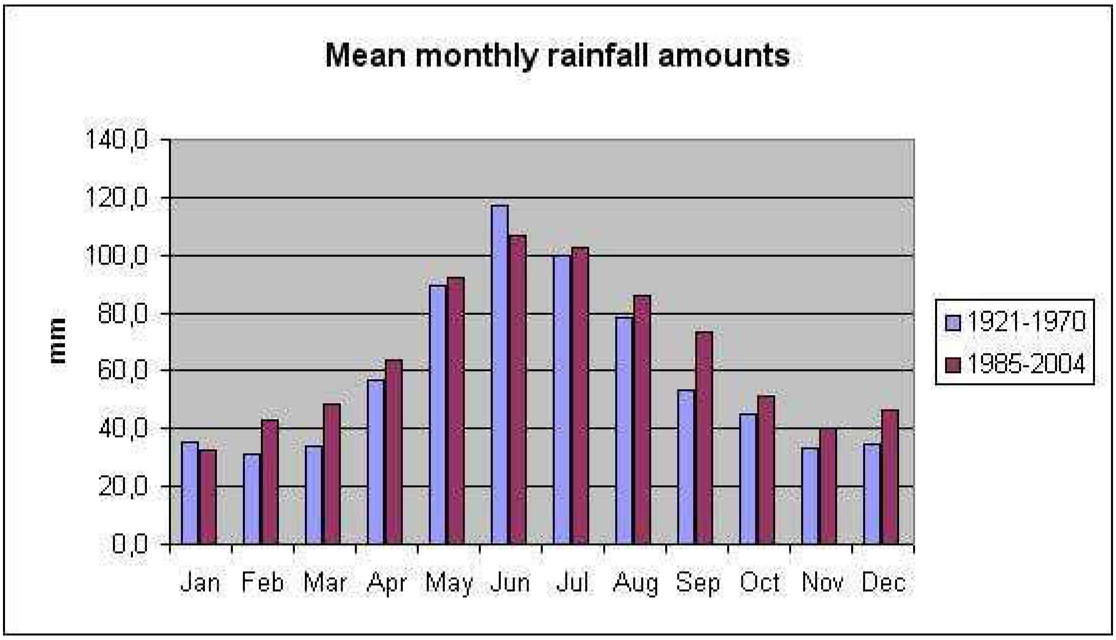

Figure 8: mean monthly rainfall amounts (Institutul Național de Hydrologie, 2004)

Comparing both years, the total rainfall amounts has risen in the second period of measurements. This could mean that rainfall will increase in the coming time, whereby the discharge could go up as well. In contradiction to this the numbers of the year 2008 indicate a reduction of rainfall amounts, where only 595 mm were registered.

Tab. 2: mean monthly rainfall amounts of the year 2008 (Institutul Național de Hydrologie, 2004)

	2008
	mm
Jan	25,8
Feb	26,0
Mar	29,9
Apr	46,2
Mai	72,1
Jun	88,5
Jul	89,2
Aug	72,6
Sept	49,8
Oct	34,4
Nov	31,6
Dec	28,9
Total	595,0

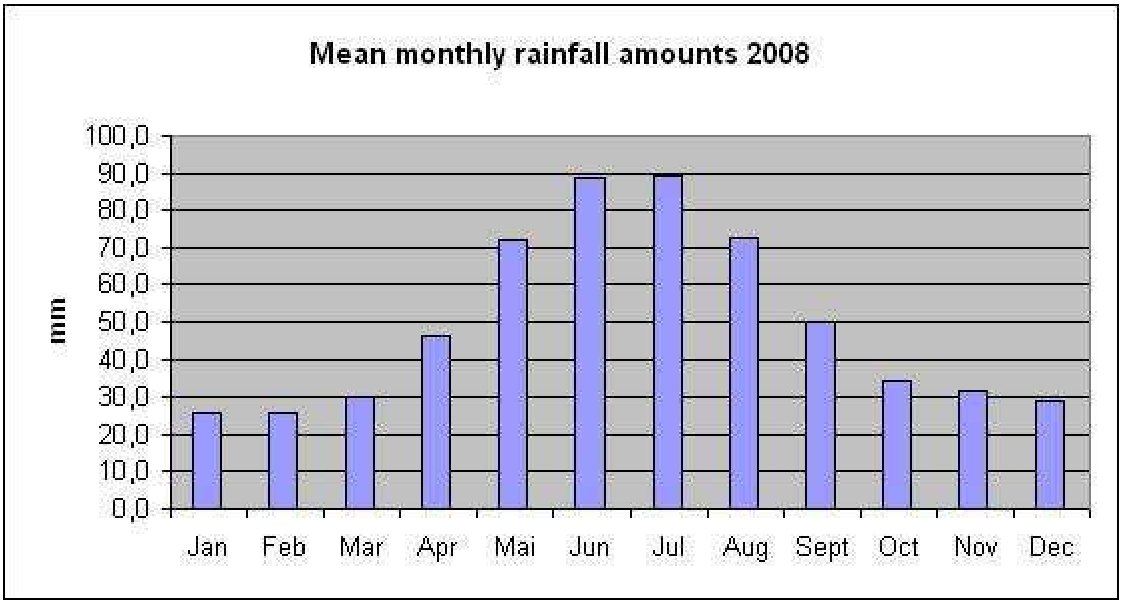

Figure 9: mean monthly rainfall amounts of the year 2008 (Institutul Național de Hydrologie, 2004)

If we compare these three data sets, it is easy to believe, that the year 2008 was an extra ordinary dry year. The conclusion for the project is to keep a middle way as rogue results can happen and nothing indicates a higher trend.

3.3 Measurement and flow meter calculation

In a section with least possible turbulence a metal pipe with a fixed tape measure was installed and surveyed once a day. In the very same area a cross section was taken. Using a flow meter, the velocity of the water pouring towards the instrument was recorded and evaluated. Together with the knowledge of the cross section area, the flow rate was calculated.

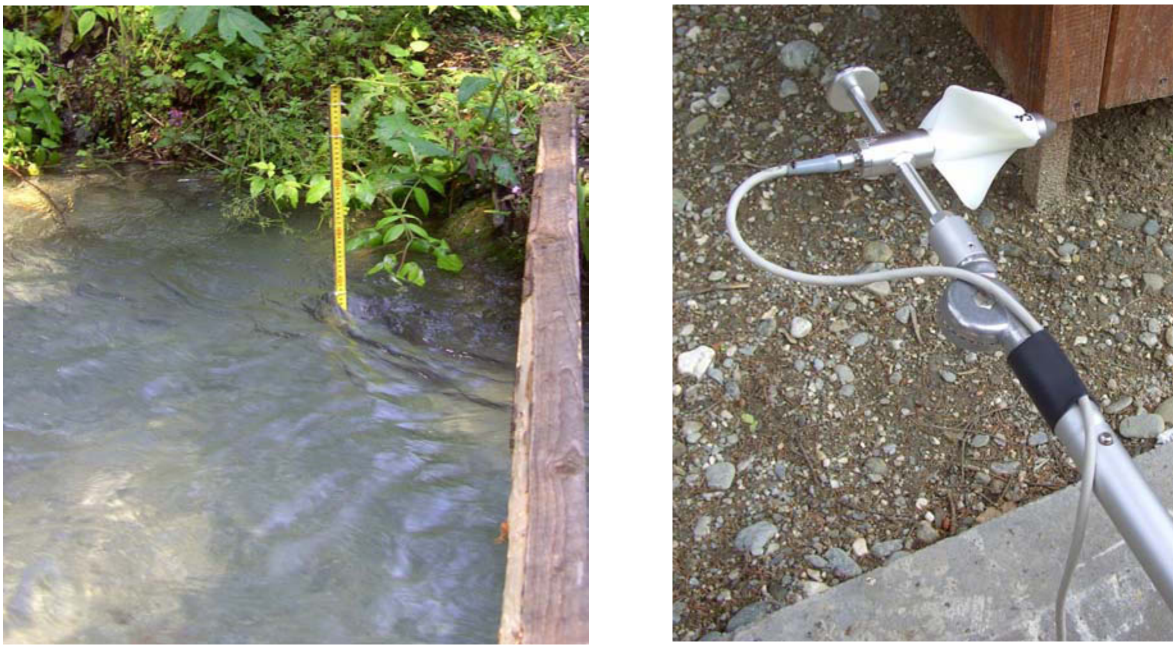

Figure 10: installed measuring device (left) and flow meter (right), (own source)

Figure 11: Poarta river looking downstream to the calmed flow section, where measurements were taken (red circle) (own source)

Tab. 3: waterdepth and corresponding flow rates (own source)

	h [m]	Q [m³/s]
july 3rd 2009	0,53	0,85
july 7th 2009	0,55	0,89
july 10th 2009	0,55	0,92

Normally these measurements are shown in a graph called lotic water which shows the connection between waterdepth and flow rates. In this case, there are far too few data sets to produce such a graph as there is no data in times of low or high channel flow, such as winter or spring time.

The measurements taken in july 2009 took place just before an extraordinary flood happened. After that, one of the bridges leading over the Poarta was gone. It was only some days later, that it was possible to reach the place of the installed measuring device again, which has vanished as well. According to inhabitants of the village, this event overtopped everything they had encountered yet. For some of them that meant a period of over 40 years.

Due to this event it is hard to give an interpretation of the data taken.

water:	**Poarta, Romania**	flowmeter-Nr:		Team:
river-km:		flowmeter equation:		
E:		a= 0,031	b= 0,156	measuring position number:
Date:	**July 3rd**	measuring time: 50 sec		measuring position name:
width: (m)	**2,8**			
Max. depth (m)	**0,53**			

measuring perpendicular:		**1**			**2**			**3**			**4**			**5**			**6**		
distance to left shore: (m)		0			0,2			0,4			0,6			0,8			1		
waterdepth: (m)	distance to next point (m)	0	0,2		0,12	0,2		0,27	0,2		0,33	0,2		0,43	0,2		0,43	0,2	
dist to bottom(60%):	velocity	0,00		0,00	0,07		0,28	0,16		0,48	0,20		0,56	0,26		0,69	0,26		0,65
area cross section: (m²)				0,012			0,039			0,060			0,076			0,086			0,089
flow rate: (m³/s)		0,000			0,011			0,029			0,043			0,059			0,058		
																	Q=	**0,20**	**m³/s**
measuring perpendicular:		**7**			**8**			**9**			**10**			**11**			**12**		
distance to left shore: (m)		1,2			1,4			1,6			1,8			2			2,2		
waterdepth: (m)	distance to next point (m)	0,46	0,2		0,48	0,2		0,48	0,2		0,49	0,2		0,51	0,2		0,52	0,2	
dist to bottom(60%):	velocity	0,28		0,86	0,29		0,91	0,29		0,80	0,29		0,85	0,31		0,90	0,31		0,95
area cross section: (m²)				0,094			0,096			0,097			0,100			0,103			0,105
flow rate: (m³/s)		0,081			0,087			0,078			0,085			0,093			0,100		
																	Q=	**0,52**	**m³/s**
measuring perpendicular:		**13**			**14**			**15**											
distance to left shore: (m)		2,4			2,6			2,8											
waterdepth: (m)	distance to next point (m)	0,53	0,2		0,52	0,2		0	0,2										
dist to bottom(60%):	velocity	0,32		0,91	0,31		0,60	0,00		0,00									
area cross section: (m²)				0,105			0,052										**Q=**	**0,13**	**m³/s**
flow rate: (m³/s)		0,096			0,031			0,000											
																	Qt=	**0,85**	**m³/s**

Figure 12: flow meter calculation sheet for July 3rd (own source)

water:	**Poarta, Romania**				flowmeter-Nr:						Team:									
river-km:					flowmeter equation:															
E:					a=	0,031	b=	0,156	measuring position number:											
Date:	**July 7th**					measuring time	50	sec	measuring position name:											
width: (m)	**2,8**																			
Max. depth (m)	**0,55**																			
measuring perpendicular:			**1**			**2**			**3**			**4**			**5**			**6**		
distance to left shore: (m)			0			0,2			0,4			0,6			0,8			1		
waterdepth: (m)	distance to next point (m)		0	0,2		0,14	0,2		0,29	0,2		0,35	0,2		0,45	0,2		0,45	0,2	
dist to bottom(60%):		velocity	0,00		0,00	0,08		0,26	0,17		0,54	0,21		0,60	0,27		0,61	0,27		0,77
area cross section: (m²)					0,014			0,043			0,064			0,080			0,090			0,093
flow rate: (m³/s)			0,000			0,011			0,035			0,048			0,055			0,072		
																		Q=	**0,22**	**m³\s**
measuring perpendicular:			**7**			**8**			**9**			**10**			**11**			**12**		
distance to left shore: (m)			1,2			1,4			1,6			1,8			2			2,2		
waterdepth: (m)	distance to next point (m)		0,48	0,2		0,50	0,2		0,50	0,2		0,51	0,2		0,53	0,2		0,54	0,2	
dist to bottom(60%):		velocity	0,29		0,91	0,30		0,93	0,30		0,80	0,31		0,84	0,32		0,88	0,32		0,94
area cross section: (m²)					0,098			0,100			0,101			0,104			0,107			0,109
flow rate: (m³/s)			0,089			0,093			0,081			0,087			0,094			0,102		
																		Q=	**0,55**	**m³\s**
measuring perpendicular:			**13**			**14**			**15**											
distance to left shore: (m)			2,4			2,6			2,8											
waterdepth: (m)	distance to next point (m)		0,55	0,2		0,54	0,2		0	0,2										
dist to bottom(60%):		velocity	0,33		0,85	0,32		0,61	0,00		0,00									
area cross section: (m²)					0,109			0,054										**Q=**	**0,13**	**m³\s**
flow rate: (m³/s)			0,093			0,033			0,000											
																		Qt=	**0,89**	**m³\s**

Figure 13: flow meter calculation sheet for July 7th (own source)

water:	**Poarta, Romania**				flowmeter-Nr:						Team:									
river-km:					flowmeter equation:															
E:					a=	0,031	b=	0,156	measuring position number:											
Date:	**July 10th**				measuring time	50	sec		measuring position name:											
width: (m)	**2,8**																			
Max. depth (m)	**0,55**																			
measuring perpendicular:			**1**			**2**			**3**			**4**			**5**			**6**		
distance to left shore: (m)			0			0,2			0,4			0,6			0,8			1		
waterdepth: (m)	distance to next point (m)		0	0,2		0,14	0,2		0,29	0,2		0,35	0,2		0,45	0,2		0,45	0,2	
dist to bottom(60%):		velocity	0,00		0,00	0,08		0,41	0,17		0,57	0,21		0,71	0,27		0,66	0,27		0,82
area cross section: (m^2)					0,014			0,043			0,064			0,080			0,090			0,093
flow rate: (m^3/s)			0,000			0,018			0,036			0,057			0,059			0,076		
																		Q=	**0,25**	**m^3\s**
measuring perpendicular:			**7**			**8**			**9**			**10**			**11**			**12**		
distance to left shore: (m)			1,2			1,4			1,6			1,8			2			2,2		
waterdepth: (m)	distance to next point (m)		0,48	0,2		0,50	0,2		0,50	0,2		0,51	0,2		0,53	0,2		0,54	0,2	
dist to bottom(60%):		velocity	0,29		0,89	0,30		0,89	0,30		0,86	0,31		0,91	0,32		0,90	0,32		0,85
area cross section: (m^2)					0,098			0,100			0,101			0,104			0,107			0,109
flow rate: (m^3/s)			0,087			0,089			0,087			0,095			0,096			0,093		
																		Q=	**0,55**	**m^3\s**
measuring perpendicular:			**13**			**14**			**15**											
distance to left shore: (m)			2,4			2,6			2,8											
waterdepth: (m)	distance to next point (m)		0,55	0,2		0,54	0,2		0	0,2										
dist to bottom(60%):		velocity	0,33		0,83	0,32		0,76	0,00		0,00									
area cross section: (m^2)					0,109			0,054										**Q=**	**0,13**	**m^3\s**
flow rate: (m^3/s)			0,090			0,041			0,000											
																		Qtot=	**0,92**	**m^3\s**

Figure 14: flow meter caluculation sheet for July 10th (own source)

3.4 Duration curve

Sorting the values of the hydrograph by the number of the days they occur forms the duration curve. If the values are decreasing, the curve is called duration curve of exceedance. This graph shows on how many days a year a special value appeared (Strobl and Zunic, 2006).

With its help the output of a power plant can be calculated.

