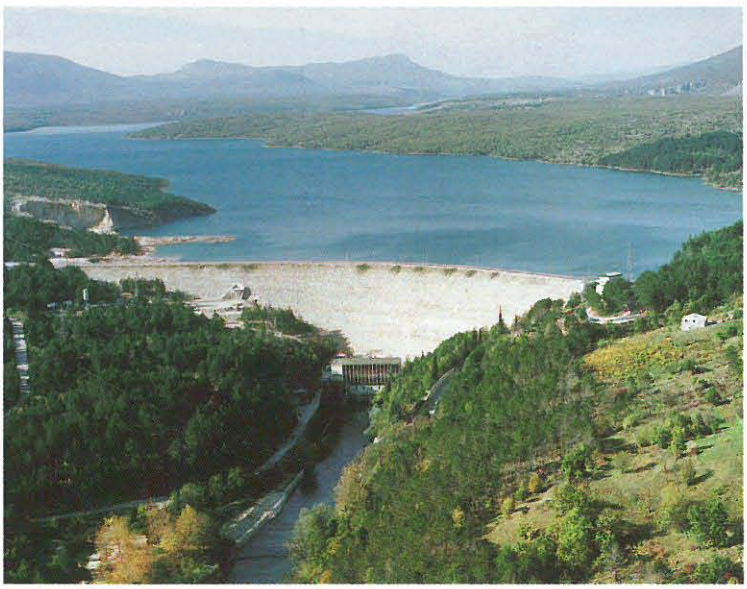
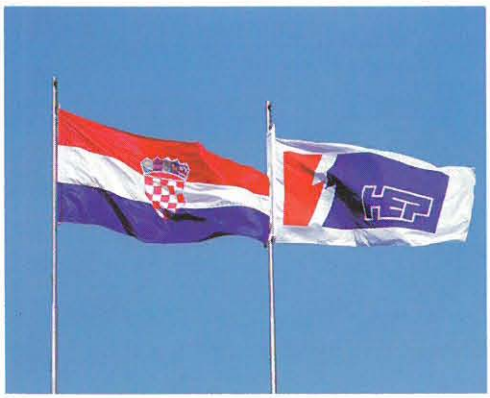
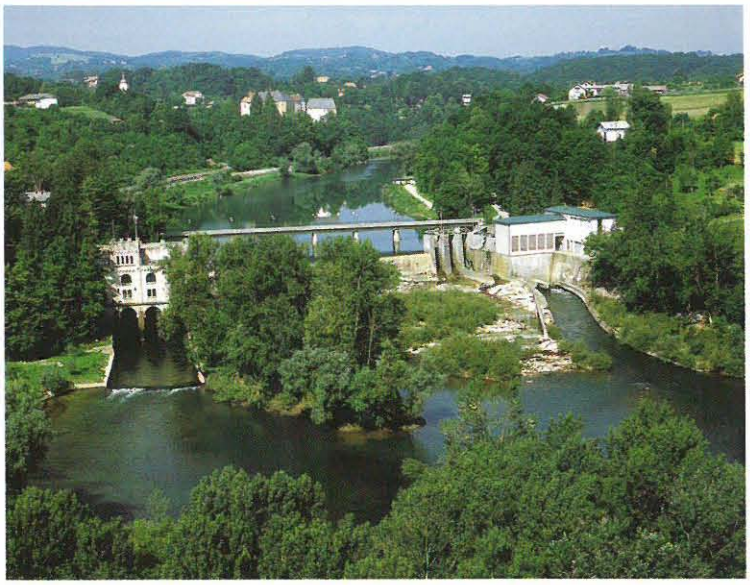




HYDROELECTRIC POWER PLANTS IN CROATIA



HYDROELECTRIC POWER PLANTS IN CROATIA

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THE BEGINNINGS OF THE HYDROPOWER POTENTIAL UTILIZATION IN CROATIA

The year 1895 should be taken as a milestone in development of water utilization in power generation projects in Croatia. That was the year when Šupuk company from Šibenik built Jaruga Hydroelectric Power Plant (HPP), the first power plant on the Skradinski Buk falls on the Krka River. This hydroelectric power plant used 10 m head for one turbine with 300 kVA single-phase generator, and the generated power was trans-mitted to 10 km distanced city of Šibenik and used for operation of mills, oil mil, paste factory, and street lighting. The new Jaruga HPP was built in 1904. Its installed capacity was 5.4 MW. This facility was extended in 1936, again to supply the Šibenik industry.

The development was furthered with construction of the Miljacka (Manojlovac) Hydroelectric Power Plant in 1906, also on the Krka, which supplied the Šibenik industry with power same as the Jaruga HPP. Its installed capacity was 17.7 MW, gross head 105 m, and installed discharge 24 m^3/s.

In 1908, 2.5 MW Ozalj HPP was built on the Kupa River, near the city of Karlovac. It was the first larger hydroelectric power plant in the continental part of Croatia, and was used for street lighting of the city of Karlovac.

The largest hydroelectric power plant at that time was Kraljevac HPP, built in 1912 on the Cetina River. Initially, it supplied with power the carbide factory in Dugi Rat. The power plant was built complete with the dam on the Cetina River and a diversion, and using the gross head of 100 m at installed discharge of 30 m^3/s. It was fitted with two generating units, rated 12.8 MW each, so the total installed capacity of the power plant at the time was 25.6 MW. In 1932, The second stage of the Kraljevac HPP was built. Two generating units were installed, 20.8 MW each, installed discharge 50 m^3/s. With total installed capacity of 67.2 MW and installed discharge of 80 m^3/s, the Kraljevac HPP was the largest hydroelectric power plant in the Balkans.

