Key Issue:
12-Benefits due to Dam Function
6-Reservoir Impoundment
5-Water Quality

Climatic Zone:
Cfb: Mild, Humid

Subjects:
- Groundwater Management System

Effects:
- Prevention of Flooding in Urban Areas
- Raising Groundwater Level for Irrigation
- Keeping Groundwater Quality in a Good Condition

Project Name: Freudenau Hydro Power Plant
Country: Vienna, Austria (Europe) (N 48°15', E 16°22')

Implementing Party & Period
- Project: Verbund - Austrian Hydro Power AG
1992 (Commencement of construction) -
- Good Practice: Verbund - Austrian Hydro Power AG
1994 -

Key Words:
Groundwater Management, Flooding, On-line Monitoring, Groundwater Quality

Abstract:
The construction of the Freudenau HPP raised concerns that the elevated water level in the Danube River would change the water-table in Vienna. Therefore, a groundwater management system consisting of 25 pairs of extraction/recharging wells along the river bank was established to maintain and improve the groundwater regime in the affected areas. This fully automated system regulates the groundwater level in the affected area according to the discharge of the Danube River.

1. Outline of the Project

1.1. General

Freudenau HPP is part of the master plan of the utilization of the Danube River in Austria. Since 1954 nine hydropower plants were erected on the Austrian section of the Danube River. These stations generate around 12 million kilowatt hours - this accounts for over 25% of the total electricity production of Austria.

On Austrian territory, Freudenau HPP is the last of the cascade and was erected from 1992 to 1998 and is located in the city of Vienna, which has a population of nearly two million and lies in the heart of Central

Europe. Like all other power plants along the Danube River, the Freudenau multi-purpose scheme has contributed significantly to improving conditions for navigation and to more efficient flood control. In its complexity, however the Freudenau plant differs from all earlier Danube power plants.

1.2. Project Development

In 1985 the first project drafts for the Freudenau plant were submitted to the Municipality of Vienna. The location for the plant defined in Donaukraft's (now: Verbund-Austrian Hydro Power AG) master plan was also recommended in an interdisciplinary study.

In the period from August 1986 to January 1988, not only the feasibility study was carried out, but a contest entitled "Opportunities for the Vienna Danube Area" was also organised. Hydro-power experts, architects, landscape designers and ecologists participated in this contest. The purpose of this contest was to select the optimum proposals for the architectural design of the barrage and to assure a harmonious integration of the power plant into its environment to achieve an ecological design of the reservoir area and to meet urban development criteria. The specifications of the winning project were integrated into the feasibility study.

Subsequently the project was submitted to the responsible water authority and subjected to an environmental impact assessment. In May 1991, a referendum was held in Vienna, the outcome of which showed that 72% of the participants approved of the power plant. In July 1991, the water authority issued the basic permit for the execution of the project. By June 1992, all other permits required for starting construction of the power scheme had been obtained.

Construction of the barrage started on October, 1st 1992. During the construction period, three million tons of construction materials were used, 6.6 million m3 of excavated material were moved, 1.3 million m3 of concrete were poured in place and some of 24,300 tons of reinforced steel were integrated into structures. Commissioning was finished in spring 1998.

1.3. General Description of the project

1.3.1. Barrage

The barrage of Freudenau HPP consists of four sections performing different functions:

- Powerhouse
- Spillway
- Navigation lock
- Fish pass

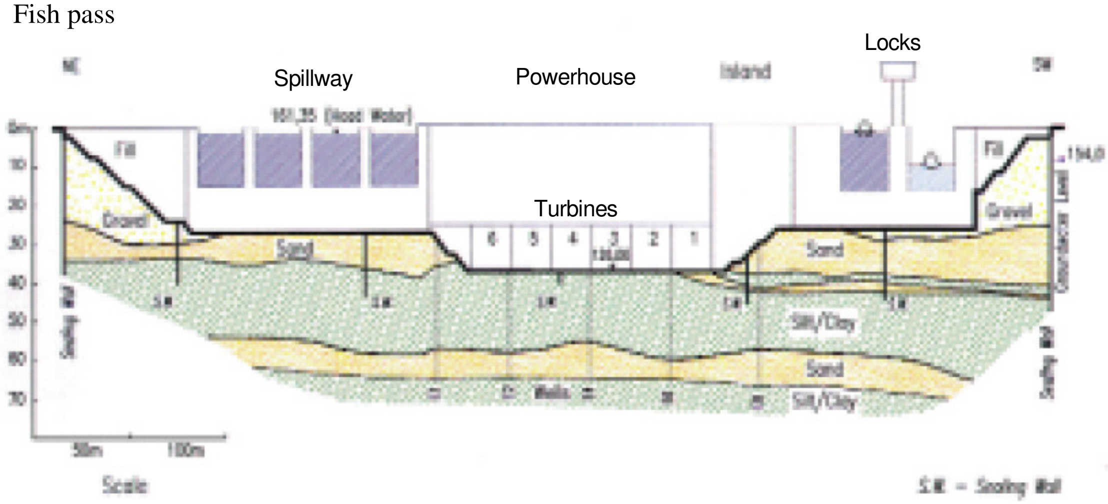

Figure 1: Cross section along the dam axis

The power house is located at the center of the river between the spillway on the left bank and the artificial island with the filling and emptying structures, the assembly hall with workshops and the administration building., The navigation locks are situated next to the artificial islands towards the right bank of the river. The plant's key design features are illustrated in Figure 1, Figure 2, and Table 1.

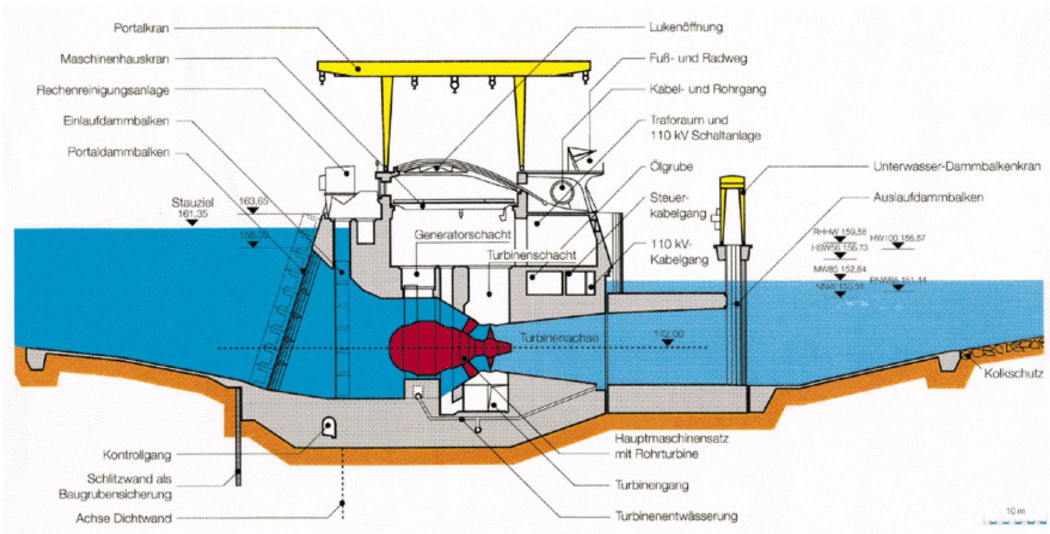

Figure 2: Cross section of the power house

Table 1: Specifications of Freudenau Hydropower Power Plant

Item	Specification	
River System	River Danube	
Catchment Area	101,731 km^2	
Type	Run-of-River (no storage)	
Power House	No. of Units	6
	Max. Outpur	172 MW
	Mean Annual Generation	1,052 GWh
	Max. Dicharge	3,000 m^3/s
Spillway	No. of Spans	4 (each 24m)
	Type of Gates	Tainter Gates with Flap
Navigation locks	No. of Chambers	2 (24 x 275 m each)
	Upper Head	Rotary Segments with Flaps
	lower Head	Mitre Gates
Fish pass	Type	Natural
	Discharge	1.2 - 7 m^3/s
Backwater area	Length	28 km
	No. of Pumping Stations	50

1.3.2. Backwater area

The length of the backwater area is 28 km. In the upstream section a series of measurements were taken (sewage treatment plants, etc.) with a view to safeguarding water quality of at least category II. Beside this important tasks were the implementation of a ground water management system and additional measurements related to urban infrastructure (e.g. raising the existing bridges across the Danube River)

1.3.2.1. Urban section (City of Vienna)

The right river bank was designed as a park like zone for recreation activities. The left bank was ecologically designed providing for a bypass channel at the barrage (fish ladder with fish way).

1.3.2.2. Rural section (Province of Lower Austria)

The river bank was landscaped for optimum integration into the environment. For this purpose, the "old Danube arms" were reconstructed and transformed into "fish ladders", "fish ways", "feeder gates" and ponds. This also led to raising of the water level in existing surface water bodies.

1.3.2.3. Downstream area (from Vienna until the Austrian - Slovakian border)

In 1996 the National Park "Donau-Auen" was established in the downstream area. In order to avoid additional scouring of the river bed in the section between Freudenau HPP and the Austrian - Slovakian border an artificial gravel feeding project started.