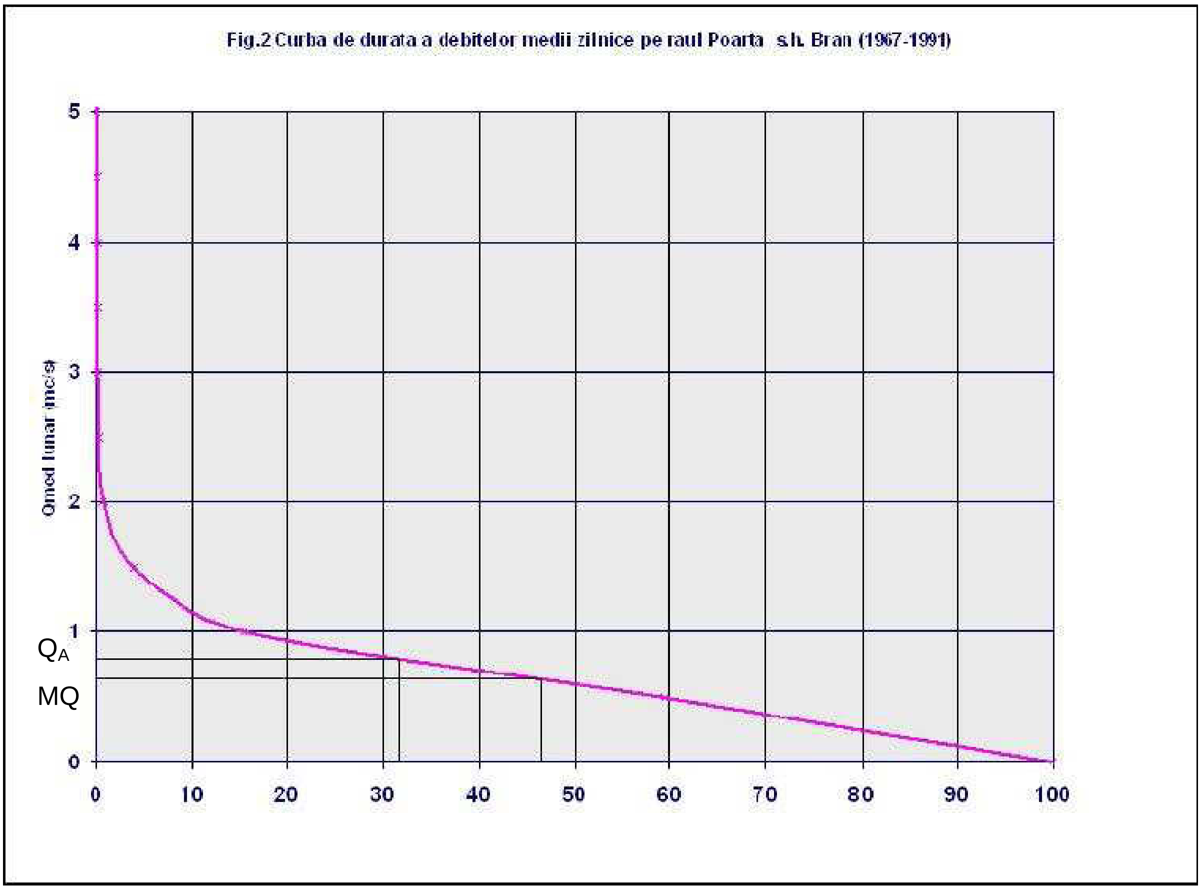

Figure 15: Duration curve of Poarta River with integrated design flow and MQ (Institutul Național de Hidrologie, 2004)

The horizontal axis of this picture is organized in percent. 365 days a year mean 100%, the vertical axis measures the daily flow in m³/s.

The definition of the design flow is the result of an optimisation process as the energy production is coupled to the flow rate. At the point where the additional growth of the function decreases, the optimal point for choosing the design flow can be found. In the following graph the standard capacity of increasing flow rates are applied. It shows the development of the energy yield. In the range between 0.8 and 0.9 m³/s the gradient becomes smaller. For this reason the design flow rate is chosen to be 0.8 m³/s.

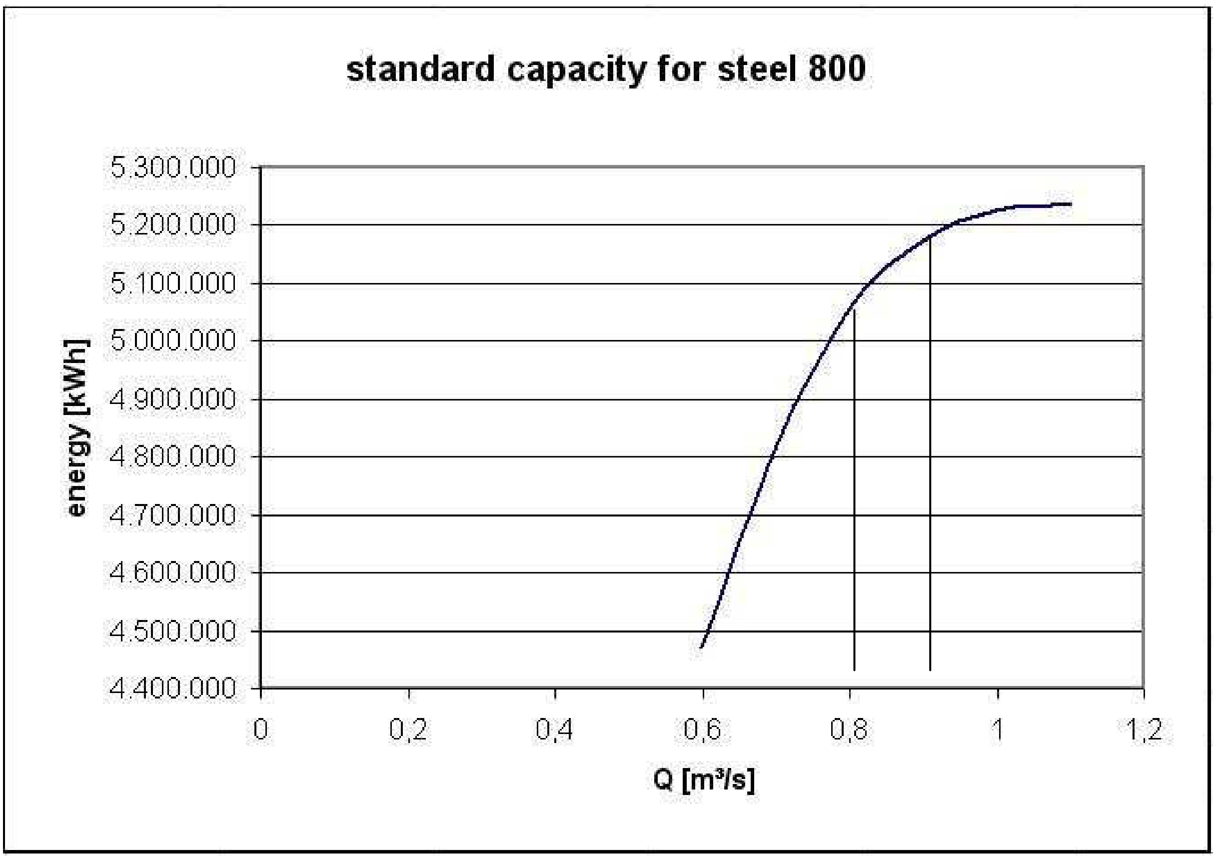

Figure 16: standard capacity for steel pipes with diameter 800 (own source)

The design flow value of 0.8 m³/s is reached on 114.8 days in a regular year, which means about 31.5%.

The average water is unknown. Therefore it is calculated as the middle value of the whole year and is done as follows:

The area below the duration curve is 5,621,695 litre per year. This value is taken out of the AutoCAD-file. As the scale is unidentified, a ratio between this value and a defined area of ten days is calculated.

area 10d	is	240.000	l/10d
area 10d	shall	864.000.000	l/10d

$$Vol_{shall} = \frac{area10d_{shall}}{area10d_{is}} \cdot Vol_{is} = 20{,}238{,}103{,}836 l / a$$

After dividing this by 31,536,000 s/a the average water results in 641.75 l/s or 0.64 m³/s. It is reached on 170 days in a regular year and means a percentage of about 46%.

3.5 Residual water situation

Vischer and Huber (2002) mention requirements the determination of the so-called instream flow, which stays in the original riverbed needs to consider. This involves especially the guarantee of a water supply for water intakes of residents downstream (water supply, irrigation, powerplants), debris transportation (solid and swimming material, ice), sufficient thinning of induced waste water (water protection), the neighbouring groundwater sources (drinking water supply, agriculture) and the protection of river landscape (recreation, maintenance) as well as waterways for shipping and fishery.

Therefore, however, there are no unified calculation methods. From the point of the energy economy a minimum is targeted, as a committed donation reduces the water intake and hereby the power production. Hence the production costs rise. From ecological perception a maximum of remaining water is desirable.

Literature mentions different calculation procedures to obtain a suitable dotation amount and classifies them into groups with the base on hydrographic-statistic data, river-hydraulic data and methods for multi-criteria decision making considering ecological parameters (Ploner, 1993).

The Republic of Austria released the ordinance for ecologic quality aims to give standards on the discharge of residual water. With this ordinance it follows the guideline of the European Union to keep at least a good state for flowing waters (Qualitätszielverordnung – Ökologie Oberflächengewässer, 2010).

Concerning residual water the following standard values are defined in §13 QZV Ökologie OG, 2010:

- For waters with a medium flow smaller than one cubic meter per second to be greater than or equal half the natural middle yearly low water value ($NQ_{\text{residual water}} \geq \frac{1}{2}$ MJNQt)
- For waters with fish habitat there also need to be minimum water depths and flow velocity which can be found in attachment G

Alas there are no data for middle low waters and natural middle yearly low water values. In this case older methods for calculating the residual water have been used (Frauenfeld, 1997):

Lanser: 5 – 10% of MQ

MQ [l/s]	5% MQ	10% MQ
642,0	32,1	64,2

Jäger: 15% of seasonal MQ, to ensure a minimum requirement for fishery

	MQ-summer [l/s]	MQ-winter [l/s]
	876,0	308,0
15%	131,4	46,2

Alarm limit value: uses not less than 20% of Q-300 to keep up an existence minimum for ecological functions

Q-300 [l/s]	20% Q-300
217,0	43,4

Mathey (CH): calculates a minimum amount for fishery by accepting losses deliberately

$$Q_{R_{\min}} = \frac{15 \cdot Q_{300}}{(\ln Q_{300})^2}$$

Q-300 [l/s]	QR-min
217,0	112,5

$$Q_{R_{\min}} = \frac{15 \cdot Q_{347}}{(\ln Q_{347})^2}$$

Q-347 [l/s]	QR-min
62,0	54,6

Büttiker: refers to waters with salmonidae, and uses Q-347 as a approximation to a natural NQ-situation

Q-347 [l/s]
62,0

Under-usage amount: amount which is deceeded 4 days in a norm year: Q-361

Q-361 [l/s]
13,6

NNQ: the smallest observed flow amount

NNQ [l/s]
0,0

“Tirol”: constant amount as a function to the intake area

$$Q_R = 2 \div 3 \frac{l}{s} \cdot km^2$$

km²	2*km²	3*km²
11,8	23,52	35,28
QRmin [l/s]	23,52	35,28

Kärntner Institut für Seenforschung (Carinthian Institute for Limnologic Studies): 10 – 15% of MQ

	MQ-summer [l/s]	MQ-winter [l/s]
	876,0	308,0
10% MQ	87,6	30,8
15% MQ	131,4	46,2

As there were no fish spotted, when the river was studied in the summer of 2009, the emphasis is laid on calculation methods, which do not support fishery reasons. These are Lanser, alarm limit value, under-usage amount, NNQ, Tirol and the manner of the Carinthian Institute. This results in the mean value of 35.6 l/s and is rounded up to 40 l/s. The dotation will be scaled in summer and winter season as follows:

MQ - Dotation [l/s]	MQ-summer [l/s]	MQ-winter [l/s]
40,0	50,0	30,0

4. Concept for a powerplant at Poarta river

The project for this thesis is designed as a diversion-type plant, so the actual powerhouse is outside the riverbed, somewhere along the course of a canal, into which the water is diverted. This water is taken from the river at a weir, is then led through a pipeline to the power station, and transferred back to the riverbed at the end of the tailrace. As done before the definition of the instream flow left in the original riverbed is set according to ecological and economic criteria.

The plant handles the water that is actually provided, as there is no space for a reservoir. Hence it contributes to cover the base load like a run-of-river power station. An advantage of the diversion-type plant is that it can be set up on dry land what is easier for constructional reasons.

4.1 Water withdrawal

Mosonyi (1991) mentions the following requirements a weir and the intake unit have to meet:

- safe release of floods
- low-loss entrance of the power flow
- preventing bedload intrusion into the canal
- deflecting and flushing of bedload accumulating in front of the weir
- protecting the canal from floating debris and ice.

As a result, the intake of the hydroelectric power station consists of a so-called Tyrolean weir, a spillway and a settling basin, which leads into an intake basin before it joins the penstock.

4.1.1 Tyrolean weir

The type of the weir has been developed by the *Tiroler Wasserkraftwerke AG (TIWAG)*, Austria, and shows a special design of a vertical-diversion intake. It is often used in mountain streams, where larger bed-load particles are being transported. The headwater passes the concrete fixed weir body and overflows a horizontal or slightly inclined rake, which lies at the bedlevel. From there it drops into a cross-flume and is conveyed into the settling basin.

At higher flow conditions the surplus water and the transported bed-load run across the rake into the tailwater. Cleaning the rake of swimming items or debris should be done automatically, by a rake inclination that is high enough.

4.1.1.1 Calculation

breadth creek [m]	5,2
breadth weir [m]	3,5
$Q_{turbine}$ [m³/s]	0,8
$Q_{weir} = Q_{turb}$ +20% security [m³/s]	0,96
rake inclination φ [°]	20
rake bar thickness [cm]	2
rake clearence [cm]	4
coefficient for flow rate through rake μ [/]	0,9
$q_0 = Q_{weir} / b_{weir}$ [m³/sm]	0,27

The minimum length of the rake is calculated as follows (Rössert, 1999 and 2000):

$$l_{\min} = 2{,}561 \cdot \frac{q_0}{\lambda \cdot \sqrt{h_0}} [m]$$

$$\lambda = \frac{A'}{A} \cdot \mu \cdot \cos\varphi \cdot \sqrt{2g \cdot \cos\varphi} = 0{,}33 \cdot 0{,}9 \cdot \cos 20 \cdot \sqrt{2g \cdot \cos 20} = 2{,}42$$

$$h_0 = \kappa \cdot h_{gr} [m]$$

$$h_{gr} = \sqrt[3]{\frac{q_0{}^2}{g}} = \sqrt[3]{\frac{0{,}27^2}{9{,}81}} = 0{,}2m$$

φ	0°	2°	4°	6°	8°	10°
κ	1,000	0,980	0,961	0,944	0,927	0,910

φ	12°	14°	16°	18°	20°	22°
κ	0,894	0,879	0,865	0,851	0,837	0,825

$$h_0 = 0{,}837 \cdot 0{,}2 = 0{,}17m$$

$$l_{\min} = 0{,}71m$$

$$l\min_{chosen} = 0{,}8m$$

with: l_{min} [m]: minimum length of the rake

A' [m²]: bore rake area

A [m²]: total rake area

h_{gr} [m]: critical depth

κ [/]: coefficient depending on rake inclination

h_0 [m]: water depth at upper rake end

The site of the Tyrolean weir is chosen, where a natural step is found in the creek. In this manner, the natural fact can be optimally used.

4.1.2 Crossflume

This concrete channel directs the water from the weir to the settling basin. Its dimensions refer to the water amount of the Tyrolean weir.

4.1.2.1 Calculation

Q [m³/s]	0,96
B [m]	0,80
L [m]	3,50
T [m]	1,25
R [m]	0,30
I [/]	0,001
k_{str} [$m^{1/3}$/s]	70

With these factors the flow velocity will be:

$$v_{str} = k_{str} \cdot R^{2/3} \cdot I^{1/2} = 1{,}00 m/s$$

Combining the flow velocity with the upper factors the transportable flow rate will be sufficient:

$$Q = A \cdot k_{str} \cdot R^{2/3} \cdot I^{1/2} = 1{,}00 m^3/s$$

With : Q [m³/s]: flow rate coming from the weir

B [m]: width of channel

L [m]: length of channel

T [m]: depth of channel

R [m]: hydraulic radius: $R(m) = \frac{A(m^2)}{U(m)}$ (Bretschneider et al., 1993)

I [/]: slope

k_{str} [$m^{1/3}$/s]: Strickler-coefficient (Bretschneider et al, 1993)

v [m/s]: flow velocity

Offering a freeboard with 0.15 m the maximum possible flow rate rises to:

$$Q_{max} = 1.17 m^3 / s$$

4.1.3 Spillway

Joined to the weir there is a spillway which is designed as a slide gate. It dispenses the compelled water amount that needs to stay in the river bed to keep up ecological functions and an optically responding view. Another purpose is to help bed-load run off to the tail water in case of higher flow conditions. Then the gate is opened up to a higher extent. In case of flood waters it needs to be able to let water run off without being a barrier.

Spillways are comprised of wooden planks edged in U-profiles, where pine has proved itself as very good plank material. The boards are elevated or lowered by hand, motorized or hydraulically to dose the residual water at the bed level. Although the planks are moved by an electric motor most of the time, a manual drive should be there as a security in times of power blackouts. At headwaters, a fixed gauge board needs to be applied (König 2005).

4.2 Settling basin

The settling basin is a structure where particles carried along are withdrawn from the water and can sediment. This ensures a longer lifetime of the turbine and the pipe. By enlarging the water surface the current velocity is reduced and the sand particles settle to the bottom. This can happen if settling time equals or even deceeds transit time. As Mosonyi (1991) mentions even grains as small as 0.25 mm may seriously damage the turbines. So particle sizes of 0.1 – 0.2 mm and even smaller should be removed. The suspended sediment is generally of mixed gradation including colloidal grains smaller than 0.002 mm up to grains of the gravel fraction with maximum 40 mm. This is the upper limit, as the tyrolean weir has a rake clearance of 40 mm and holds back larger fractions.