By the end of the Second World War, with the exception of the 1.7 MW Duga Resa HPP on the Mrežnica River, all other hydroelectric power plants had the capacity up to 1 MW. At the eave of the Second World War, 165 power plants were in operation in Croatia, with installed capacity of 176 MW, and the most of them were hydroelectric power plants.

After the Second World War, the reconstruction of the facilities damaged during the war started and the preparations for construction of the new ones were initiated. This was the period when the construction of the hydroelectric power system was conceived. The hydroelectric power plants were no more considered as facilities harnessing the favorable local river conditions. Rather, the concept of utilizing the entire catchment areas and planned water harnessing prevailed.

The first power plants which enhanced the Croatian power system capacities were commissioned in 1952. These were 84 MW Vinodol HPP whose construction lasted, with interruptions, from 1939, 2.1 MW Zavrelje HPP near Dubrovnik and Ozalj 2 HPP. The construction of new hydroelectric power plants and increase in installed power has been continuous since.

CROATIAN WATER POWER

The majority of the Croatian water power is concentrated on 23 major water courses. The Drava, Sava, Kupa and Una watercourses partly run through Croatia. The Trebišnjica River is in Bosnia and Herzegovina, but its power generation capacities are the most favorable on the head towards the Adriatic sea which belongs to Croatia. Therefore, that part of its potential is shown as the part of the Croatian hydro potential.

Below is given the tabulated presentation of the gross capacities of the major water courses. The part which can still be technically exploited and the development level to the present day.

WATER COURSE	GROSS WATER POWER (TWh)	TECHNICALLY EXPLOITABLE (TWh)	DEVELOPED WATER POWER (TWh)	DEVELOPMENT LEVEL (%)
DRAVA*	4.00	2.60	1.23	47.3
SAVA*	3.80	1.00	0.00	0.0
KUPA	3.03	2.00	0.24	11.9
UNA*	0.20	0.10	0.00	0.0
RJEČINA	0.56	0.18	0.12	66.6
MIRNA	0.08	0.04	0.00	0.0
RAŠA	0.04	0.02	0.00	0.0
LIKA and GACKA	2.00	1.40	1.00	71.4

WATER COURSE	GROSS WATER POWER (TWh)	TECHNICALLY EXPLOITABLE (TWh)	DEVELOPED WATER POWER (TWh)	DEVELOPMENT LEVEL (%)
LIČANKA-LOKVARKA	0.20	0.15	0.13	86.8
KRKA	1.02	0.66	0.16	24.2
ZRMANJA	0.20	0.10	0.00	0.0
CETINA	5.70	3.70	2.75	74.3
TREBIŠNJICA*	0.50	0.50	0.50	100.0
TOTAL	21.33	12.45	6.13	49.2

* only the parts belonging to Croatia

CONSTRUCTION OF HYDROELECTRIC POWER PLANTS IN CROATIA

Since its beginning in 1895, the hydroelectric power plant projects in Croatia reached their peak after the Second World War, when the significant utilization of the water potentials commenced. Since the first hydroelectric power plant, Jaruga, was put into operation, the following facilities were constructed:

Hydroelectric power plant	*Commissioned in*	*Hydroelectric power plant*	*Commissioned in*
Jaruga HPP	1895/1903	Senj HPP	1965
Miljacka HPP	1906	Dubrovnik HPP	1965
Ozalj HPP	1908	Rijeka HPP	1968
Kraljevac HPP (first and second stage)	1912/1932	Sklope HPP	1970
Vinodol HPP	1952	Orlovac HPP	1974
Zavrelje HPP	1952	Varaždin HPP	1975
Ozalj 2 HPP	1952	Golubić HPP	1981
Miljacka HPP	1956	Čakovec HPP	1982
Fužine PHPP	1957	Velebit PHPP	1984
Gojak HPP	1959	Lepenica HPP	1987
Peruća HPP	1960	Dubrava HPP	1989
Zakučac HPP (first and second stage)	1961/1980	Đale HPP	1989

This table does not include the small hydroelectric power plants with less than 1 MW installed capacity.

Construction of the above enlisted hydroelectric power plants resulted in increase in installed capacity and power output in Croatia. The following table gives an overview of hydropower exploitation based installed capacities and gross power outputs in comparison with the total installed capacities and outputs of all power generation facilities in Croatia.

Since the recent war which started in 1991, the situation in the country enabled undertaking of only maintenance and rehabilitation activities in individual facilities and development of design documentation for the new ones.

Year	Installed capacity (MW)		Output (GWh)	
	TOTAL	HPPs	TOTAL	HPPs
1945	178	97	224	94
1950	188	89	577	326
1960	470	289	1671	1197
1970	1334	798	4622	3656
1980	2922	1577	9208	6253
1990	3644	2075	11294	4158
1997	3746	2075	11217	5246

According to the available data, currently available Croatian production capacities total 4396 MW. Out of the total available capacity, 47% is hydro power, and 44% is thermal power which includes 650 MW outside the Croatian borders. The remaining capacities include the Krško Nuclear Power Plant and the diesel facilities.

HYDROELECTRIC POWER PLANT

JARUGA

The Jaruga 2 Hydroelectric Power Plant (HPP) is one of the oldest power generating facilities in the world. Its present location dates back to 1903, and it is placed in the vicinity of an even older station from 1895. Since its construction in 1903, the Jaruga HPP has been refurbished on several occasions (1916, 1937, 1970 and 1995), and the basic concept had always been maintained.

