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**INTERDISCIPLINARY AGRICULTURAL- AND NATURAL SCIENCES  
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**DOCTORAL (PHD) THESIS**

**THE RELATIONSHIP AMONG BIOLOGICAL WATER QUALIFICATION  
AND HYDROLOGICAL FACTORS OF THE BERETTYÓ RIVER**

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Debrecen

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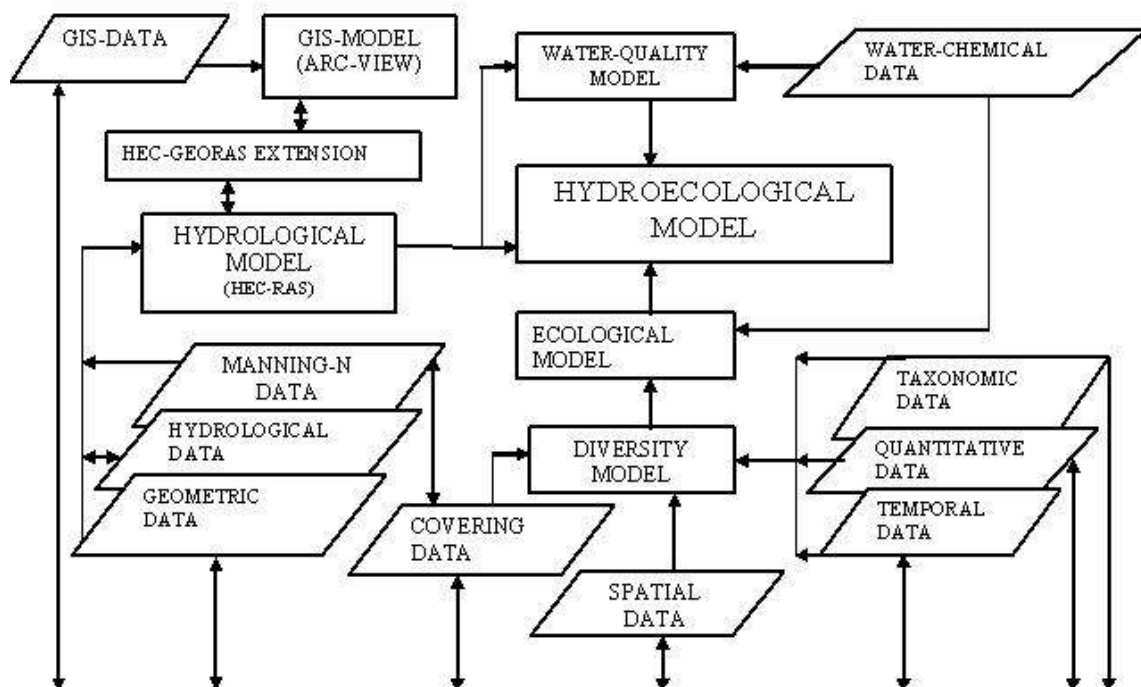
## 1. Main objectives of the researches:

1. Developing and uploading a hydraulic model, which able to load and execute real time events, and able to simulate estimates, in order to generate hydraulic (water physical and geometric) data for environmental analysis.
2. Examine interactions between hydrologic and biologic factors, establishment water quality of sampling holes, particularly in the low water periods.
3. Composition and selection of the monitoring methods (environmental rapid tests), which can service calculable data about water quality, and which require slim period and wealth.
4. On the basis of the above results selection of the group of environmental factors which has preferential importance of ecological rehabilitation of the regulated surface streams.

## 2. Material and methods

### 2.1. The hydroecological model

The applied hydroecological environmental model system is visible on the 1. Graph. Expansion of the model is among the further objects, and will be widely used for the long term monitoring of biodiversity.