2. Features of the Project Area

2.1. Geographic location

The Danube River is the second longest river in Europe with a total length of 2,850 km and a total catchment area of 817,000 km^2. The project area is located on the upper reach of the Danube River (distance from the mouth: 1,921 km) within the city of Vienna/Republic of Austria. Vienna is the capital and center economic of economic life of Austria with a total population of 1.7 million.

Figure 3: The Danube Basin

2.2. Hydrology

Catchment area (River Danube at Vienna):	101,731 km^2
Minimum discharge:	390 m^3/s
Mean discharge:	1,900 m^3/s
100 years flood:	10,400 m^3/s
Maximum flood:	14,000 m^3/s
Slope:	40 cm/km

2.3. Danube River in Vienna

The relationship between Vienna and the Danube River was always ambivalent. On the one hand the Danube River was an important water way but on the other hand the city of Vienna was permanently endangered by floods. Therefor from 1870 - 1875 widespread river training works took place. The original aims of this project can be outlined as follows:

- Flood protection
- Concentration of the discharge into one uniform river bed
- Improvement of conditions for navigation

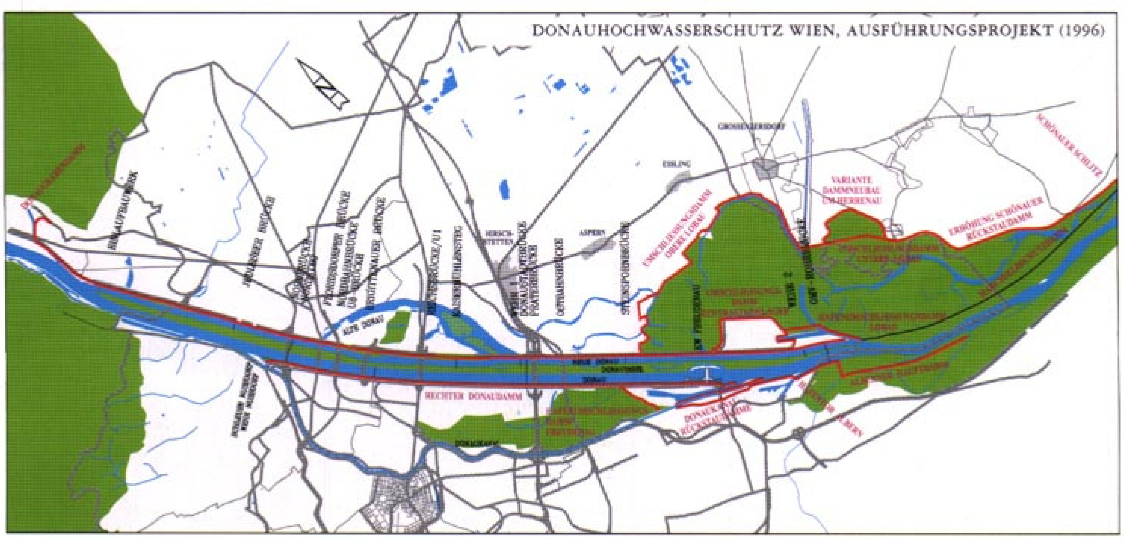

Figure 4: River Danube in Vienna

From 1970 - 1988 this system was supplemented by a bypass canal (the "New Danube") in order to guarantee the total flood protection for the city of Vienna.

The above mentioned river training works leads subsequently to a progressive scouring of river bed and lowering of groundwater level in the surrounding areas (refer to Figure 5).

Figure 5: Lowering of the low water level due to river bed erosion

3. Benefits

Due to the construction of the Freudenau HPP, the elevated water level in the impounded river would change drastically the groundwater flow as well as submerge some city areas in the 2nd district of Vienna, and flood a large amount of house basements in the 20th district of the city.
On the other hand, the previous river works have lowered the groundwater level in the surrounding areas for a long period causing decrease of irrigation water and deterioration of groundwater quality.
To prevent the flooding of urban areas, a sealing system was constructed along the right bank of the Danube River over a 13 km distance. Furthermore, to improve the lowering of groundwater level and deterioration of water quality, a groundwater management and monitoring system was installed. These systems were commissioned in 1994.

3.1 Objectives of the Groundwater Management System

The objectives of these systems can be outlined as follows:

- Simulation of the groundwater regime prior to the construction of the hydro power plant (ground water dynamics in the affected area)
- Avoid flooding of house basements and adjoining landscape (verification of maximum ground water level)
- Raising of the groundwater level during low water periods (a consequence of deepening of the river bed)
- Improvement of water supply to Prater Park area (flood plain forests, vegetation period)
- Improvement of groundwater quality (on-line and off-line monitoring of water quality)

3.2 Outline of the Groundwater Management System

The essential components of the groundwater management system are: a groundwater model, recharging and extraction wells, regulating wells and controlling wells, all connected to a control centre through a data transmission system. The groundwater level is controlled via 25 pairs of wells, each