The Jaruga HPP is the last power plant in the Krka catchment, from its spring to the sea. It uses the gross head of about 26 m, which is a portion of the naturally concentrated head of about 45 m at the Skradin Buk waterfall. Visovačko Jezero lake is upstream the waterfall and the Krka and Prokljansko Jezero lake, affected by the sea backwaters, downstream. This is a typical run-off-the-river plant of diversion type, with no possibility of water regulation. Total installed capacity is 5.4 MW and average annual output 35 GWh.

The Jaruga HPP run-off-the-river system includes a diversion intake structure in the abutment of the small impounded stretch of the Krka at the Skradinski Buk waterfall. The spillway sill of this impoundment is on elevation of about 25.30 m a.s.l., which is half-way the waterfall height. The run-off-the-river system consists of the intake structure with a flat sill and four bays fitted with sliding gates, tunnel driven in travertine (with gravity flow), concrete (self-regulated) canal with almost vertical sides which expands into a compensation reservoir - forebay, partition structures fitted with two groups of five sliding gates each, two penstocks connected to turbines and draft tubes with outlets into the Krka.

The power house is a massive brickwork building, 13.00 x 35.00 m, total height 14.00 m, which accommodates two generating units with double horizontal-shaft Pelton-Francis turbines, installed flow rate 15.5 m^3/s and rating 2.94 MW.

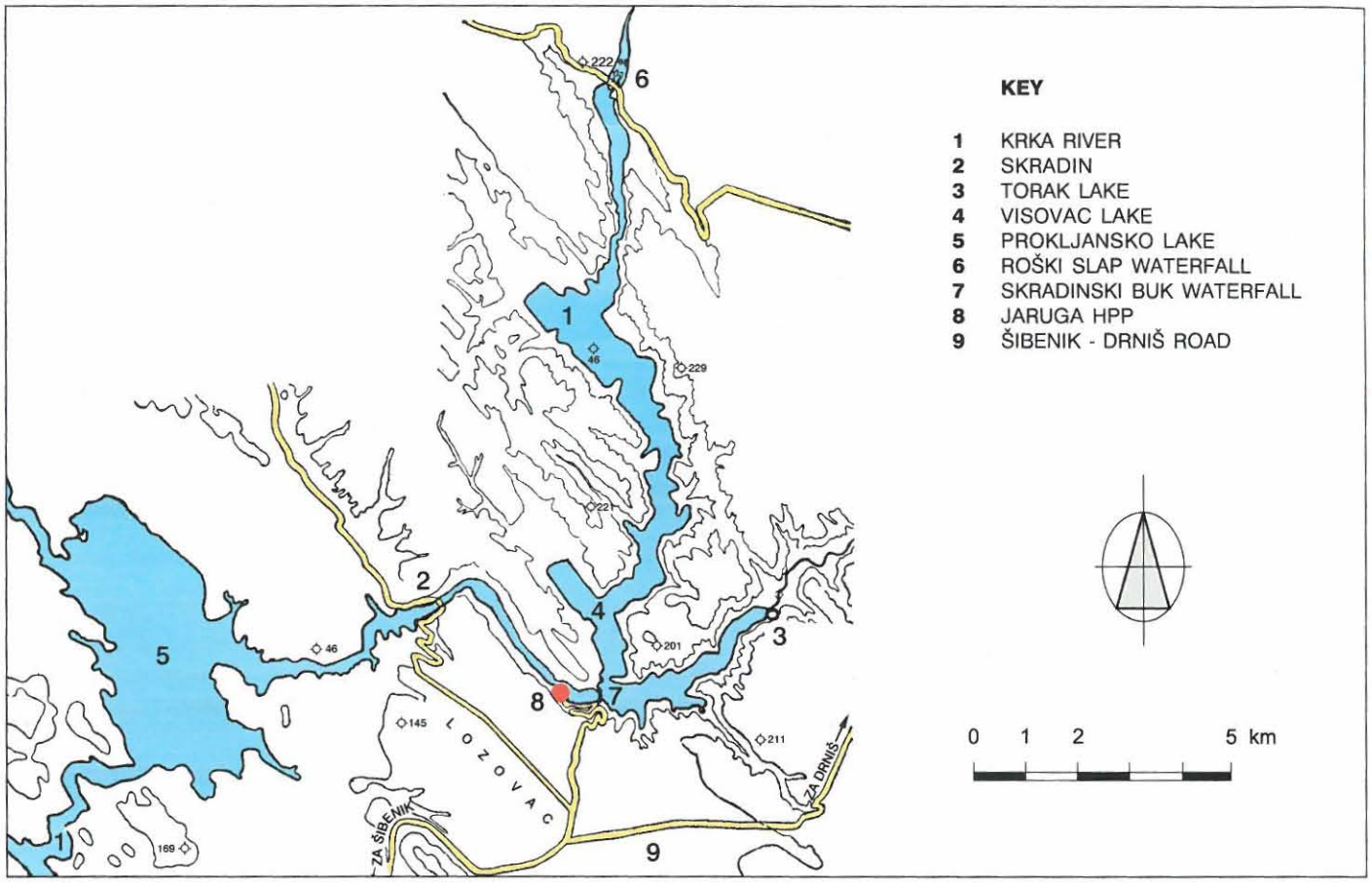
The generators are 4 MVA, horizontal-shaft. Since the rating of the existing turbines is insufficient, the generators are operating below their rated power and the output is consequently lower than possible.

The generators, same as turbines, were manufactured in 1937. The turbines were manufactured by Voith, Austria. The equipment for the power plant built in 1903 was manufactured by Ganz, and its refurbishment in 1937 was based on the original power plant concept. The generator rehabilitation from 1974 was carried out by Končar Zagreb.