1. Figure. The hydroecological model



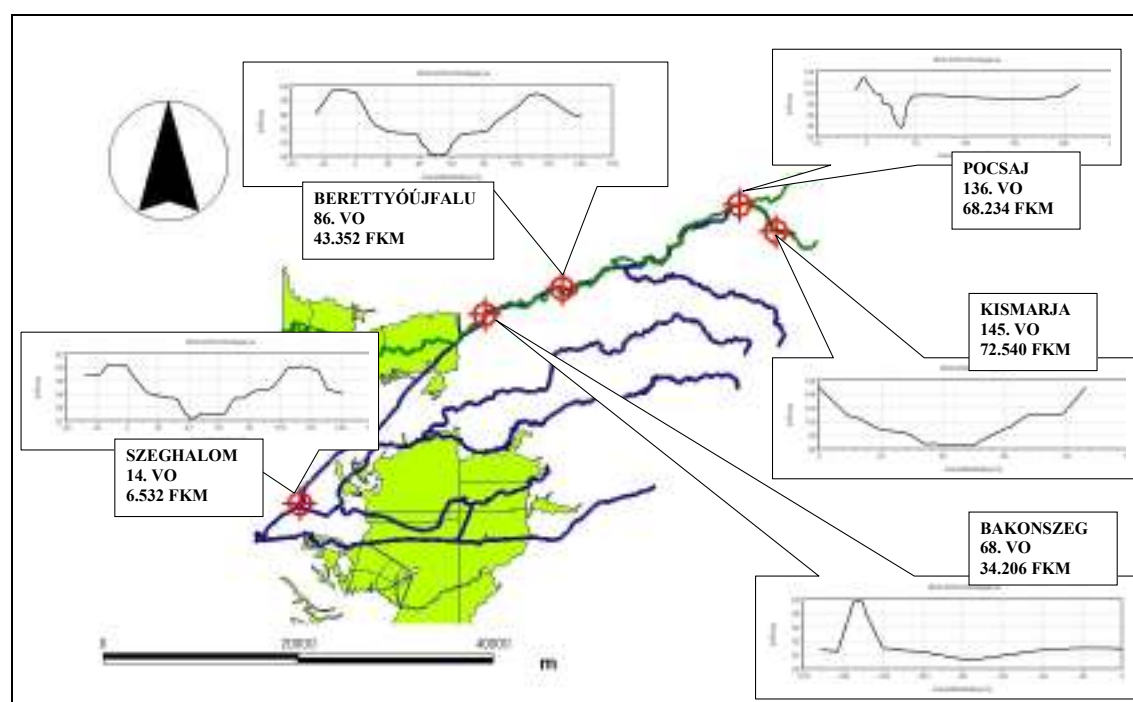
## 2.2. Searching places and sampling periods

I classified the Hungarian section of the Berettyó River in ecological and hydrological points of views. I selected upstream type reaches with gritty – sandy river bottom (Kismarja, Pocsaj, and Bakonszeg), a regulated middle stream type reach with sandy – muddy river bottom (Berettyóújfalu), and a downstream type reach with muddy river bottom (Szeghalom) (Table 1. and 2. Figure).

Table 1. Geographic data of examined cross sections

Cross section (XS)	Water management object	River station (km)	EOV-coordinates of XS s			
			Left bank		Right bank	
			X	Y	X	Y
Kismarja	145.	72,540	861139.77	215818.69	861158.65	215902.43
Pocsaj	136.	68,234	858023.73	218544.66	858096.65	218765.03
Berettyóújfalu	86.	43,352	838702.39	209997.46	838642.16	210140.29
Bakonszeg	68.	34,206	830823.50	206277.20	830680.70	206321.70
Szeghalom	14.	6,532	812095.63	187608.84	812010.76	187754.77

The water qualification samplings were in vegetation periods of 2003-2005 years, by the months. The periods of the localization, and biological and water qualification sampling were 45 -60 minutes.



2. Figure. The searching places with representative cross-sections



### **2.3. The applied statistical methods**

Because of the water tide and flow are based on real measurements, the extreme low and high water levels and connected hydraulic parameters must not leave out of consideration, and the sudden water quality changes (runoff of pollution, eutrophication), too.

Aims of the analyses have been the next:

- How can to minimize the number of hydrological and water quality factors without considerable information lost?
- How can be represented the hydrologic and environmental status which is determined by primary coefficients, by the calculated, uncorrelated factors?
- What relationships exist among the prime, and the calculated factors?
- The hydrological and water quality factors how are clustered by the theoretical factors?
- The factors how can be aggregated and rearranged?
- The individual calculated factors how can be identified as the attribute of the Berettyó River?