The dimensioning of the length of the settling basin calculates with the design flow and the degree of efficiency wanted. Rules of layout can be found by Giesecke and Mosonyi (2005):

$$h/B_s \approx 1{,}25/1{,}0$$
$$B_s < L_s/8$$

Furthermore Vischer and Huber (2002) give layout rules for the critical velocity:

$$v < v_{crit}$$
$$v_{crit} = 13 \cdot R^{1/6} \cdot d^{1/2}$$

The bottom plate of the basin is shaped with a deeper lying flume in the middle and declining soles on each side leading into that flume. A spillway is situated at the end to flush settled particles back into the riverbed. The cleared water falls over an edge into a basin where the entry into the penstock is located. If more water is taken than the turbine can handle the chamber will fill up until a sensor opens another spillway to let the spare water run off into the riverbed again.

4.2.1 Calculation

Foundation for the assessment of the sand filter is the determination of type and amount of the transported grains. This was not investigated and needs to be done in case of following the project. As a characteristic particle sand with d=0.2 mm and a specific gravitiy of ρ=2.56 kg/dm³ was chosen. So the settling velocity is v_S=0.023 m/s (Institut für Siedlungwasserbau, Industriewasserwirtschaft und Gewässerschutz, 2008)

The length of the settlling basin is calculated after Giesecke and Mosonyi (2005):

$$L_s \cdot v_s = h \cdot v = \frac{Q}{B_s}$$

Q [m³/s]	0,96
v_S [m/s]	0,023

By assuming that L_S=21.0 m, B_S can be calculated:

$$B_s = \frac{Q}{L_s \cdot v_s} = 2{,}00m$$

From this follows that with an assumed flow velocity of v = 0.2 m/s the depth will be:

$$h = \frac{L_s \cdot v_s}{v} = 2{,}40m$$

v_{crit} is calculated with 0.25 m/s and is higher than the flow velocity with 0.2 m/s.

So the chosen dimensions are:

L = 21.0 m

B = 2.0 m

h = 2.4 m

Along the side, which is directed to the riverbed, relief overflows are set out to let the surplus water leave the basin. Hence the basin won't come under pressure, which would bring turbulence and a reduction of the effectiveness.

4.3 Intake chamber

The intake chamber collects the water coming from the settling basin. Its dimensions are 2.0 x 4.0 x 3.9 m and can approximately hold 31 m^3. Over an overflow the water falls into the chamber. This overflow can transport 1.04 m^3/s and is hereby able to manage the amount taken in and transported by the previous buildings.

4.4 Penstock

Basically the aim of a works water line is to create a shortest possible connection between intake and powerhouse. This is the reason why in many cases not unpressurised pipes but entirely filled and pressurised ducts are used. So, the considerably higher energy losses due to friction can be kept low. The penstock usually aligns with the terrain and therefore looks bended in the longitudinal section. In the ground plan the pipe is laid as straight as possible, but changes in direction can not always be prevented by the reason of topography, building ground and development. It can be placed above or below ground. Resulting from large temperature fluctuation or varying works water temperature there can be vast longitudinal tensions in the pipes laid aboveground.

As building material steel, cast iron, concrete, plastics or even wood come into question, whereby for hydropower plants steel pipes are used often. Alternatives to the old fibre cement are asbestos-free cement or glass-reinforced plastic and can be found by plants with smaller flow rate or lower pressure.

Concrete basements serve as support for the penstock, which are formed like simple sockets and which allow small movements, or as fixed-points that anchor the pipeline at single positions.

To keep the costs of redeeming private property as low as possible, the penstock is laid beneath the road wherever it is useful. Nevertheless precedence is given to a straight duct. With a head of 155 m and a length of 4086 m a request was raised to an Austrian company and delivered the following offers (ALPE, 2010):

- DN 800 (813 x 7.1 mm) produced out of material L235 with a specific weight of 141 kg/m. It is delivered in pieces by 12 meter each with chamfered ends. The laying will happen by pushing-in.
- DN 800 (813 x 7.1 mm) produced out of material L235 with a specific weight of 202 kg/m. It is delivered in pieces by 12 meters each with one end right-angled, one end with push-in-welding-socket. The laying will happen by welding.
- DN 900 (914 x 8.0 mm) produced out of material L235 with a specific weight of 179 kg/m. Delivery length is 12 meter with chamfered ends. The laying will happen by pushing-in.
- DN 900 (914 x 8.0 mm) produced out of material L235 with a specific weight of 259 kg/m. It is delivered in pieces by 12 meters each with one end right-angled, one end with push-in-welding-socket. The laying will happen by welding.

The same request was raised to HOBAS Rohre GmbH (2008) to receive an offer for a glass-reinforced plastic pipe with the following result:

- DN 800 (D outside 820 mm), pressure stage PN 16, nominal rigidity SN 10000, coupling on one side. It is delivered in pieces by 6 meters each. The laying will happen by pushing-in.
- DN 900 (D outside 924 mm), pressure stage PN 16, nominal rigidity SN 10000, coupling on one side. It is delivered in pieces by 6 meters each. The laying will happen by pushing-in.

4.4.1 Friction loss calculation for GRP DN 800

Q]m³/s]	0,8
d [m]	0,8
l [m]	4086
ν [m²/s]	1,24E-06
k [m]	3,00E-05

$$A = \frac{d^2 \cdot \pi}{4} = 0{,}5m^2$$

$$v = \frac{Q}{A} = 1{,}6 m/s$$

$$\text{Re} = \frac{v \cdot d}{\nu} = 1{,}03 \cdot 10^6$$

$$\lambda_{rough} = \frac{1}{(2 \cdot \lg(d/k) + 1{,}14)^2} = 0{,}0100$$

$$\lambda_{transient\_area} = \frac{1}{\left[-2 \cdot \lg(\frac{k/d}{3{,}71} + \frac{2{,}51}{\text{Re} \cdot \sqrt{\lambda}})\right]^2} = 0{,}0123$$

Control for $\lambda =$ $\text{Re} \cdot \sqrt{\lambda_{rough}} \cdot k/d = 4$

< 200…transient area

> 200…rough area

$$h_v = \lambda \cdot \frac{l \cdot v^2}{d \cdot 2g} = 8{,}14m$$

4.4.2 Friction loss calculation for GRP DN 900

Q]m³/s]	0,8
d [m]	0,9
l [m]	4086
ν [m²/s]	1,24E-06
k [m]	3,00E-05

$$A = \frac{d^2 \cdot \pi}{4} = 0{,}64m^2$$

$$v = \frac{Q}{A} = 1{,}26 m/s$$

$$\text{Re} = \frac{v \cdot d}{\nu} = 9{,}13 \cdot 10^5$$

$$\lambda_{rough} = \frac{1}{(2 \cdot \lg(d/k) + 1{,}14)^2} = 0{,}0098$$

$$\lambda_{transient\_area} = \frac{1}{\left[-2 \cdot \lg(\frac{k/d}{3{,}71} + \frac{2{,}51}{\text{Re} \cdot \sqrt{\lambda}})\right]^2} = 0{,}0125$$

Control for $\lambda =$ $\text{Re} \cdot \sqrt{\lambda_{rough}} \cdot k/d = 3$

< 200…transient area

> 200…rough area

$$h_v = \lambda \cdot \frac{l \cdot v^2}{d \cdot 2g} = 4{,}56m$$

4.4.3 Friction loss calculation for steel DN 800

Q]m³/s]	0,8
d [m]	0,8
l [m]	4086
ν [m²/s]	1,24E-06
k [m]	5,00E-05

$$A = \frac{d^2 \cdot \pi}{4} = 0{,}5m^2$$

$$v = \frac{Q}{A} = 1{,}6m/s$$

$$\mathrm{Re} = \frac{v \cdot d}{\nu} = 1{,}03 \cdot 10^6$$

$$\lambda_{rough} = \frac{1}{(2 \cdot \lg(d/k) + 1{,}14)^2} = 0{,}0110$$

$$\lambda_{transient\_area} = \frac{1}{\left[-2 \cdot \lg(\frac{k/d}{3{,}71} + \frac{2{,}51}{\mathrm{Re} \cdot \sqrt{\lambda}})\right]^2} = 0{,}0128$$

Control for $\lambda = \mathrm{Re} \cdot \sqrt{\lambda_{rough}} \cdot k/d = 7$

< 200…transient area

> 200…rough area

$$h_v = \lambda \cdot \frac{l \cdot v^2}{d \cdot 2g} = 7{,}92m$$

4.4.4 Friction loss calculation for steel DN 900

Q]m³/s]	0,8
d [m]	0,9
l [m]	4086
ν [m²/s]	1,24E-06
k [m]	5,00E-05

$$A = \frac{d^2 \cdot \pi}{4} = 0{,}64m^2$$

$$v = \frac{Q}{A} = 1{,}26m/s$$

$$\mathrm{Re} = \frac{v \cdot d}{\nu} = 9{,}13 \cdot 10^5$$

$$\lambda_{rough} = \frac{1}{(2 \cdot \lg(d/k) + 1{,}14)^2} = 0{,}0107$$

$$\lambda_{transient\_area} = \frac{1}{\left[-2 \cdot \lg(\frac{k/d}{3{,}71} + \frac{2{,}51}{\mathrm{Re} \cdot \sqrt{\lambda}})\right]^2} = 0{,}0129$$

Control for $\lambda =$ $\mathrm{Re} \cdot \sqrt{\lambda_{rough}} \cdot k/d = 5$

< 200…transient area

> 200…rough area

$$h_v = \lambda \cdot \frac{l \cdot v^2}{d \cdot 2g} = 4{,}71m$$

4.5 Powerhouse

The powerhouse is situated on the slope leading down from the plateau on the east side of road 73, where a good accessibility for the building vehicles is given. The plateau measures about 360 m² and lies at a head of 742 m. Here the connection to the main electricity network is available. As it is state-of-the-art the design of the house matches with the surrounded buildings as it needs to fit and integrate into the landscape.

Figure 17: slope and plateau with the position of the powerhouse indicated by red ellipse (own source)

Figure 18: position of the powerhouse (own source)

The core of a hydropower plant is the mechanical typesetting, consisting of a turbine, a generator and control equipment.

4.5.1 Turbine

Turbines are the hydraulic machines that convert the upstream energy into a rotation and are distinguished by the head, flow rate and admission flow. Furthermore they are categorized into reaction turbines and impulse turbines. Combining small water flows and high heads a Pelton turbine is providing the best solution and are therefore often used in alpine regions. It belongs to the impulse turbines. Here the potential and the pressure energy of water is converted completely into velocity energy. This energy is then transferred to the turbine which converts it into mechanical energy. The pressure before and after the turbine is the same; it is roughly the same as the atmospheric pressure (Kaltschmitt et al., 2007).

On demand a turbine with the following data was offered (Kössler, 2010):

Turbine type	Pelton vertical
Head	140,00 m
Flow rate	0,8 m^3/s
Frequency	50 Hz
Number of rotations	600,00 rpm
Turbine efficiency factor	0,9
Cos φ	0,9
Turbine power ~	990 kW

Four jet nozzles direct the water onto the wheel and bring it into rotation which is converted into electricity by a generator

4.5.2 Generator

In the generator mechanical energy from the turbine is converted into electrical energy. The appropriate machine is delivered by the same company as the turbine, which has given the following information on request (Kössler, 2010):

Generator power ~	950 kW
Generator power ~	1060 kVA
Generator efficiency factor	0,96

4.5.3 Control equipment

To keep the energy production steady and safe several devices are installed. This means protection for overvoltage and revolutions per minute, overloading of turbine and generator and feed back of the turbine. The instruments are delivered and installed by the company providing the turbine (Kössler, 2010)

5. Power production

Basically the energy yield of a hydropower plant depends on the net head H_n and the flow rate Q. At the turbine the available energy of the water flow ρ·Q with the potential g·H is converted to rotation power.

$$P = \eta \cdot \rho \cdot Q \cdot g \cdot H_n [kW]$$

with: η total efficiency factor of the hydropowerplant [0,80 - 0,90]

ρ density of water [1 kg/m³]

g gravitational acceleration [9,81 m/s²]

Q flow rate [m³/s]

H_n net head [m]

The difference between the geodetically available head and the for energy production useable head consider friction- and bending losses inside the penstock, as well as the intake losses. For modern plants the efficiency factor lies between 0,80 and 0,90.

The rated efficiency P_a is only to be reached at the rated flow rate Q_a. This water amount fluctuates thanks to natural reasons and is hit or transgressed on only 30 to 60 days a year (Strobl and Zunic, 2006).

After evaluating the efficiency, this number is multiplied with the hours when this head and flow rate is actually reached. Summing it up to a year the annual production can be estimated:

$A = P \cdot t$ [kWh]

5.1 Calculation

The calculation is done on basis of the duration curve and with the following parameters:

- Total efficiency factor $\eta_{total} = \eta_{turbine} \cdot \eta_{generator} = 0,9 \cdot 0,96 = 0,864$ (Kössler, 2010)
- Flow rate Q: 0.80 m³/s as design flow

- Net head H_n: $H_n = H_{absolut} - h_v$ this variable changes with material and diameter size, as the friction losses are determined by them.

In the following sections the annual production is calculated for different materials and pipe diameters.

5.1.1 Glass-reinforced plastic pipe DIN 800

The duration curve gives information about discharge and period of reached water levels. With the formula above the capacity is determined. For this, the flow rate is reduced by the value of the environmental flow, which is separated in summer and winter half-year. Then the capacity value is multiplied with the period of the flow rate in days and multiplied by 24h, which gives the production for this water level in kWh. The production for the whole year is calculated by summing up the partial capacities.

For 60 days the useable flow rate is below 20% of the rated flow rate or 0.13 m³/s respectively, thus the turbine is not working in the guarantee range anymore and needs to be turned off.

Tab. 4: flow rates in connection with their friction losses for a GRP pipe with DIN 800

H [m] =	155,22
Q [m³/s]	hv [m]
1,3	8,14
1,1	8,14
0,9	8,14
0,8	7,21
0,7	5,53
0,6	4,05
0,5	2,80
0,4	1,95
0,3	1,10
0,16	0,29
0	0,00

Tab. 5: calculation of annual production for a glass-reinforced plastic pipe with DIN 800

Powerplant Poarta, Romania						
rated discharge:		**0,80**	**m³/s**		**year:**	
rated head:					**η total:**	**0,864**
environmen	summer:	**0,05**	**m³/s**		**river:**	**Poarta**
flow:	winter:	**0,03**	**m³/s**			
nat. discharge in m³/s	duration curve in days	useable discharge in m³/s	useable head in m	capacity in kW	duration in days	production in kWh
1,300	27,20	0,800	147,08	997,3	27,20	651.051
1,100	46,21	0,800	147,08	997,3	19,01	455.018
0,900	83,95	0,800	147,08	997,3	37,74	903.334
0,800	114,75	0,750	148,01	940,9	30,80	695.485
0,700	149,33	0,650	149,69	824,7	34,58	684.442
0,600	184,15	0,550	151,17	704,7	34,82	588.898
0,500	215,97	0,450	152,42	581,4	31,82	443.967
0,400	247,02	0,370	153,27	480,7	31,05	358.182
0,300	276,04	0,270	154,12	352,7	29,02	245.650
0,160	305,33	0,130	154,93	170,7	29,29	120.000
0,000	365,00	0,000	155,22	0,0	59,67	0
			Annual production in kWh/year			**5.146.027**

The annual production for a power plant using a GRP-pipe with a diameter of 800 mm will be up to 5,150 MWh/a.

5.1.2 Glass-reinforced plastic pipe DIN 900

Tab. 6: flow rates in connection with their friction losses for a GRP pipe with DIN 900

H [m] =	155,22
Q [m³/s]	hv [m]
1,3	4,56
1,1	4,56
0,9	4,56
0,8	4,04
0,7	3,10
0,6	2,28
0,5	1,58
0,4	1,10
0,3	0,62
0,16	0,17
0	0

Tab. 7: calculation of annual production for a glass-reinforced plastic pipe with DIN 900

Powerplant Poarta, Romania						
rated discharge:			**0,80 m³/s**		**year:**	
rated head:					**η total:**	**0,864**
environmen	summer:		**0,05 m³/s**		**river:**	**Poarta**
flow:	winter:		**0,03 m³/s**			
nat. discharge in m³/s	duration curve in days	useable discharge in m³/s	useable head in m	capacity in kW	duration in days	production in kWh
1,300	27,20	0,800	150,662	1021,6	27,20	666.895
1,100	46,21	0,800	150,662	1021,6	19,01	466.091
0,900	83,95	0,800	150,662	1021,6	37,74	925.317
0,800	114,75	0,750	151,177	961,0	30,80	710.382
0,700	149,33	0,650	152,118	838,1	34,58	695.527
0,600	184,15	0,550	152,941	713,0	34,82	595.813
0,500	215,97	0,450	153,644	586,0	31,82	447.529
0,400	247,02	0,370	154,118	483,3	31,05	360.172
0,300	276,04	0,270	154,598	353,8	29,02	246.411
0,160	305,33	0,130	155,053	170,8	29,29	120.098
0,000	365,00	0,000	155,220	0,0	59,67	0
			Annual production in kWh/year			**5.234.235**

The annual production for a power plant using a GRP-pipe with a diameter of 900 mm will be up to 5,230 MWh/a.