The 6.3 kV switchgear has seven bays, and was refurbished in 1994.

BASIC TECHNICAL CHARACTERISTICS

HYDROLOGICAL DATA	*mean annual rainfall*	1,337 mm
	Krka flow rate at Skradinski Buk waterfall	
	- mean annual	51.11 m^3/s
	- minimum	7.1 m^3/s
POWER GENERATION DATA	*gross head*	26 m
	installed discharge	Q_i = 31 m^3/s
	installed capacity	2 x 2,7 = 5,4 MW
	mean annual output	35 GWh
EQUIPMENT DATA		
turbines	*type*	Pelton-Francis, double, horizontal-shaft
	year of manufacture	1936
	units	2
	rating	2.94 MW
	design head	24.5 m
	installed discharge	15.5 m^3/s
	speed	375 rpm
generators	*type*	three-phase, synchronous
	year of manufacture	1936
	units	2
	rating	2 x 4,000 kVA
	voltage	6,300 V, 50 Hz
	power factor	cos φ = 0.7
	speed	n = 375 rpm
switchgear		6.3 kV



JARUGA HPP GENERAL MAP

DATA ON STRUCTURES

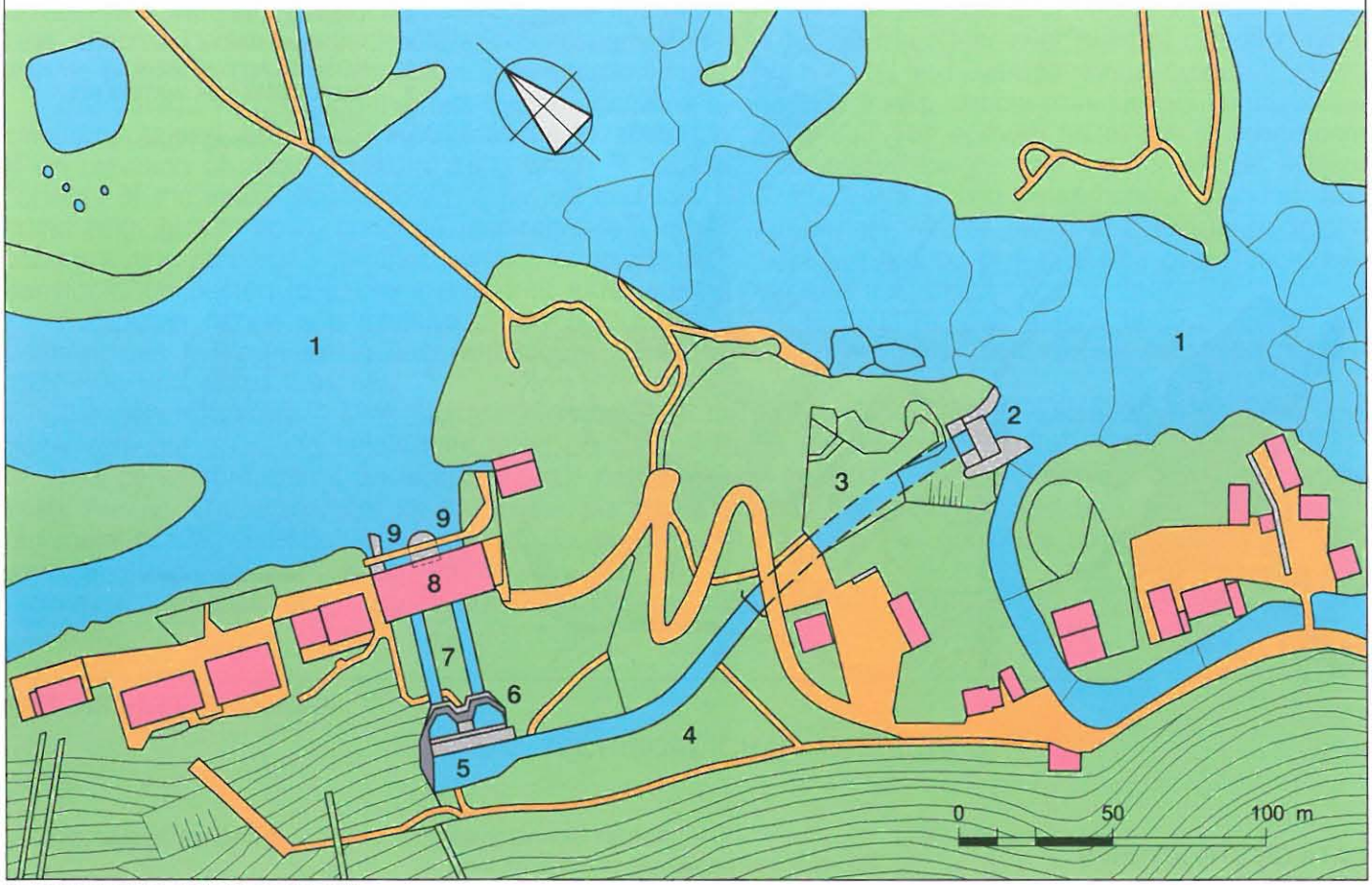
headrace tunnel	*length*	82.7 m
	head	6.2 ‰
headrace canal	*length*	78 m
	head	6.2 ‰
penstock	*length*	28 m
	diameter	2.5 m

POWER PLANT COMMISSIONING

Construction start:	1895
Construction end and start of power generation exclusively for street lighting:	June 12, 1895
New power plant constructed:	1903