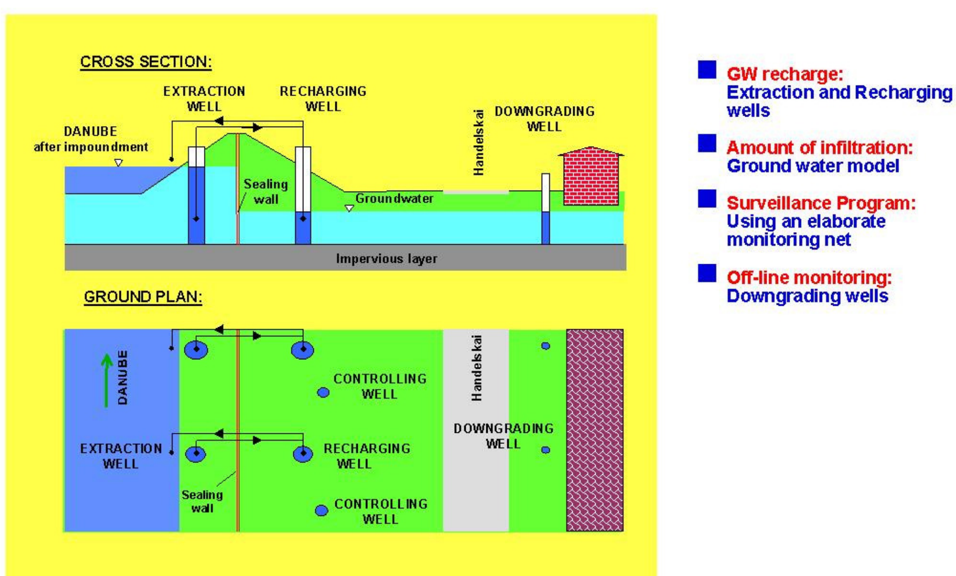

Figure 6: Groundwater management system

consisting of an extraction and a recharging well located on each side of the sealing wall. Depending on the discharge of the Danube River and groundwater levels, bank-filtered water is pumped from the extraction well to the recharging well or pumped back from the recharging well into the Danube River. Water management is automatically controlled by means of a mathematical groundwater model to assure the desired water quantity. All data relating to the management system such as water levels, pumping rates and water quality parameters from the on-line monitoring stations are continuously transmitted to the control centre.

3.3 Water Quality Monitoring

The infiltration of contaminated bank filtrate into the groundwater of the area under management in the 2nd and 20th districts is prevented through round-the-clock monitoring of the water quality in seven on-line monitoring stations. The bank-filtered water is analysed in three on-line stations and the Danube water in four monitoring stations. If a maximum permissible value is exceeded either in groundwater or in river water, the well operation is shut off. The following parameters are continuously analysed and recorded:

- Temperature
- Electrical conductivity
- pH value
- Redox potential
- Turbidity
- Oxygen concentration
- Ammonia
- Spectral absorption coefficient
- Organic carbon
- Total hydrocarbon content (mineral oils and other petroleum products)

Figure 7: Online - monitoring station for water quality

4. Effects of the Benefits

The ground water regime in the 2^{nd} and 20^{th} districts of Vienna mainly depends on the water level changes of the Danube River and the Danube canal. The developed fully automated groundwater management system keeps the groundwater flow in a nearly natural and predefined state. Further it is possible to control the ground water movement in order to avoid high water levels in the densely settled areas as well as to prevent excessive lowering of the ground water table. Without the planned preventive measures, this situation would have led to stagnation of water in the proximity of the right river bank, promoting undesirable changes in ground water quality.

Based on more than 6 years experience the benefits of the project can be described as follows in accordance to the objectives:

- Groundwater level control in order to avoid flooding of house basements and thereby protecting the city dwellings from floods
- It was possible to rise the groundwater level in the Prater region during the vegetation period in order to intensify irrigation
- Improvement of the oxygen level of the infiltration water by mechanical aeration
- Guarantee the ground water quality through continuous monitoring

Without the groundwater management system the progressive deepening of the groundwater level would proceed. The effects in this case would be:

- Increasing degradation of the hydrologic conditions for the wetlands (Prater area)
- Increasing problems with the foundations of the historic houses (wooden pillars!)
- Flooding of house basements during floods

Through the groundwater management system it was possible not only to mitigate impacts from the Freudenau HPP but also to improve the groundwater regime in accordance to the above mentioned objectives.

4. Reasons for Success

The reason for success of the groundwater management system is based on the following principles:

- intensive hydrological investigations and groundwater modeling since 1985
- stakeholder participation and information of the involved parties (especially municipality of Vienna)
- permanent monitoring of the impacts during operational phase

5. Further Information

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