5.1.3 Steel pipe DIN 800

Tab. 8: flow rates in connection with their friction losses for a steel pipe with DIN 800

H [m] =	155,22
Q [m³/s]	hv [m]
1,3	8,45
1,1	8,45
0,9	8,45
0,8	7,48
0,7	5,71
0,6	4,18
0,5	2,87
0,4	2,00
0,3	1,12
0,16	0,30
0	0,0

Tab. 9: calculation of annual production for a steel pipe with DIN 800

Powerplant Poarta, Romania						
rated discharge:		**0,80**	**m³/s**		**year:**	
rated head:					**η total:**	**0,864**
environmen	summer:	**0,05**	**m³/s**		**river:**	**Poarta**
flow:	winter:	**0,03**	**m³/s**			
nat. discharge in m³/s	duration curve in days	useable discharge in m³/s	useable head in m	capacity in kW	duration in days	production in kWh
1,300	27,20	0,800	146,770	995,2	27,20	649.667
1,100	46,21	0,800	146,770	995,2	19,01	454.051
0,900	83,95	0,800	146,770	995,2	37,74	901.413
0,800	114,75	0,750	147,740	939,2	30,80	694.229
0,700	149,33	0,650	149,506	823,7	34,58	683.583
0,600	184,15	0,550	151,042	704,1	34,82	588.414
0,500	215,97	0,450	152,346	581,1	31,82	443.749
0,400	247,02	0,370	153,220	480,5	31,05	358.075
0,300	276,04	0,270	154,100	352,7	29,02	245.617
0,160	305,33	0,130	154,923	170,7	29,29	119.997
0,000	365,00	0,000	155,220	0,0	59,67	0
			Annual production in kWh/year			**5.138.795**

The annual production for a power plant using a steel pipe with a diameter of 800 mm will be up to nearly 5,140 GWh/a.

5.1.4 Steel pipe DIN 900

Tab. 10: flow rates in connection with their friction losses for a steel pipe with DIN 900

H [m] =	155,22
Q [m³/s]	hv [m]
1,3	4,71
1,1	4,71
0,9	4,71
0,8	4,17
0,7	3,19
0,6	2,34
0,5	1,61
0,4	1,12
0,3	0,63
0,16	0,17
0	0,00

Tab. 11: calculation of annual production for a steel pipe with DIN 900

Powerplant Poarta, Romania						
rated discharge:		**0,80**	**m³/s**		**year:**	
rated head:					**η total:**	**0,864**
environmen	summer:	**0,05**	**m³/s**		**river:**	**Poarta**
flow:	winter:	**0,03**	**m³/s**			
nat. discharge in m³/s	duration curve in days	useable discharge in m³/s	useable head in m	capacity in kW	duration in days	production in kWh
1,300	27,20	0,800	150,512	1020,6	27,20	666.228
1,100	46,21	0,800	150,512	1020,6	19,01	465.625
0,900	83,95	0,800	150,512	1020,6	37,74	924.392
0,800	114,75	0,750	151,049	960,2	30,80	709.779
0,700	149,33	0,650	152,029	837,6	34,58	695.117
0,600	184,15	0,550	152,882	712,7	34,82	595.583
0,500	215,97	0,450	153,608	585,9	31,82	447.426
0,400	247,02	0,370	154,096	483,3	31,05	360.122
0,300	276,04	0,270	154,589	353,8	29,02	246.396
0,160	305,33	0,130	155,052	170,8	29,29	120.097
0,000	365,00	0,000	155,220	0,0	59,67	0
			Annual production in kWh/year			**5.230.764**

The annual production for a power plant using a steel pipe with a diameter of 900 mm will be up to 5,200 MWh/a.

5.1.5 Summary

The next table gives a summary of the annual productions in dependence of the used material.

Tab. 12: overview of annual production

GRP-800	5.146.027	kWh
GRP-900	5.234.235	kWh

Steel-800	5.138.795	kWh
Steel-900	5.230.764	kWh

The different material influences the annual production only in a small way. Both pipes with a diameter of 800 mm are in the same range of annual production. The same is true for the pipes of 900 mm. The decision which pipe to choose is made by the investment price.

6. Profitability

The profitability depends on investment and maintenance costs on one side and economical profit on the other side.

6.1 Specific penstock costs

The material and the dimension of the penstock play an important role for energy production. Therefore specific costs were calculated to set the investment costs in relation to the annual production that can be won. The friction losses h_v depend on the material influencing the coarseness values, the length of the penstock and the diameter. They are subtracted from the net head and result in ΔH. Multiplying the length of the pipe with the prices given per meter results in the investment costs. The energy production and work output have been calculated before. The final result is a division of the investment costs by kWh.

In a small extent the glass-reinforced plastic pipes gain more energy due to less friction losses. However due to the much higher investment costs their specific costs are very high.

By contrast to GRP-pipes, the investment costs of steel pipes with plug-in sleeve mechanism and welding sleeve mechanism are lower. This means a better ratio between investment costs and energy profit. As the calculation shows, the penstock made of steel with the plug-in sleeves and a diameter of 800 mm reaches specific costs of 0.12 € per kWh and is therefore the cheapest option. Nevertheless it is questionable that the plug-in method can handle the upcoming hydrostatic pressure. Hence one can recommend for the steel pipes with DIN 800 using the welding method to connect the pipe parts. Their specific costs range at 0.19 €/kWh.

Tab. 13: overview of the specific costs for the penstock depending on pipe dimension and material

QA [m³/s] = 0,8

η tot = 0,864

GRP 800			
Dim.penstock	hv =	8,14	m
	Hroh =	155,22	m
	ΔH =	147,08	m
	€/lfm	464,07	€
	L =	4086	m
	€-tot	1.896.190	€
	P =	997,3	kW
energy prod.	A =	5.146.027	kWh
spec.costs:		**0,37**	**€/kWh**

Steel 800	**plug-in**		
Dim.penstock	hv =	8,45	m
	Hroh =	155,22	m
	ΔH =	146,77	m
	€/lfm	154	€
	L =	4086	m
	€-tot	629.244	€
	P =	995,2	kW
energy prod.	A =	5.138.795	kWh
spec.costs:		**0,12**	**€/kWh**

Steel 800	**welding**		
Dim.penstock	hv =	8,45	m
	Hroh =	155,22	m
	ΔH =	146,77	m
	€/lfm	233	€
	L =	4086	m
	€-tot	952.038	€
	P =	995,2	kW
energy prod.	A =	5.138.795	kWh
spec.costs:		**0,19**	**€/kWh**

GRP 900			
Dim.penstock	hv =	4,56	m
	Hroh =	155,22	m
	ΔH =	150,66	m
	€/lfm	572,98	€
	L =	4086	m
	€-tot	2.341.196	€
	P =	1021,6	kW
energy prod.	A =	5.234.235	kWh
spec.costs:		**0,45**	**€/kWh**

Steel 900	**plug-in**		
Dim.penstock	hv =	4,71	m
	Hroh =	155,22	m
	ΔH =	150,51	m
	€/lfm	189	€
	L =	4086	m
	€-tot	772.254	€
	P =	1020,6	kW
energy prod.	A =	5.230.764	kWh
spec.costs:		**0,15**	**€/kWh**

Steel 900	**welding**		
Dim.penstock	hv =	4,71	m
	Hroh =	155,22	m
	ΔH =	150,51	m
	€/lfm	283	€
	L =	4086	m
	€-tot	1.156.338	€
	P =	1020,6	kW
energy prod.	A =	5.230.764	kWh
spec.costs:		**0,22**	**€/kWh**

6.2 Costs for pipe installation

Lendenfeld (2010) calculated the following matters of expense per 100 m:

- Ten foundations: 10,000 – 12,000 €
- 100 m pipeline: 23,300 €
- Establishing accessibility: 12,000 €
- Soil improvement: 15,000 €
- Pipe installation: 2,000 €

Total amount: 63,300 €/100 m

x 40

Total costs for laying the whole pipe: appr. 2.6 million Euro

6.3 Costs for enclosed area

According to a rough cost estimate by Haselmeyer (2010), the costs for one square meter are multiplied by 3,000 Euro. This allows the calculation for the intake area and the construction of the powerhouse.

6.3.1 Intake area

The intake area consists of these components:

- Tyrolean weir and spillway: 20.5 m²
- Crossflume: 23.6 m²
- Settling basin: 294.8 m²
- Intake chamber: 104.6 m²

The sum of all parts means a total investment amount of appr. 1,331,000 Euro.

6.3.2 Powerhouse

Haselmeyer (2010) calculated the rough cost estimate for the powerhouse with the size of 47.65 m² and estimated a total sum of about 143,000 Euro for the construction of the powerhouse.

6.4 Costs for electromechanical equipment

Kössler (2010) gives the following price information:

- Pelton turbine: 580,000 €
- Electric equipment: 220,000 €
- Generator:180,000 €

Total amount: 980,000 €

6.5 Green certificates

In Romania, a trade system of green certificates is implemented. In general, one green certificate is traded for 1 MWh of produced energy on a special market organized for this purpose. In this manner the producers of energy which comes from a renewable energy source (RES) obtain extra income in addition to income generated by the sale of energy (The Romanian Digest, 2008).

According to Law 220/2208, the producers will receive (The Romanian Digest, 2008):

- one green certificate for each 1 MWh produced and delivered in the electric power network from new hydroelectric stations/groups or from refurbished hydroelectric stations/groups with a maximum output of 10 MW;
- one green certificate for each 2 MWh delivered in the electric power network from hydroelectric stations with an installed power between 1 and 10 MW, which do not fall under the provisions of the previous paragraph;
- two green certificates for each 1 MWh delivered in the electric power network from hydroelectric stations with an installed power of up to 1 MW/unit;
- two green certificates, until 2015, and a green certificate, starting from 2016, for each 1 MWh delivered in the electric power network by the producers of electric power from wind energy;
- 3 green certificates for each 1 MWh delivered in the electric power network by the producers of electricity from biomass, biogas, bioliquid, waste fermentation gas, geothermal power and associated combustible gases;

- 4 green certificates for each 1 MWh delivered in the electric power network by the producers of electricity from solar power.

As the installed capacity of this plant lies by 990 kW, it stays under the limit of 10 MW and will gain one green certificate for each 1 MWh.

The minimum trading value is € 27/certificate, while the maximum trading value is € 55/certificate. The trading values have to be annually adjusted by the consumer price index for Romania. The certificates are thus sold on the market at the market price which cannot be lower than € 27, but cannot exceed € 55.

Depending on the current market situation prices between 27 Euro and 55 Euro/certificate can be achieved.

This allows the following calculation:

annual production	5.140	MWh/a
27€/GC	138.780	€/a
55€/GC	282.700	€/a
average: 41€/GC	210.740	€/a

6.6 Sail on energy market

In the years 2006 until 2008 the average price on the electricity market was 161.65 lei/MWh. The extreme values reached 30.21 lei/MWh at its lowest and 260.75 lei/MWh at its maximum (OPCOM, 2008). With the current exchange rate (OANDA, 2010) the average price means 36.66 €/MWh, the minimum is 6.85 €/MWh and a maximum of 60.49 €/MWh.

It can be assumed that the price for electricity will follow this example and be in this range in the coming years.

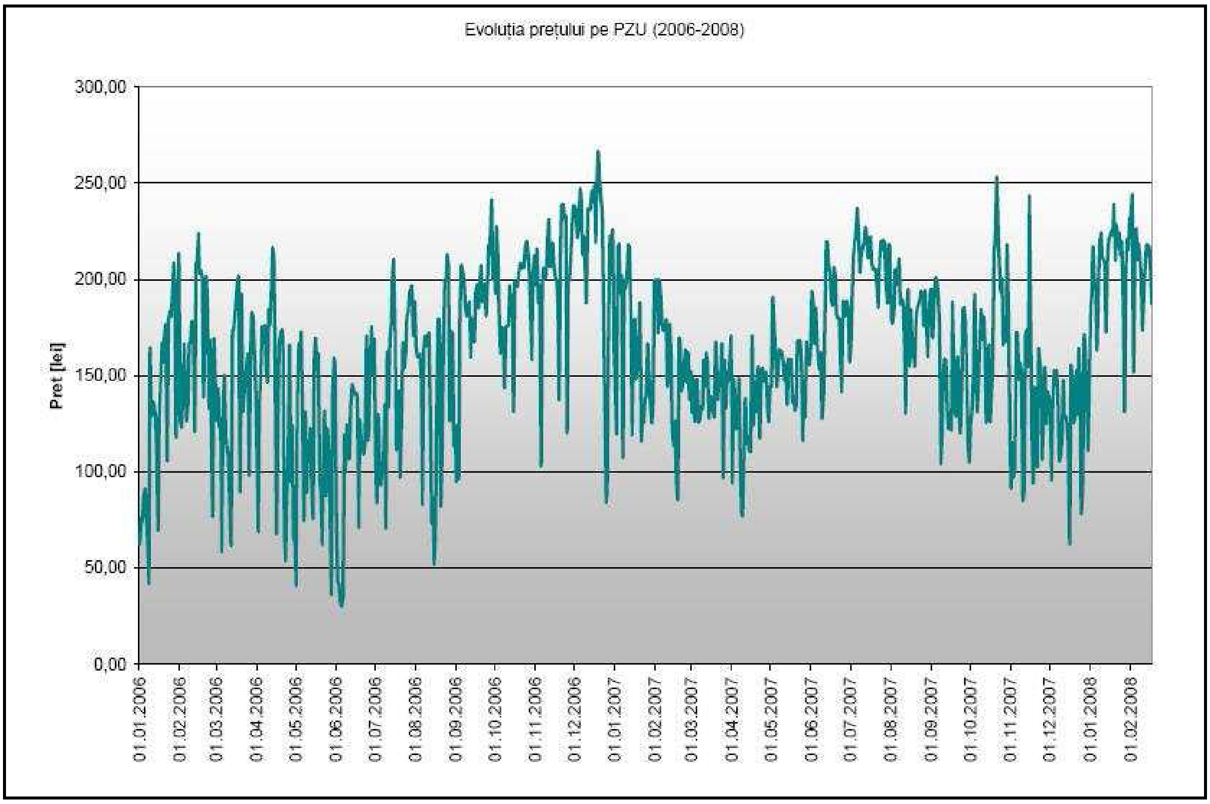

Figure 19: price development on the energy market in Romania in the period between 2006-2008 (OPCOM, 2008)

With the predicted outcome of 5,140 MWh/a the avail will reach an average avail of 188,400 €/a. At least 35,200 €/a can be gained on the one hand and a maximum of 310,800 €/a on the other hand.

6.7 Supplied households

In the paper published by RenERg EuReg (s.a.) the energy consumption of different cities in Romania published.

Tab. 14: Total electric energy consumption and consumption of households in main cities in central Romania in the year 2008 (RenERg EuReg)

	Total Consumption	consumption households	consumption /inhabitant	consumption household/inhabitant
	MWh		kWh	
Alba	367.585,17	163.591,97	980,9	436,6
Braşov	**869.298,76**	**307.060,10**	**1.457,4**	**514,8**
Covasna	223.179,75	97.480,38	999,9	436,7
Harghita	363.011,82	153.708,90	1.114,6	472,0
Mureş	959.577,86	260.826,66	1.650,5	448,6
Sibiu	514.479,88	223.823,74	1.215,9	529,0
TOTAL	3.297.133,24	1.206.491,74		

About a third of the total electric energy consumption is used by households. In the following Braşov, as it is the nearest city to the project area, is chosen as calculation example.

The city of Braşov with about 210,000 inhabitants uses 307,060 MWh for all households. Circa 3 people live in one household and form 70,000 households. This means a consumption of about 4.38 MWh per household and year.

Hence, the annual production of about 5,100 MWh with the Poarta power plant provides electric energy for roughly 1160 households.

6.8 Summery

Tab. 15: overview over costs and avail results

Costs for	price [€]	average avail for	price [€]
Intake area	1.331.000		
Penstock incl laying	2.532.000	green certificates	210.740
Powerhouse	143.000	sail on market	188.400
electr. equipment	980.000		
Sum	4.986.000	**Sum**	399.140

A rough estimation in how many years this project will amortize can be calculated by dividing 5,000,000 € costs by 400,000 € avail. The result of this rough calculation is 13 years. From this time on it will bring positive numbers. This computation, however, does not take any repair and maintenance costs into consideration nor economic calculation approaches.

7. Plans

7.1 Overview site plan

7.2 Catchment area

7.3 Longitudinal section

7.4 Overview intake area

7.5 Details intake area

7.6 Overview power house

7.7 Details powerhouse

8. Conclusion and future steps

The Romanian data availability differs strongly from the Austrian one. Hence, it is not surprising, that it is not always traceable how and where the data is gathered.

An example is the cadastral map. Different kind of maps have been the basis for the detail planning, only one showing contour lines the others not. The using of the property is not evident and the property numbers are shown neither.

Another example is found in the duration curve. The labelling of the abscissa is done in percent instead of 365 days, as it is standard. Furthermore the curve finishes at zero m^3/s, which would mean, that there are days with no water at all. It raises the suspicion, that the data is only machine generated and not the result of measurements taken regularly.