KEY

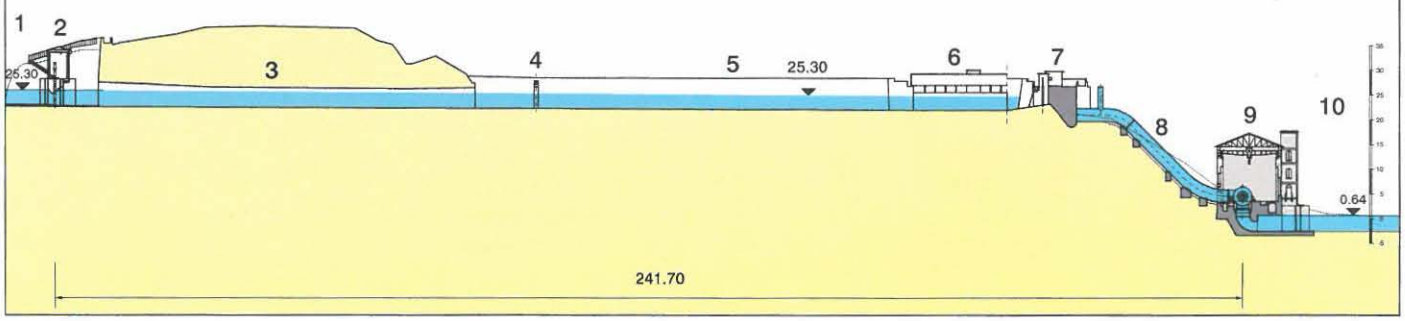
1 KRKA RIVER
2 INTAKE STRUCTURE
3 HEADRACE TUNNEL
4 HEADRACE CANAL
5 SURGE CHAMBER
6 PARTITION STRUCTURE
7 STEEL PENSTOCK
8 POWER HOUSE
9 OUTLET STRUCTURE



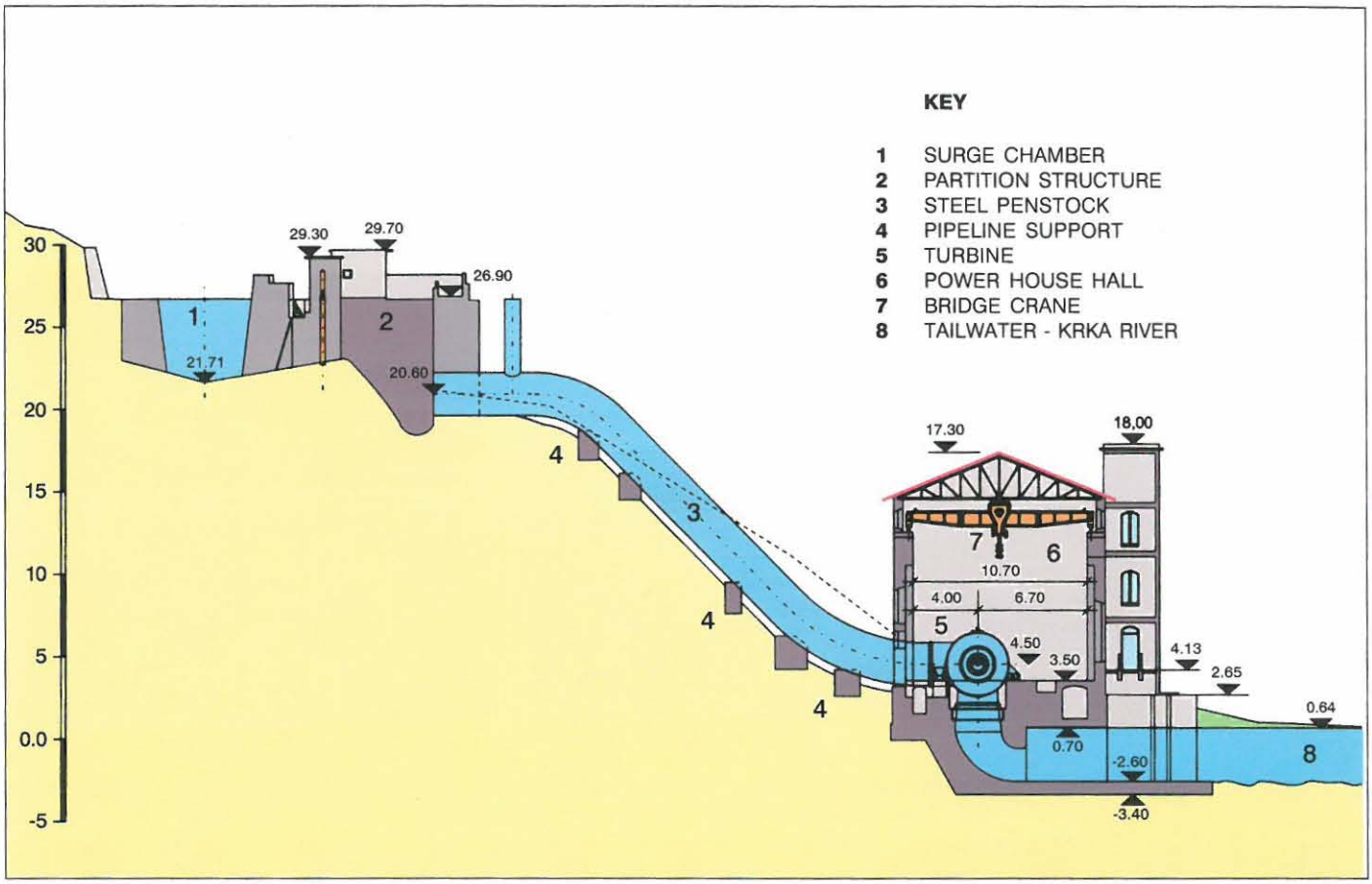
STRUCTURES ARRANGEMENT

KEY

1 HEADWATER - KRKA RIVER
2 INTAKE STRUCTURE
3 HEADRACE TUNNEL
4 BRIDGE
5 HEADRACE CANAL
6 SURGE CHAMBER
7 PARTITION STRUCTURE
8 STEEL PENSTOCK
9 POWER HOUSE
10 TAILWATER - KRKA RIVER