Problems could be caused by the laying of the pipe. As the street is very narrow, it might be not enough space for the special machines bringing up the penstock. The heavy weight of about two tons for each individual piece requires large vehicles. Embedding the pipe in the street, the necessary depth and security arrangement for protecting the trench against collapsing may mean too large breadths than the street can manage. In addition it means less bending losses if the penstock was laid as straight as possible. Alas, the available data was not sufficient to allow a planning of the penstock in this way. The effect of this was that the friction losses would decrease. They, however, have not been taken into calculation.

With the available data the result of the energy production gives hope that the use of hydropower at this creek could amortize within an interesting time horizon, especially regarding the point of view that the offers for material and men's work are gathered on Austrian price level. Appling lower wage levels and material prices in Romania, the relationship between costs and avail will decrease. By this, the amortizing period will become lower.

The possibility to supply about 1160 households means the supply for the whole village Poarta and even more houses in vicinity.

All in all this is an interesting project and surely worth for further investigation.

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10. Appendix

10.1 Offer ALPE Kommunal- und Umwelttechnik Ges.m.b.H&Co.KG:

Prices for steel penstock

10.2 Offer HOBAS Rohre GmbH:

Prices for GRP penstock

10.3 Offer Kössler Hydro Electro Power Ges.m.b.H:

Prices and design details for electro technical equipment

10.4 Offer ZI Mag. Arch. Gottfried Haselmeyer

Rough cost estimate for erection of the powerhouse

ALPE KOMMUNAL- UND UMWELTTECHNIK GES.M.B.H. & Co. KG ALPE

Ziv. Ing. Büro Groissmaier
z. Hd. Frau Dipl. Ing. [redacted]
[redacted]
A - 3100 St. Pölten
Fax: 02742 37700 77

Ihre Kundennummer: 2310809
Bearbeiter: Gabi Kluibenschädl
Kontakt: [redacted]

11.03.2010

Angebots-Nr: **10-00216**
Ihre Anfrage: **Kraftwerksleitung**

ANGEBOT

Wir danken für Ihre Anfrage und bieten Ihnen nachstehend, unter Zugrundelegung unserer Verkaufs- und Lieferbedingungen, wie folgt an:

Pos	Artikel	Menge Meh	Einzelpreis	Rabatt	EUR- Betrag
1	**NVROHR** Stahlrohre DN 800 (813 x 7,1 mm) Stangenlänge 12 m nach DIN EN 10220 / DIN EN 10224, oder wahlweise EN 10208-2, hergestellt aus Werkstoff L235, mit Abnahmeprüfzeugnis nach EN 10204/3.1 Ausgabe Januar 2005, innen und außen UP-spiralgeschweißt, Schweißnaht 100% US-geprüft, 10 % der Schweißnaht geröntgt, in Herstellungslängen von 12 m, eine Ende rechtwinkelig, ein Ende mit Einsteckschweißmuffe, innen Zementmörtelauskleidung gemäß DIN 2614-II-S mit hochsulfatbeständigem Portlandzement CEM/ 42,5 R-HS/NA gem. DIN 1164, außen PE-Umhüllung gem. DIN 30670 S,n, LDPE, Farbe schwarz, Enden mit Kunststoffkappen verschlossen ink. Schrumpfmanschette zur Nachumhüllung im Muffenbereich Gewicht: 202 kg/m	**4.008,000 m**	**233,000**		**933.864,00**
2	**NVROHR** Stahlrohre DN 900 (914 x 8,0 mm) Stangenlänge 12 m nach DIN EN 10220 / DIN EN 10224, oder wahlweise EN 10208-2, hergestellt aus Werkstoff L235, mit Abnahmeprüfzeugnis nach EN 10204/3.1 Ausgabe Januar 2005, innen und außen UP-spiralgeschweißt, Schweißnaht 100% US-geprüft, 10 % der Schweißnaht geröntgt, in Herstellungslängen von 12 m, eine Ende rechtwinkelig, ein Ende mit Einsteckschweißmuffe, innen Zementmörtelauskleidung gemäß DIN 2614-II-S mit hochsulfatbeständigem Portlandzement CEM/ 42,5 R-HS/NA gem. DIN 1164, außen PE-Umhüllung gem. DIN 30670 S,n, LDPE, Farbe schwarz, Enden mit Kunststoffkappen verschlossen inkl. Schrumpfmanschette zur Nachumhüllung im Muffenbereich Gewicht: 259 kg/m	**4.008,000 m**	**283,000**		**1.134.264,00**
	Alternativ:				
3	**NVROHR** Stahlrohre DN 800 (813 x 7,1 mm) Stangenlänge 12 m nach DIN EN 10220 / DIN EN 10224, oder wahlweise EN 10208-2, hergestellt aus Werkstoff L235, mit Abnahmeprüfzeugnis nach EN 10204/3.1 Ausgabe Januar 2005, innen und außen UP-spiralgeschweißt, Schweißnaht 100% US-geprüft, 10 % der Schweißnaht geröntgt, in Herstellungslängen von 12 m, mit abgeschrägten Enden. rohschwarz Gewicht: 141 kg/m	**4.008,000 m**	**154,000**		**617.232,00**
	Alternativ:				
4	**NVROHR** Stahlrohre DN 900 (914 x 8,0 mm) Stangenlänge 12 m nach DIN EN 10220 / DIN EN 10224, oder wahlweise EN 10208-2, hergestellt aus Werkstoff L235, mit Abnahmeprüfzeugnis nach EN 10204/3.1 Ausgabe Januar 2005, innen und außen UP-spiralgeschweißt, Schweißnaht 100% US-geprüft, 10 % der Schweißnaht geröntgt, in Herstellungslängen von 12 m, mit abgeschrägten Enden. rohschwarz	**4.008,000 m**	**189,000**		**757.512,00**

ALPE KOMMUNAL- UND UMWELTTECHNIK GES.M.B.H. & Co. KG

Ziv. Ing. Büro Groissmaier
z. Hd. Frau Dipl. Ing. [redacted]
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Ihre Kundennummer: 2310809
Bearbeiter: Gabi Kluibenschädl
Kontakt: [redacted]

11.03.2010

Angebots-Nr: **10-00216**
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Wir danken für Ihre Anfrage und bieten Ihnen nachstehend, unter Zugrundelegung unserer Verkaufs- und Lieferbedingungen, wie folgt an:

Pos	Artikel	Menge Meh	Einzelpreis	Rabatt	EUR- Betrag
	Gewicht: 179 kg/m				

Nettobetrag:	EUR	2.068.128,00
USt 20,0%	EUR	413.625,60
Gesamtbetrag:	**EUR**	**2.481.753,60**

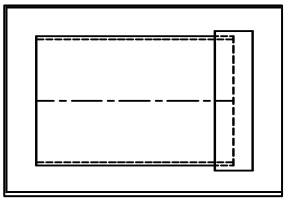
Lieferzeit: **nach Vereinbarung**
Lieferbedingung: **frei Baust. unabgel.kompl.Sattelz.soweit befahrbar**
Zahlungskondition: **30 Tage netto n. Rechnungsdatum mit Bankgarantie**

Wir hoffen, Ihnen ein interessantes Angebot unterbreitet zu haben und würden uns über Ihren Auftrag sehr freuen.

Mit freundlichen Grüßen
ALPE GMBH & Co. KG

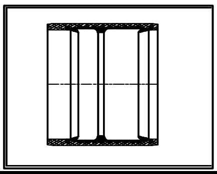
PREISLISTE 1/2008
(PRICE LIST)
HOBAS GF-UP DRUCKROHR-PROGRAMM
(HOBAS UP-GF pressure pipe system)

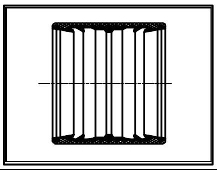
DRUCKROHRE
mit einseitig aufgezogener Kupplung, in ca. 6 m Längen



DN	DA mm	Preis EURO/m PN 6 SN 5.000	Preis EURO/m PN 10 SN 5.000	Preis EURO/m PN 10 SN 10.000	Preis EURO/m PN 16 SN 10.000
150	168	-	-	30,96	-
200	220	-	-	56,46	61,68
250	272	-	-	75,16	83,05
300	324	-	-	93,74	105,51
350	376	100,41	110,61	117,29	130,77
400	427	116,08	131,86	141,09	158,57
500	530	160,40	174,97	186,86	214,79
600	616	197,55	221,95	239,32	282,18
700	718	244,54	282,18	302,46	361,34
800	820	314,84	356,61	380,77	464,07
900	924	381,14	437,84	468,80	572,98
1000	1026	444,76	518,70	556,59	686,26
1200	1229	594,59	710,79	764,58	955,09
1400	1434	841,07	1.008,15	1.077,35	-
1600	1638	1.082,70	1.301,37	1.387,82	-
1800	1842	1.315,09	-	-	-
2000	2047	1.572,87	-	-	-
2400	2400	2.394,03	-	-	-

Druck-Kupplungen

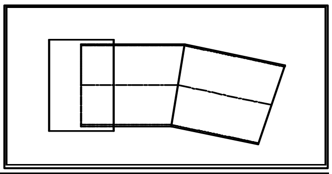




DN	PN 6 EURO/Stk	PN 10 EURO/Stk	PN 16 EURO/Stk	DN	PN 6 EURO/Stk	PN 10 EURO/Stk	PN 16 EURO/Stk
150	40,68	76,74	-	1000	316,90	359,64	519,80
200	66,78	-	75,89	1100	auf Anfrage	auf Anfrage	auf Anfrage
250	75,16	-	86,45	1200	391,58	518,46	776,11
300	83,05	-	99,20	1300	auf Anfrage	auf Anfrage	auf Anfrage
350	-	-	115,11	1400	478,76	693,31	-
400	-	-	127,49	1500	auf Anfrage	auf Anfrage	-
500	-	-	150,68	1600	708,36	982,53	-
600	-	-	207,87	1800	823,10	-	-
700	-	217,34	266,03	2000	920,00	-	-
800	-	253,28	342,04	2200	auf Anfrage	-	-
900	284,97	301,48	413,92	2400	auf Anfrage	-	-

DN 150 - DN 250 Typ DC
ab DN 300 Typ FWC

BOGEN, einschnittig



BOGEN 11 ¼ GRAD,
mit einseitig aufgezogener Kupplung

DN	PN 6 EURO/Stk	PN 10 EURO/Stk	PN 16 EURO/Stk	DN	PN 6 EURO/Stk	PN 10 EURO/Stk	PN 16 EURO/Stk
150	246,12	273,56	-	600	796,51	929,71	1.178,74
200	273,56	317,39	359,28	700	1.018,83	1.216,50	1.588,04
250	332,57	372,76	424,73	800	1.238,24	1.482,53	2.013,98
300	385,87	432,74	497,82	900	1.448,53	1.801,86	-
350	444,03	500,61	579,78	1000	1.702,66	2.233,75	-
400	519,68	600,90	694,52	1200	2.327,98	3.150,23	-
500	679,46	765,55	911,74	1400	3.081,26	4.354,47	-

BOGEN 22 ½ GRAD,
mit einseitig aufgezogener Kupplung

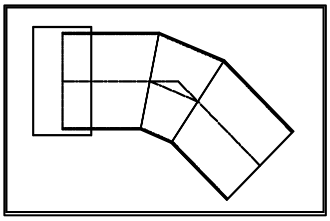
DN	PN 6 EURO/Stk	PN 10 EURO/Stk	PN 16 EURO/Stk	DN	PN 6 EURO/Stk	PN 10 EURO/Stk	PN 16 EURO/Stk
150	256,32	275,74	-	600	837,19	976,58	1.234,23
200	288,74	320,91	363,17	700	1.036,31	1.236,41	1.611,84
250	336,94	377,61	430,19	800	1.281,22	1.532,07	2.073,97
300	391,58	439,05	504,98	900	1.528,06	1.894,14	-
350	450,95	508,02	588,28	1000	1.797,13	2.344,12	-
400	527,57	610,25	704,96	1200	2.327,98	3.251,61	-
500	701,93	790,08	941,73	1400	3.255,86	4.559,42	-

BOGEN 30 GRAD,
mit einseitig aufgezogener Kupplung

DN	PN 6 EURO/Stk	PN 10 EURO/Stk	PN 16 EURO/Stk	DN	PN 6 EURO/Stk	PN 10 EURO/Stk	PN 16 EURO/Stk
150	259,47	280,11	-	600	885,51	1.031,58	-
200	292,14	324,55	-	700	1.099,21	1.308,42	-
250	341,43	382,59	-	800	1.384,18	1.650,21	-
300	403,60	451,92	-	900	1.657,25	-	-
350	465,64	524,17	-	1000	1.953,15	-	-
400	545,78	631,38	-	1200	2.631,89	-	-
500	728,64	818,97	-	1400	3.622,06	-	-

PREISLISTE 1/2008
(PRICE LIST)
HOBAS GF-UP DRUCKROHR-PROGRAMM
(HOBAS UP-GF pressure pipe system)

BOGEN, zweischnittig



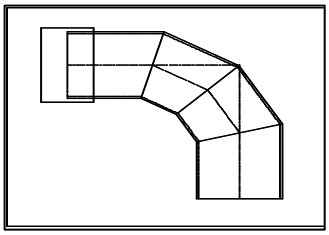
BOGEN 45 GRAD,
mit einseitig aufgezogener Kupplung

DN	PN 6 EURO/Stk	PN 10 EURO/Stk	PN 16 EURO/Stk	DN	PN 6 EURO/Stk	PN 10 EURO/Stk	PN 16 EURO/Stk
150	392,43	441,48	-	600	1.372,40	1.637,34	-
200	461,76	517,61	-	700	1.724,28	2.079,79	-
250	542,74	612,56	-	800	2.120,95	2.602,14	-
300	637,45	718,92	-	900	2.522,61	-	-
350	740,90	840,59	-	1000	2.959,48	-	-
400	858,68	998,55	-	1200	4.068,16	-	-
500	1.132,11	1.297,37	-	1400	5.506,49	-	-

BOGEN 60 GRAD,
mit einseitig aufgezogener Kupplung

DN	PN 6 EURO/Stk	PN 10 EURO/Stk	PN 16 EURO/Stk	DN	PN 6 EURO/Stk	PN 10 EURO/Stk	PN 16 EURO/Stk
150	401,53	452,41	-	600	1.456,79	1.733,87	-
200	472,44	529,15	-	700	1.854,32	2.228,53	-
250	556,95	628,59	-	800	2.309,28	2.818,75	-
300	656,51	739,57	-	900	2.756,59	-	-
350	772,83	875,19	-	1000	3.275,41	-	-
400	896,20	1.042,14	-	1200	4.559,66	-	-
500	1.199,38	1.370,95	-	1400	6.180,98	-	-

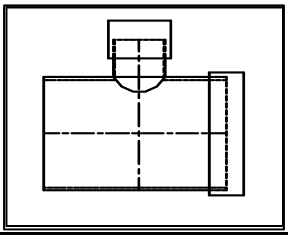
BOGEN, dreischnittig



BOGEN 90 GRAD,
mit einseitig aufgezogener Kupplung

DN	PN 6 EURO/Stk	PN 10 EURO/Stk	PN 16 EURO/Stk	DN	PN 6 EURO/Stk	PN 10 EURO/Stk	PN 16 EURO/Stk
150	555,98	615,96	-	600	2.090,48	2.507,43	-
200	653,97	734,83	-	700	2.687,86	-	-
250	774,17	876,41	-	800	3.378,13	-	-
300	924,37	1.043,36	-	900	-	-	-
350	1.082,09	1.228,89	-	1000	-	-	-
400	1.266,28	1.475,97	-	1200	-	-	-
500	1.710,19	1.966,51	-	1400	-	-	-

PREISLISTE 1/2008
(PRICE LIST)
HOBAS GF-UP DRUCKROHR-PROGRAMM
(HOBAS UP-GF pressure pipe system)



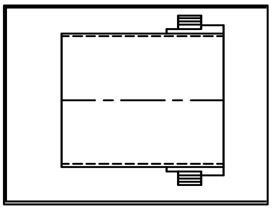
T-STÜCKE 90 GRAD, MIT GFK-ABGANG PN 6
mit je einer aufgezogenen Kupplung am Durchgang und Abgang

DN	DN 1 150 EURO/Stk	DN 1 200 EURO/Stk	DN 1 250 EURO/Stk	DN 1 300 EURO/Stk	DN 1 350 EURO/Stk	DN 1 400 EURO/Stk	DN 1 500 EURO/Stk
150	409,79						
200	442,57	475,60					
250	463,94	507,17	557,07				
300	500,01	543,59	593,50	647,65			
350	535,22	584,15	634,05	688,21	748,31		
400	614,26	682,62	732,52	786,80	846,78	906,15	
500	749,64	826,02	875,92	929,95	990,18	1.049,55	1.246,25
600	877,50	923,76	973,66	1.027,94	1.088,04	1.147,41	1.343,99
700	1.001,59	1.054,41	1.104,43	1.158,58	1.218,81	1.278,18	1.474,76
800	1.191,12	1.240,66	1.290,57	1.344,84	1.404,94	1.464,32	1.660,90
900	1.576,02	1.624,84	1.674,74	1.728,77	1.788,99	1.848,37	2.045,07
1000	1.787,29	1.839,87	1.889,77	1.943,93	2.004,03	2.063,40	2.260,10
1200	2.014,96	2.083,68	2.133,83	2.187,86	2.248,08	2.307,46	2.504,15

PREISLISTE 1/2008
(PRICE LIST)
HOBAS GF-UP DRUCKROHR-PROGRAMM
(HOBAS UP-GF pressure pipe system)

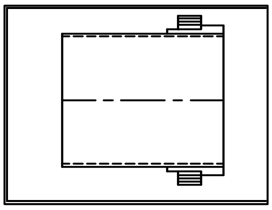
F-STÜCKE - PN 10, Standardlänge = 0,4 m, ohne Kupplung
mit Edelstahl-Losflansch, PN 10 gebohrt, ohne Schrauben und Dichtung

DN	Artikel-Nr.	Preis EURO/Stk	DN	Artikel-Nr.	Preis EURO/Stk
150		439,05	400		1.361,72
200		548,82	500		1.994,56
250		724,27	600		2.482,78
300		878,47	700		3.260,23
350		1.080,63	800		4.446,38



F-STÜCKE - PN 10, Standardlänge = 0,4 m, ohne Kupplung
mit Stahl vz.-Losflansch, PN 10 gebohrt, ohne Schrauben und Dichtung

DN	Artikel-Nr.	Preis EURO/Stk	DN	Artikel-Nr.	Preis EURO/Stk
150		407,48	400		1.286,80
200		509,35	500		1.721,12
250		635,27	600		2.186,89
300		813,51	700		2.982,67
350		1.011,79	800		3.595,59



F-STÜCKE - PN 10, Standardlänge = 0,4 m, ohne Kupplung
mit Los- u. Blindflansch, PN 10 gebohrt, mit Schrauben u. Dichtung
bis DN 600 Ausführung in Edelstahl, ab DN 700 Stahl verzinkt

DN	Artikel-Nr.	Preis EURO/Stk	DN	Artikel-Nr.	Preis EURO/Stk
150		622,76	400		2.278,31
200		800,52	500		3.602,64
250		1.148,63	600		4.739,61
300		1.515,31	700		5.068,78
350		1.816,19	800		6.053,84

Kössler Gesellschaft m.b.H

Hydro Electric Power

Projekt Name	Poarta Rumänien
Turbinentype	Pelton Vertikal
Fallhöhe	140,00 [m]
Durchfluss	0,80 [m³/s]
Frequenz	50 [Hz]
Drehzahl	600,00 [rpm]
Turbinen Wirkungsgrad	0,9
Generator Wirkungsgrad	0,96
Cos Phi	0,9
Transformator Wirkungsgrad	0,99

Turbinen Leistung ~	990 [kW]
Generator Leistung ~	950 [kW]
Generator Leistung ~	1060 [kVA]
Kosteninformation Turbine	580.000 €
Kosteninformation E-Technik	220.000 €
Kosteninformation Generator	180.000 €
Kosteninformation Elektromechanische Ausrüstung	980.000 €

Lieferumfang

- Turbine
- Hilfsaggregate (Hydraulic, Absperrorgan, Bremse und Kühlwasser falls erforderlich)
- Generator
- Elektrotechnik
- Transport
- Montage Supervision
- Inbetriebnahme

Lieferzeit für Elektromechanische Ausrüstung

Weiter Kosteninformationen anhand statistischer Werte:

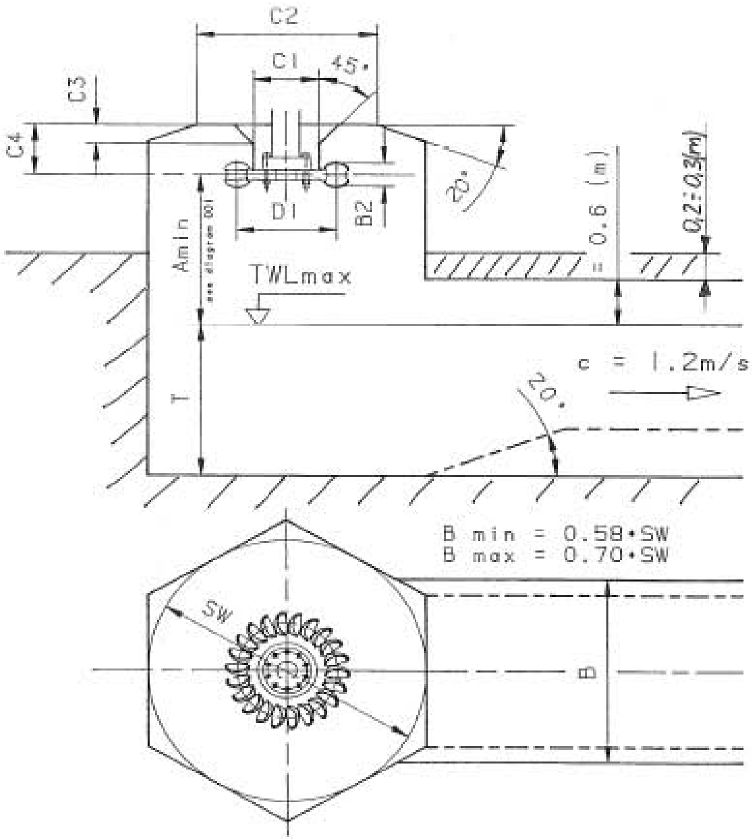
Volllaststunden	4500	[h]
Jahresleistung bei 4500 Volllaststunden	4.230,00	[MWh]
CO2 Equivalenzfaktor	0,7	
CO2 Einsparungs Equivalent	3.000,00	[T CO2 Equivalenz]

Haushalte mit Strom versorgt werden, bei einem Durchschnittlichen Jahreshaushaltsverbrauch von

Haftungsausschluss

Unsere Feasibility Indication basiert auf den von Ihnen zur Verfügung gestellten Daten und Informationen. Alle hierin angeführten technischen Angaben, Daten, Leistungswerte, Preise und Lieferzeiten sind unverbindlich zu betrachten und dienen rein zur Information.

VERTICAL SHAFT MULTIJET CASING



Main dimensions for turbine:			
Project:	POARTA / Romania		
Turbine:	PV4c / 800 / 230		
D1	800	mm	
B2	230	mm	
C1	478	mm	
C2	1536	mm	
C3	184	mm	
C4	483	mm	+ appr. 100 mm for flange thickness
C5		mm	
C6		mm	
C7		mm	
C8		mm	
B	1537	mm	
R1		mm	
E1		mm	
E2		mm	
F1		°	
SW	2364	mm	
Tc	434	mm	
Lc	4,3	m	
W		mm	
W1		mm	
W2		mm	
T	1051	mm	
Amin (CL)	1,37	m	

All dimensions are for information only!

ARCHITEKT MAG. ARCH. GOTTFRIED HASELMEYER
Staatlich befugter und beeideter Ziviltechniker

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Fax 0 27 42 / 35 18 35 – 4
e-mail office@haselmeyer.at
Internet www.haselmeyer.at

St. Pölten, am 24.11.2010

Grobkostenschätzung Projekt Poarta

Sehr geehrte Frau Irene Leitner!

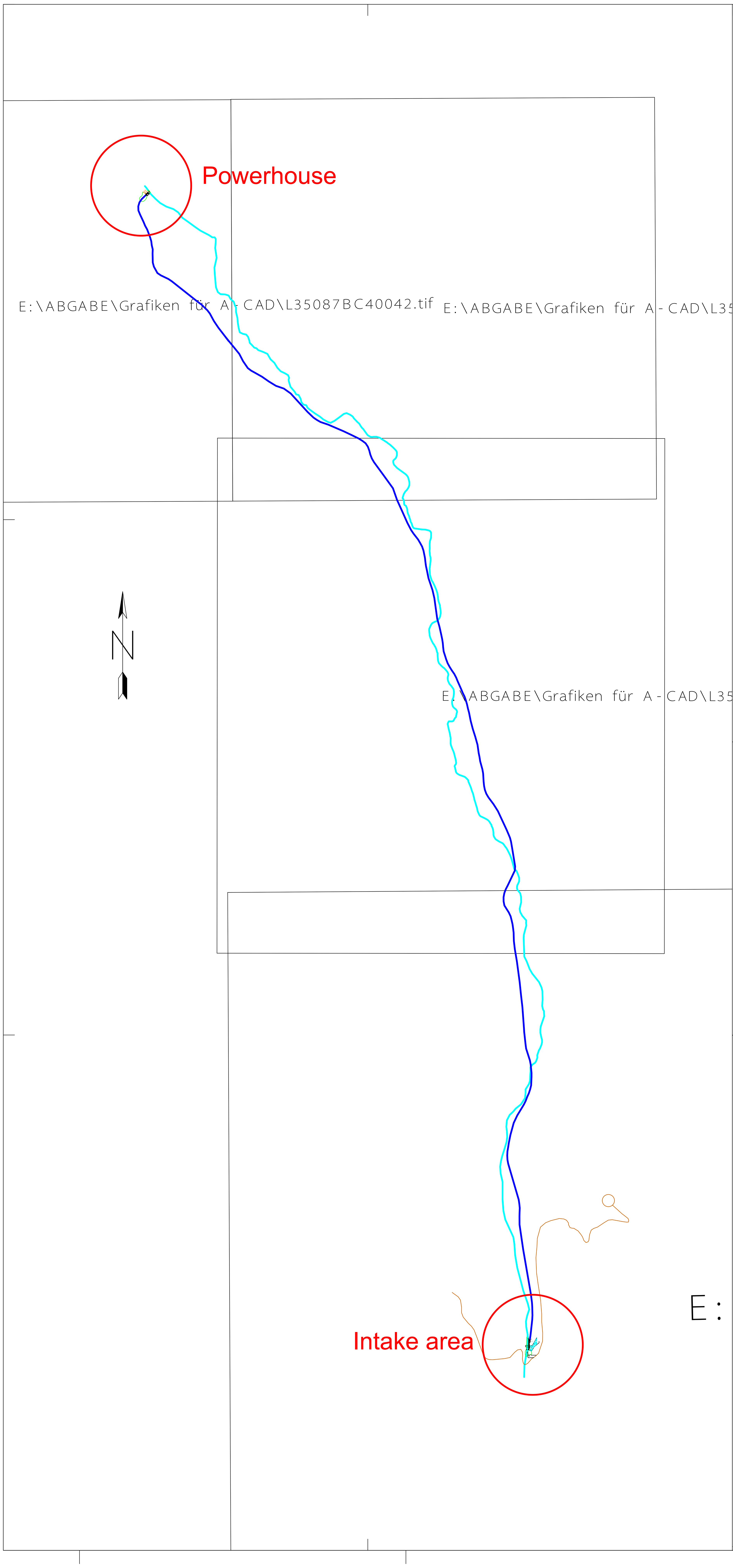
Wir beziehen uns auf Ihr Email samt dwg Datei „Projekt Hidro 04-11-2010" und geben Ihnen die geschätzten reinen Baukosten (ohne Einrichtung) wie folgt bekannt:

47,65m2 x 3.000,- =	€ 142.950,00	
gerundet	**€ 143.000,-**	**Netto**

folgende Annahmen wurden zugrunde gelegt: verkehrstechnisch mit LKW normal erreichbar, Bodenbeschaffenheit tragfähig.

Mit freundlichen Grüßen

Architekt Haselmeyer



office map of the political district Brasov
total penstock length: 4086 m
total head difference: 155 m
intake area at 900 m
powerhouse at 739 m
average slope: -3.4 %

Poarta creek

penstock DN 800

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Institut für Wasserwirtschaft, Hydrologie und konstruktiven Wasserbau

Small Hydropower Plant Poarta, Romania

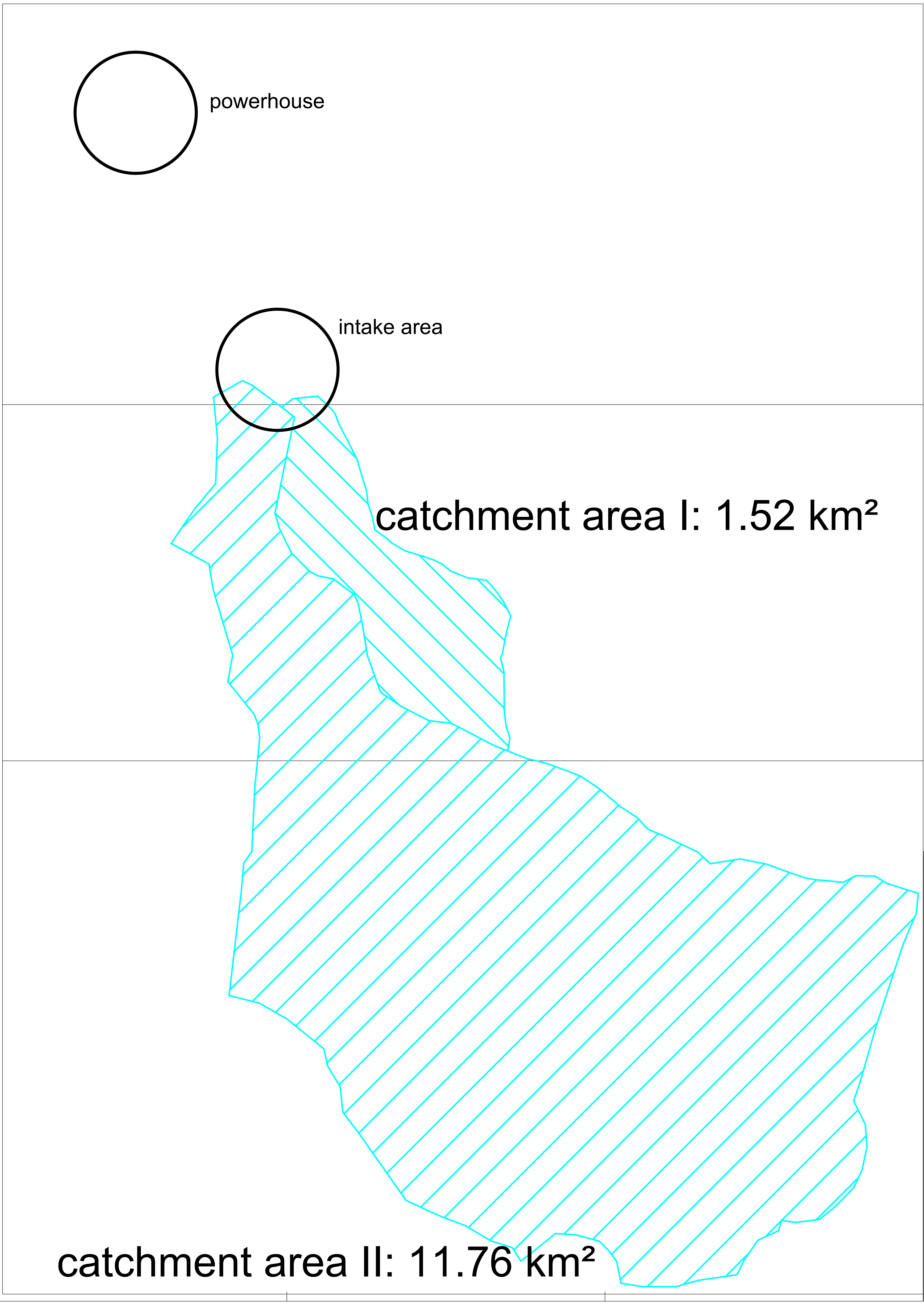
Overview site plan

SCALE	DESIGN
M 1:5000	Irene Leitner H 910 0240094 Date:December 2010

ADVISER
Dipl.-Ing. Dr. Bernhard Pelikan
Universität für Bodenkultur, Vienna

Diploma thesis

Insert no. 7.1



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Small Hydropower Plant
Poarta, Romania

catchment area

SCALE	DESIGN
M 1:10000	Irene Leitner H 910 0240094 Date:December 2010

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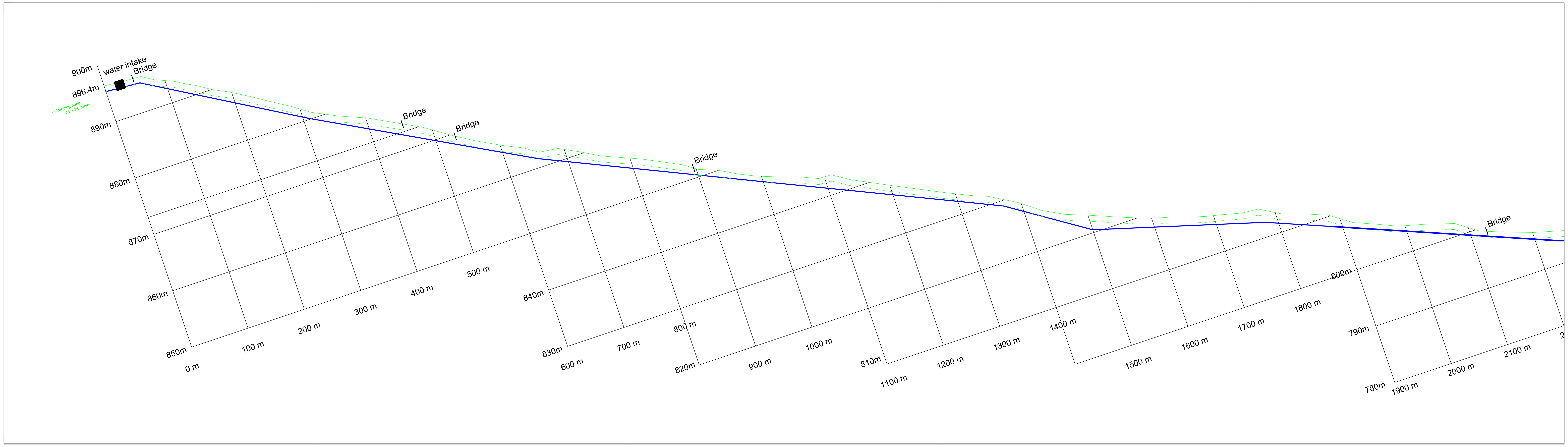
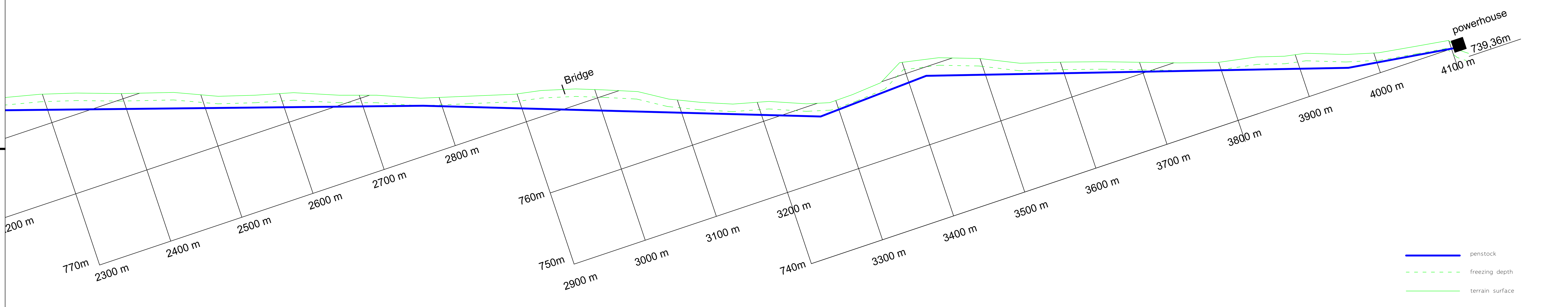
	Diploma thesis	Insert no. 7.2