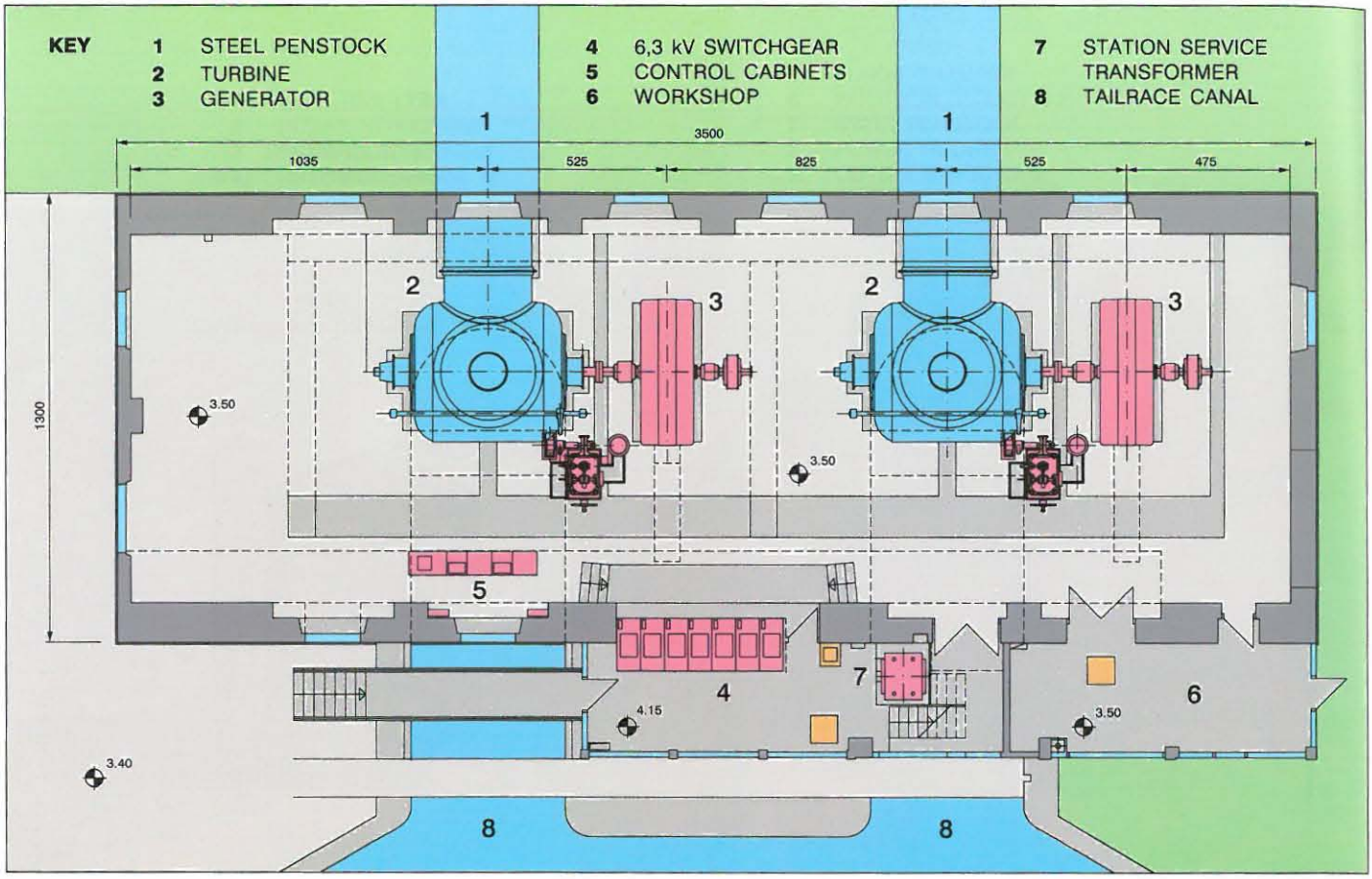


POWER PLANT LONGITUDINAL SECTION

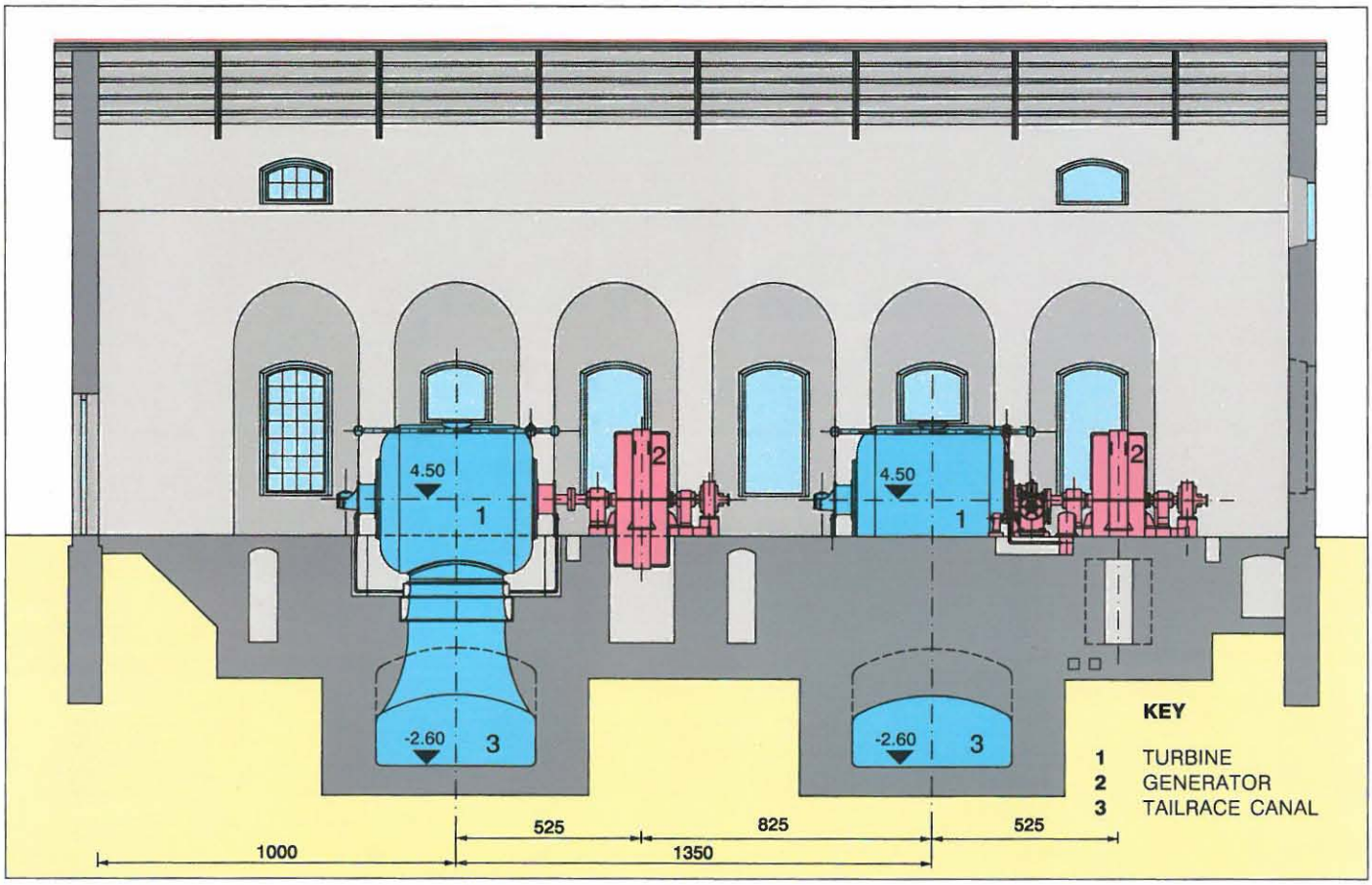


JARUGA HPP LONGITUDINAL SECTION

POWER HOUSE

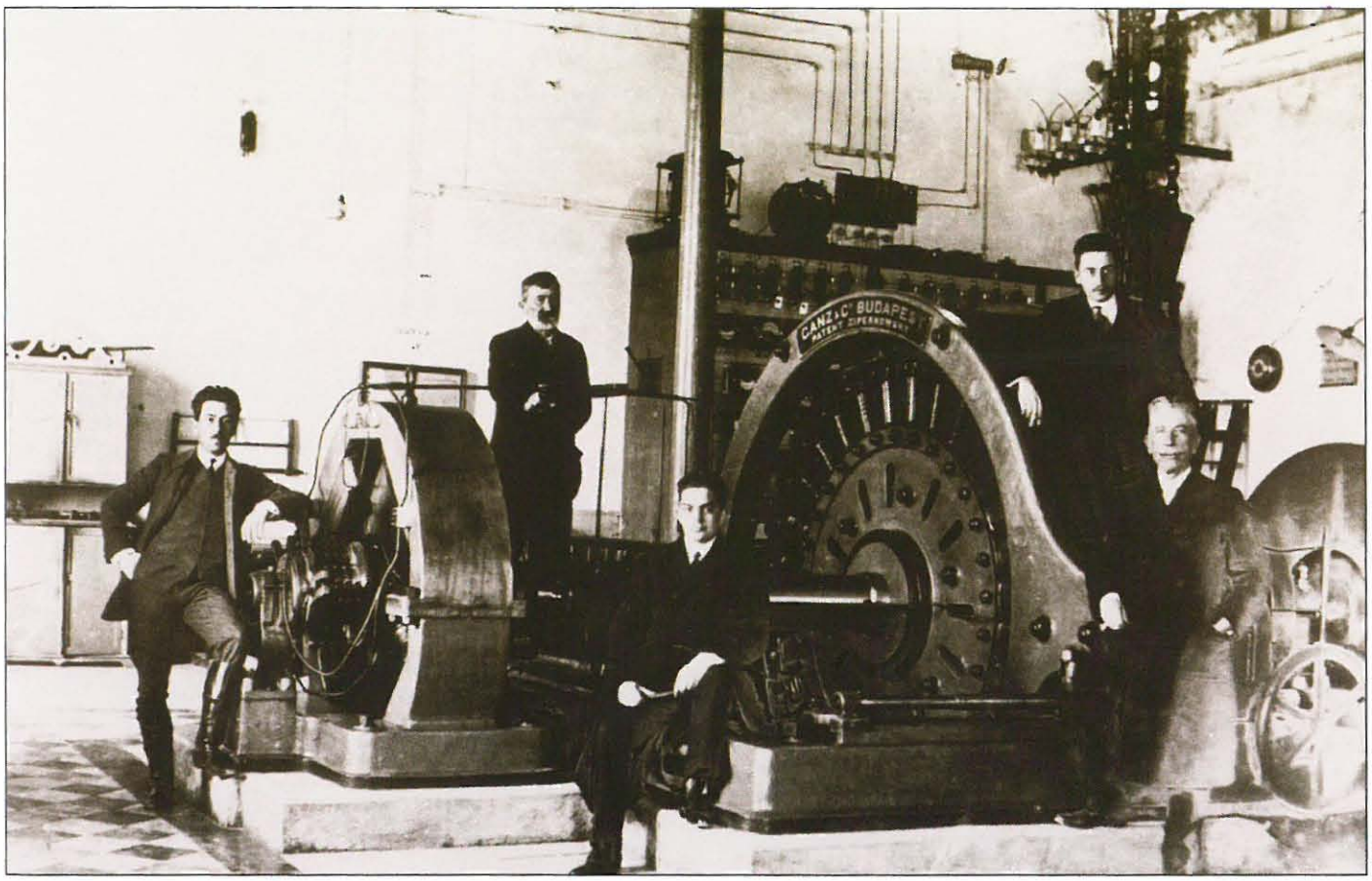


POWER HOUSE LAYOUT

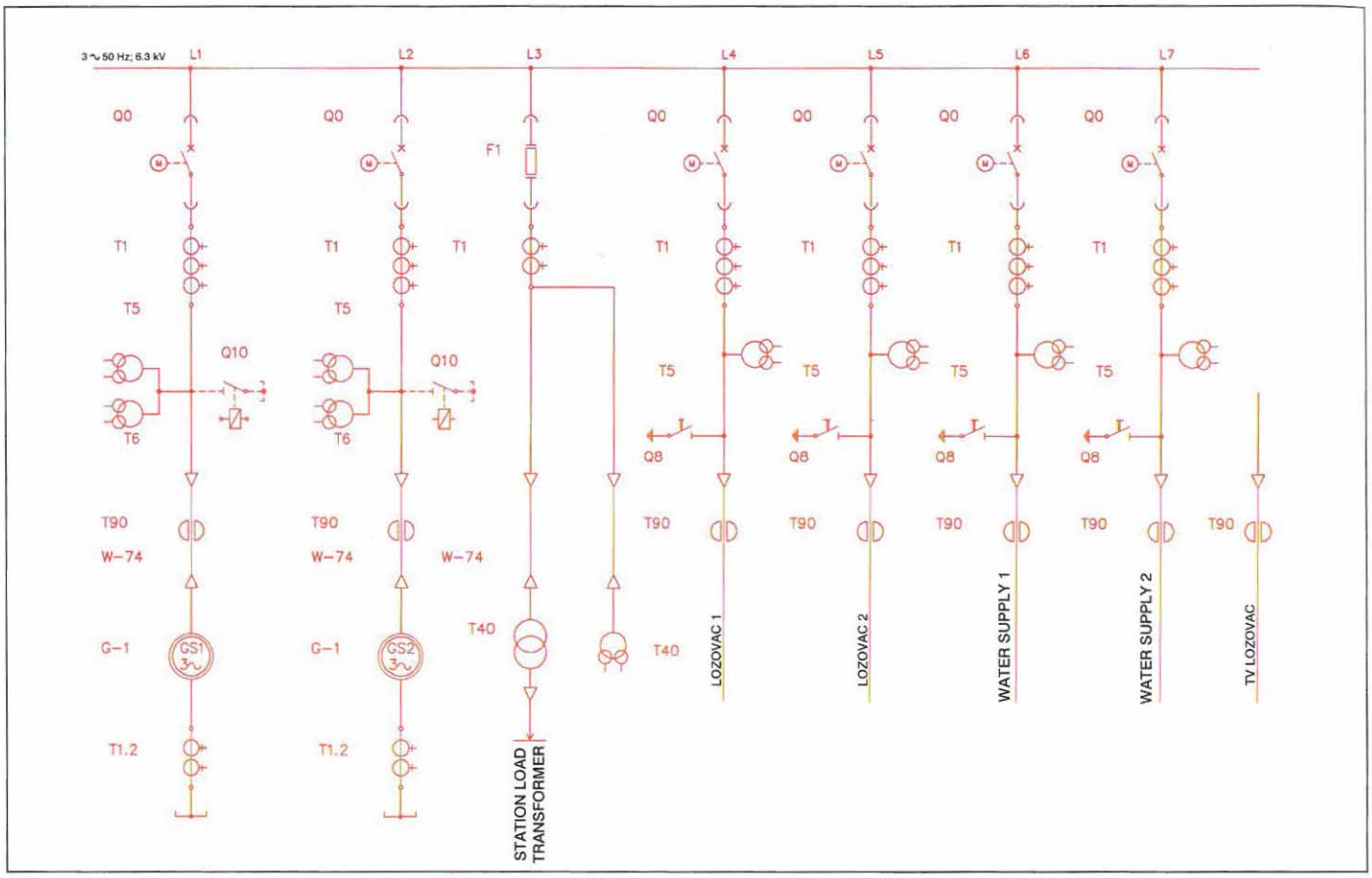


POWER HOUSE LONGITUDINAL SECTION

POWER HOUSE INTERIOR



JARUGA 1 HPP GENERATORS



SINGLE-LINE DIAGRAM

JARUGA 1 HPP AND JARUGA 2 HPP SHORTLY AFTER CONSTRUCTION COMPLETION