Kleberand



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Small Hydropower Plant Poarta, Romania

longitudinal section

SCALE	DESIGN
M 1:2500/250	Irene Leitner H 910 0240094 Date:December 2010

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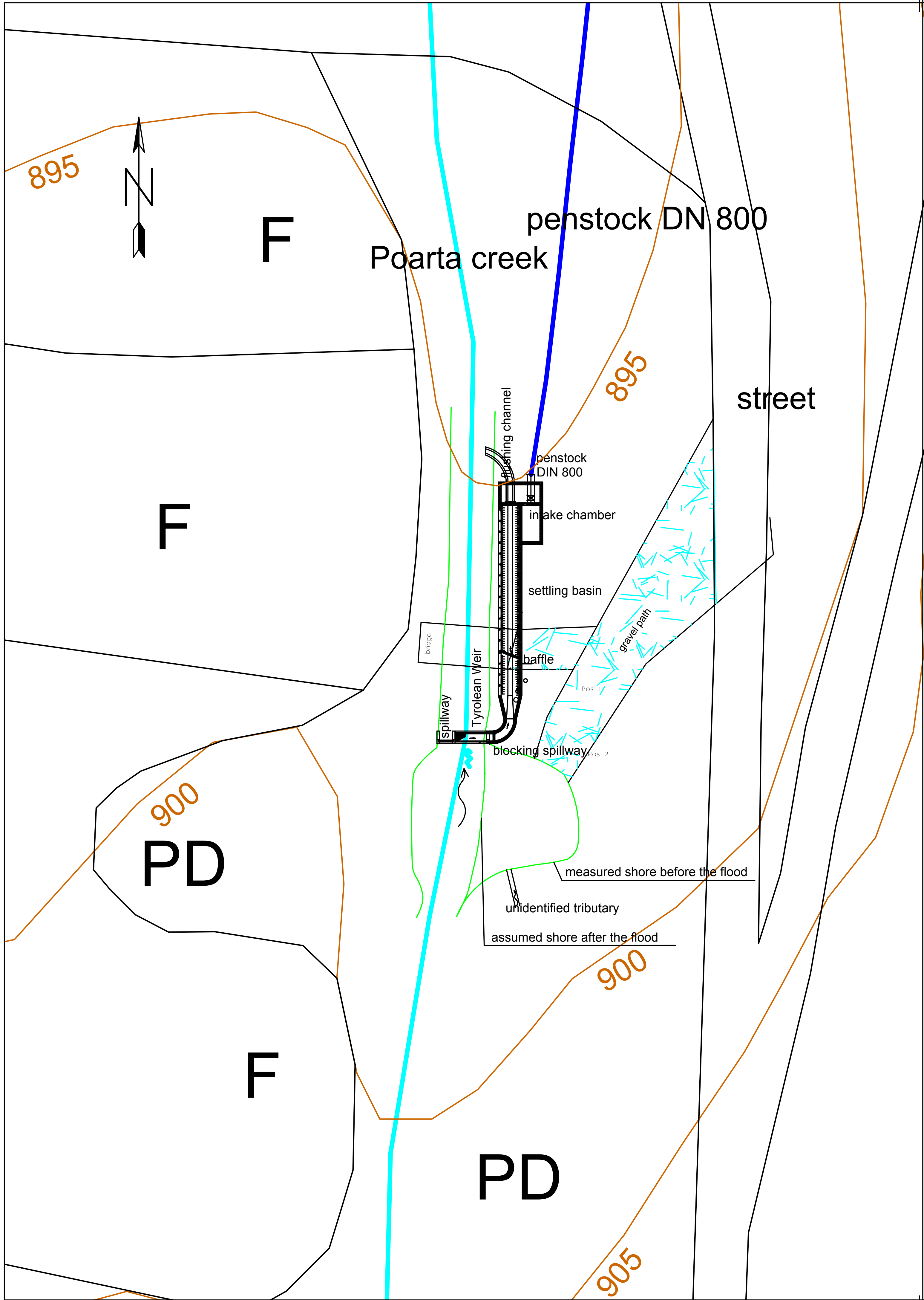

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Small Hydropower Plant Poarta, Romania

overview intake area

SCALE	DESIGN
M 1:500	Irene Leitner H 910 0240094 Date:December 2010

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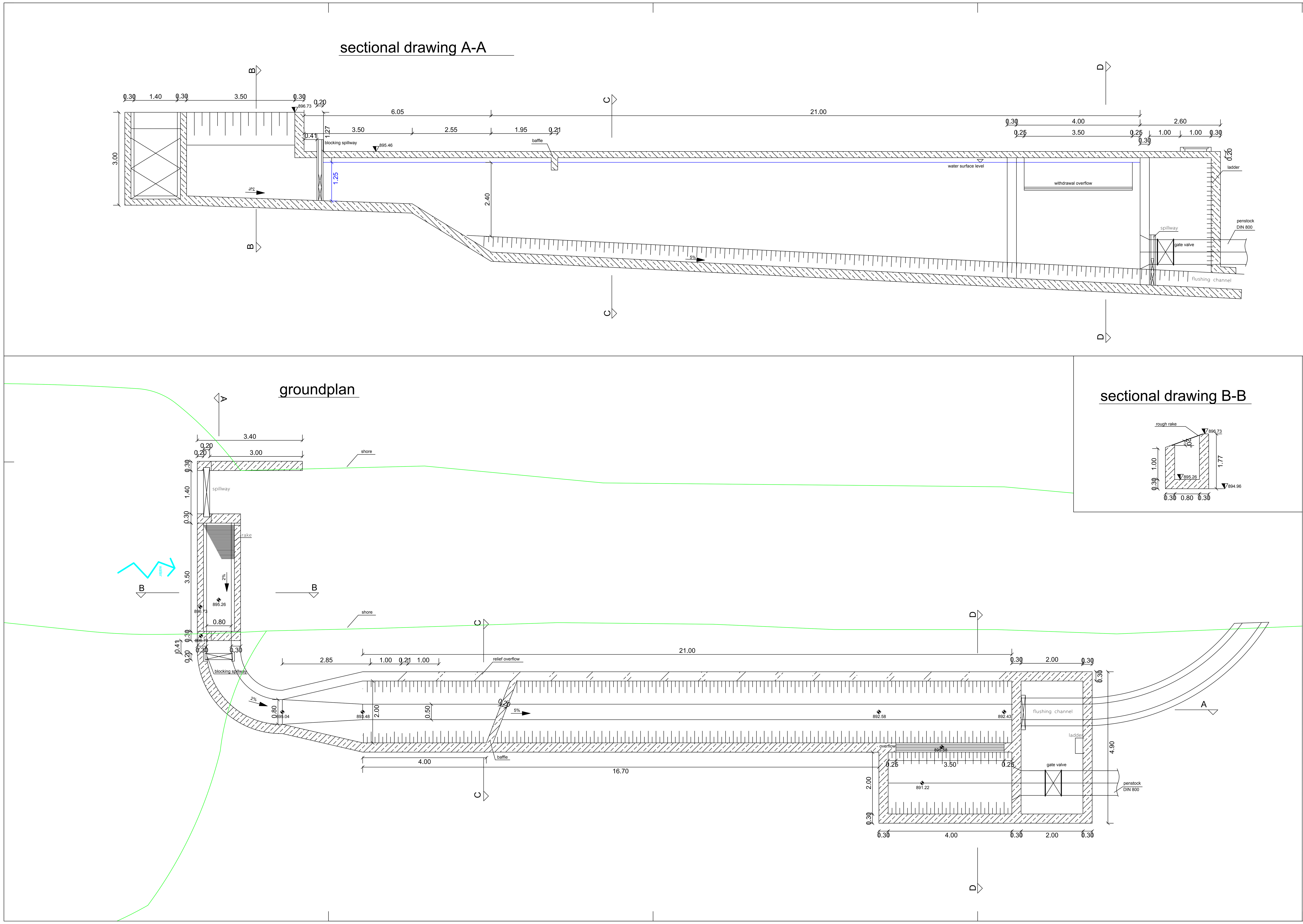
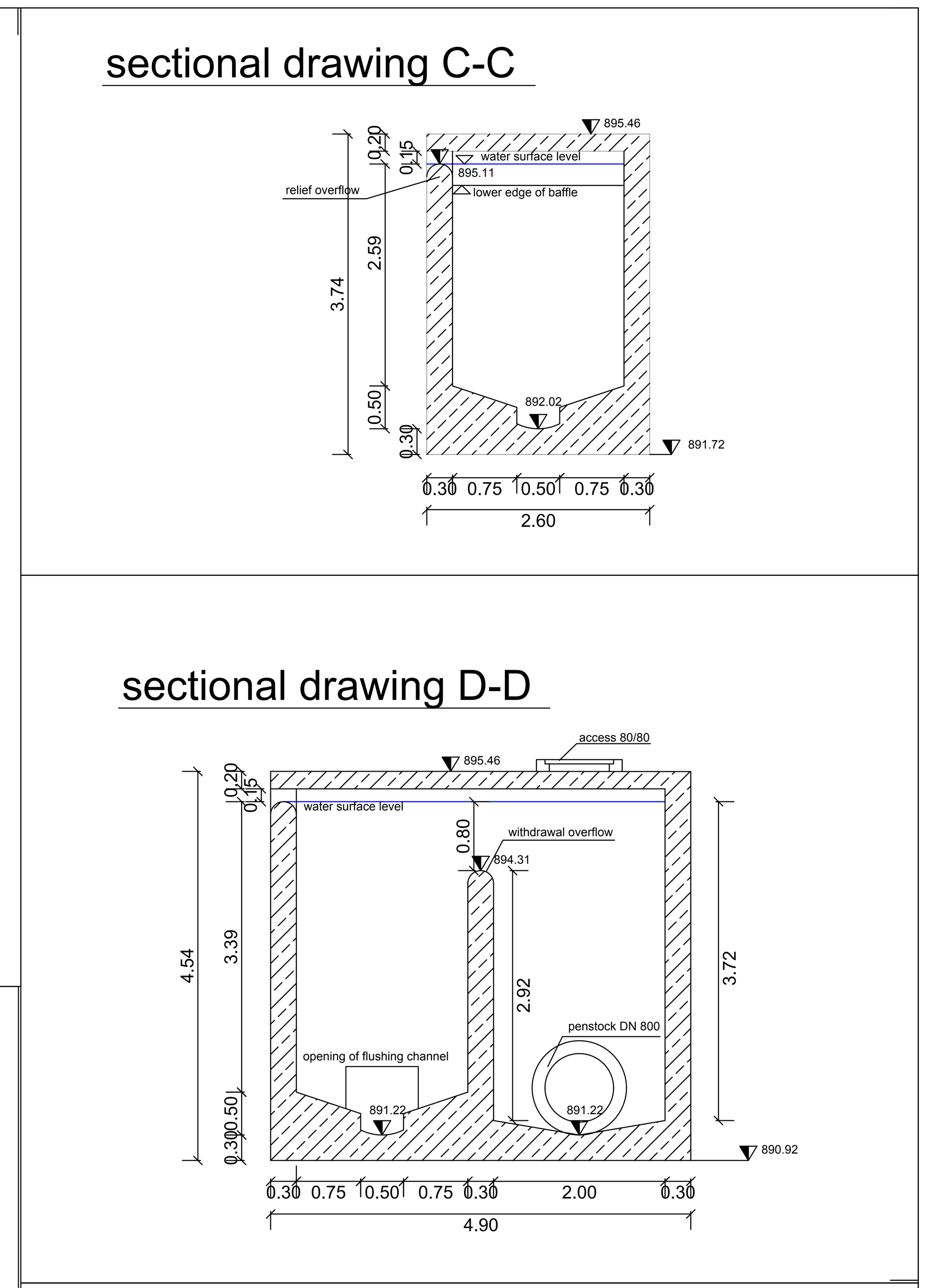
	Diploma thesis	Insert no. 7.4





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Small Hydropower Plant Poarta, Romania

Details intake area

groundplan and cross-sections

SCALE	DESIGN
M 1:50	Irene Leitner H 910 0240094 Date:December 2010

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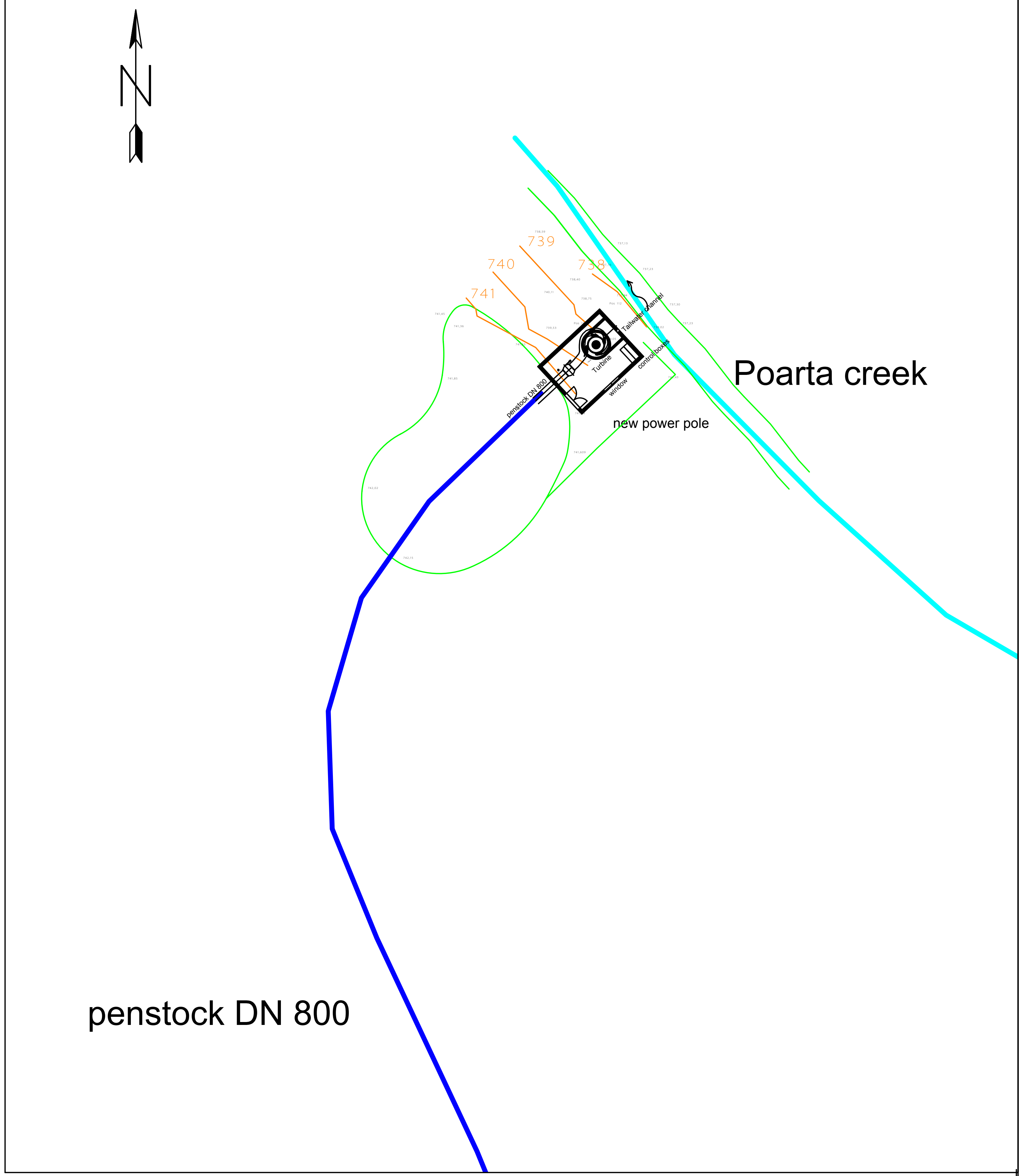
Insert no.
7.5



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Small Hydropower Plant Poarta, Romania

overview powerhouse area

SCALE	DESIGN
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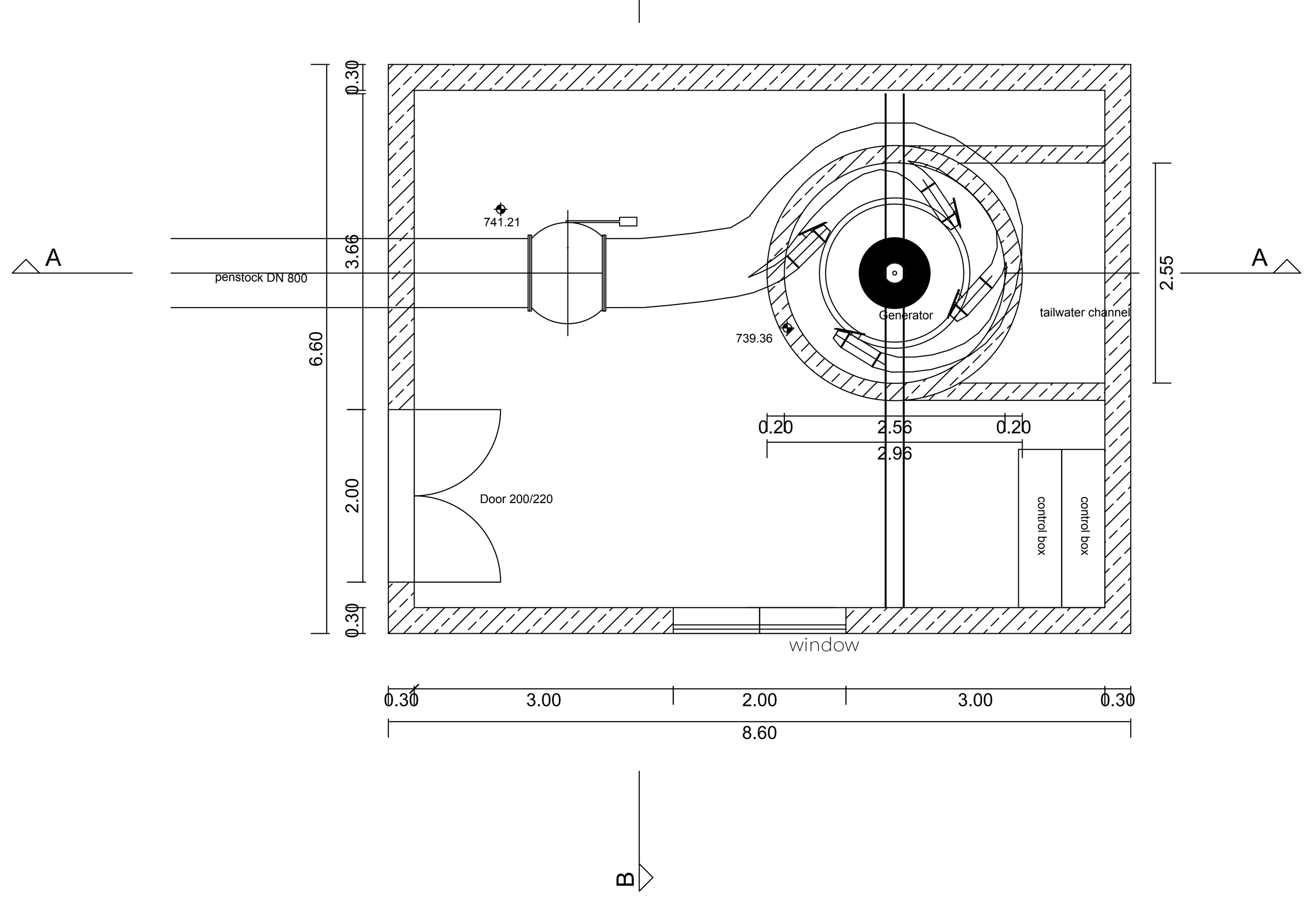
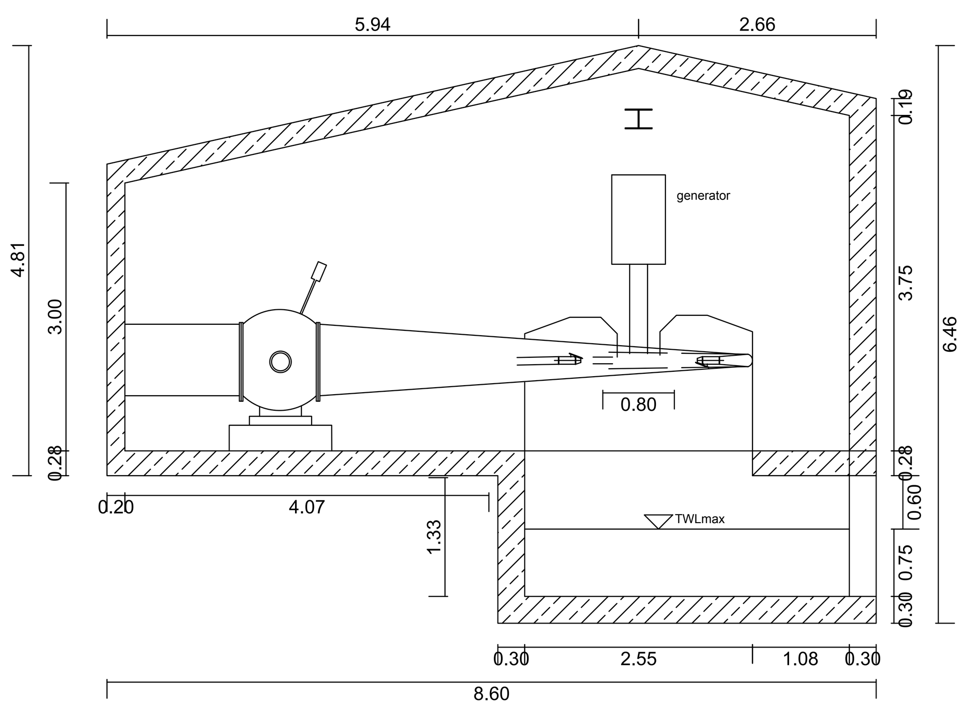
	Diploma thesis	Insert no. 7.6

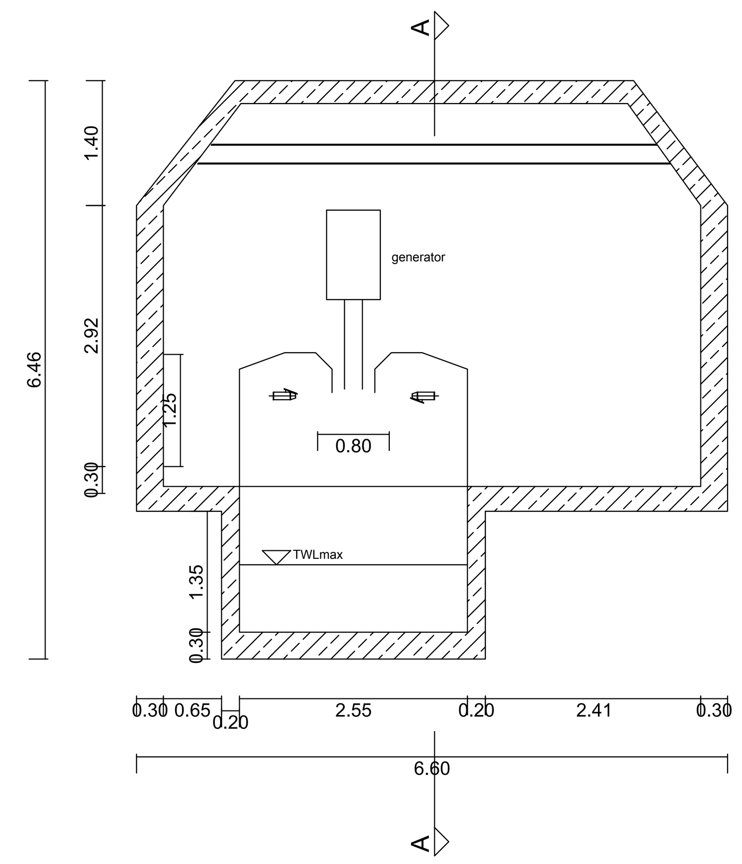
groundplan



sectional drawing A-A



sectional drawing B-B



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Small Hydropower Plant Poarta, Romania

Details powerhouse
groundplan and cross-sections

SCALE	DESIGN
M 1:50	Irene Leitner H 910 0240094 Date:December 2010

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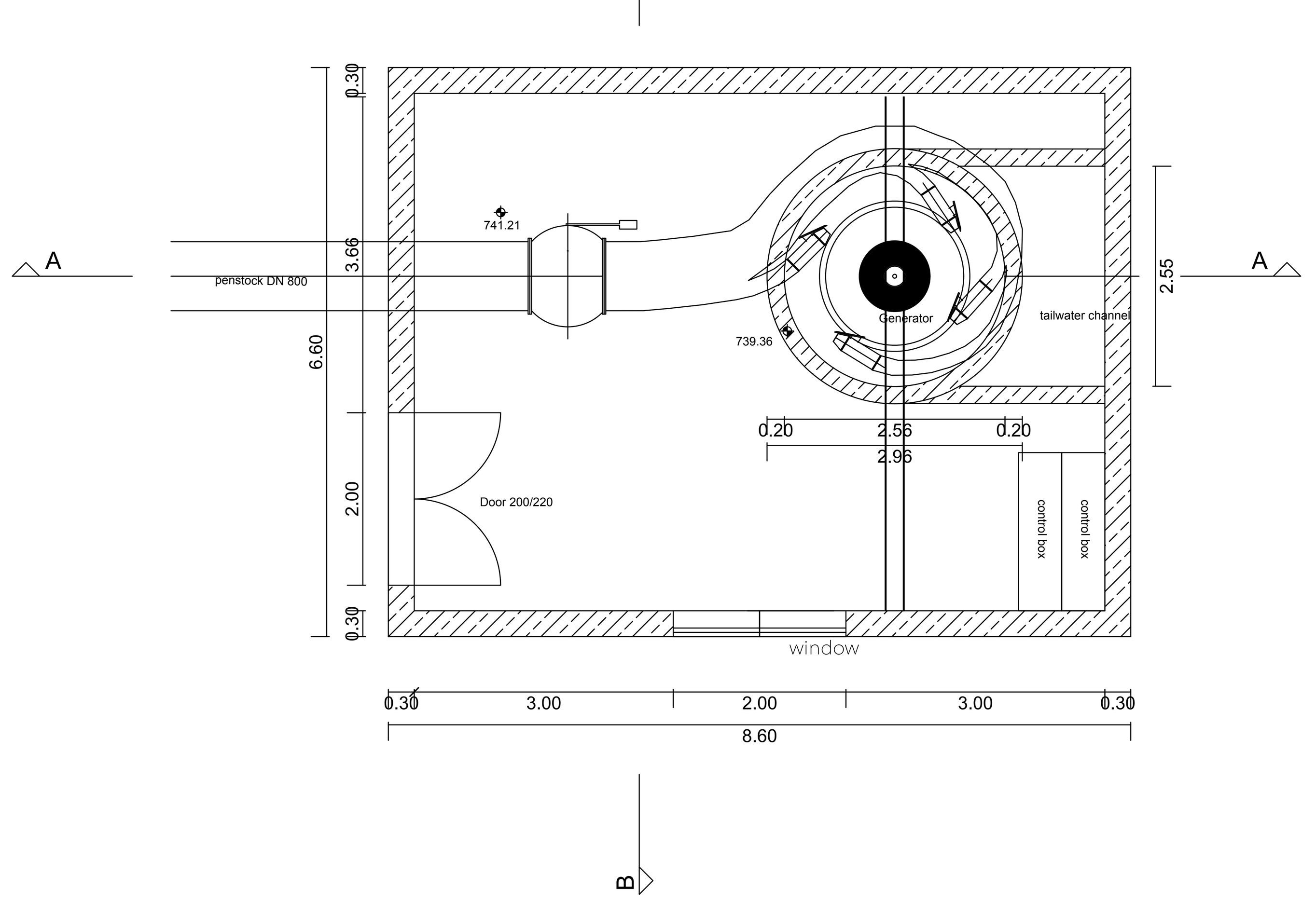
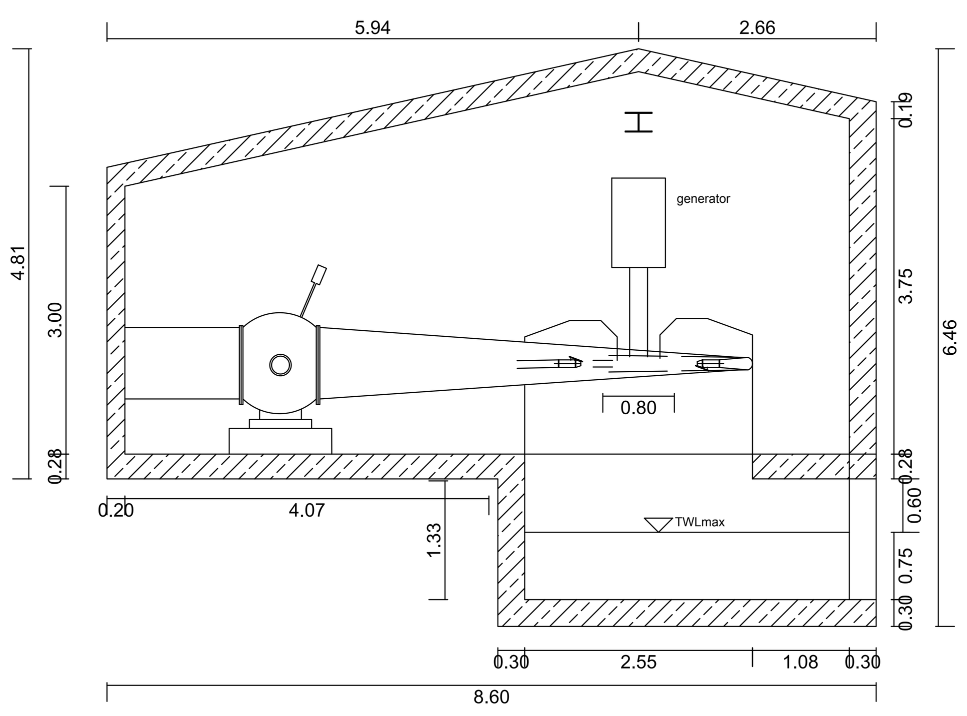
	Diploma thesis	Insert no. 7.7

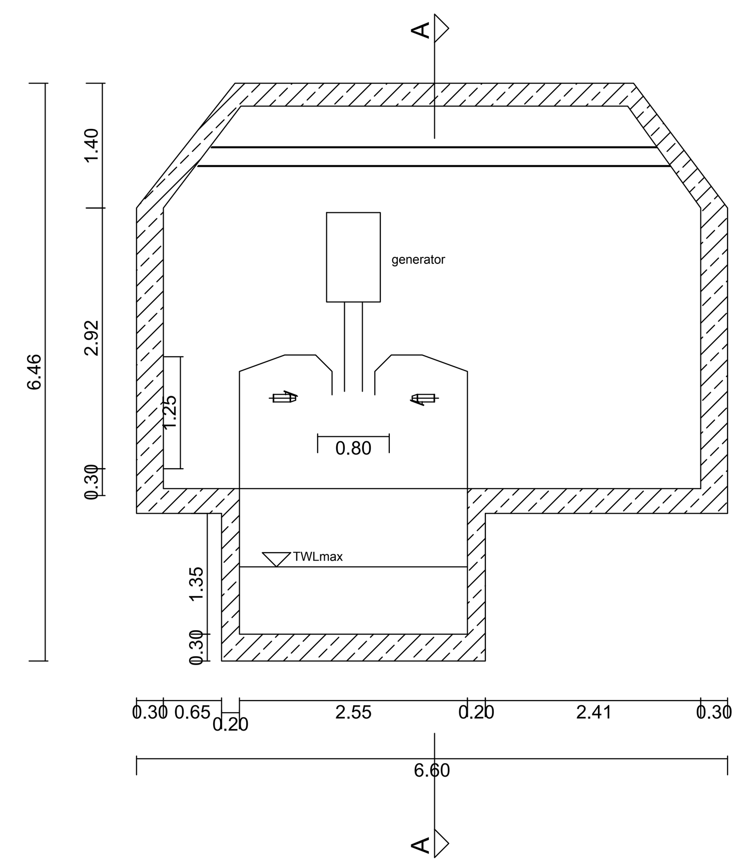
groundplan



sectional drawing A-A



sectional drawing B-B



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Small Hydropower Plant Poarta, Romania

Details powerhouse
groundplan and cross-sections

SCALE M 1:50 — DESIGN Irene Leitner, H 910, 0240094, Date:December 2010

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Universität für Bodenkultur, Vienna

Diploma thesis — Insert no. 7.7