### **2.4. Foundation of the hydrologic model**

#### **2.4.1. Input data of HEC-RAS**

The HEC-RAS is an interactive, integrated software system which works in multi module environment. The software is one-dimensional hydraulic analysis programme, which can produce pseudo-3-dimensional model of streams by arrangement of digitalized cross-sections. The hydraulic time series were generated by application of Hec-Ras. The boundary conditions of search terms were determined by the records of water gauges of section defence inspectorships of Szeghalom, Berettyóújfalu and Pocsaj.

Input data of the HEC-RAS:

1. Geometric data (Cross sections, X – Y – Z coordinates)
2. Manning's n values
3. Subcritical Flow Contraction and Expansion Coefficients

Boundary conditions:

Computed and measured water level, discharge records and stage-discharge curve, hydrograph data under steady and non-steady flow conditions.



For the sake of precise data input and demonstration an ESRI ArcView shape file was used as data layer.

The recording of basic data was carried out in the frame of several field sampling campaigns.

In order to improve the accuracy of measurements two devices (TRIMBLE Explorer and a stable JAVAD Legacy DGPS combined with a field sampler) were used simultaneously for the determination of geographic position.

By using the most accurate JAVAD for signal collection up to 500 Kb (app. 10 minutes) an accuracy of  $\pm 0,2$  m can be achieved, but with the application of a base and a rover receiver the accuracy could be improved with an order of magnitude. The applied system used the WGS-84 projection system, therefore data transformation to EOVS coordinate system had to be performed during post-processing.

#### **2.4.2. Examined hydraulic parameters**

The examined hydraulic parameters are demonstrated on Table 2.

Table 2. **Examined hydraulic parameters**

<b>Geometric Parameters</b>	<b>Energetic Parameters</b>	<b>Parameters of Conveyance</b>
Water Surface Elevation (m)	Shear Total (N/m <sup>2</sup> )	Total Flow (m <sup>3</sup> /sec)
Maximum Main Channel Depth (m)	Total Energy (m)	Average Velocity (m/sec)
Flow Area (m <sup>2</sup> )	Power Total (J/m <sup>2</sup> s)	Froude-Number (F <sub>r</sub> )
Wetted Perimeter (m)	Slope of Energy Gradeline (‰)	Reynolds-Number (Re)
Top Width (m)	Friction Loss (m)	
Hydraulic Radius (m)	Total Energy Loss (m)	
Hydraulic Depth (m)		
Arrangement		

## **2.5. Water qualification**

### **2.5.1. Physical, chemical and biochemical water qualification methods**

Water conductivity was measured with a WTW LF 325-B/Set 1 device, absolute and relative dissolved oxygen content was determined with WTW OXI 325-B/Set 1, while redox-potential and pH with WTW pH 325-B/Set 1. All instruments measure the actual temperature as well.

BOD<sub>5</sub> was measured with a WTW Oxitop microprocessor vacuum manometer, which records the daily rate of pressure decrease caused by O<sub>2</sub> depletion during 5 days. Water



samples were stored in a cooler until analysis, incubation of samples started the same day as sample collection at a temperature of 20°C. Constant stirring of samples was ensured by an electro-magnetic stirrer.

Sediment sampling was performed with an Eijkelkamp probe. Sediment particles were fractionated with a VIVAC sieve/screen set in air-dry condition.

Sample-taking, transport and preservation of samples was carried out according to the „MSZ ISO 5667 – 6 (1995) standard.

Datasets from the automatic water-quality monitoring station on the left bank of the Berettyó River (66.172 fkm) were used as reference data in the evaluation of own measurements.

Measured water-quality parameters were: temperature, pH, conductivity, dissolved oxygen content, turbidity, total organic carbon (TOC), ammonia, green algae, cyan bacteria, Bacillariophyceae = Diatoms, Pyrrophyta and chlorophyll-a content as well as toxicity.

#### **2.5.2. The determination of water quality according to the Hungarian Macrozoobenton Family Point-System (MMCP) based on bioindicators.**

Sampling was performed with a dip-net, under low water level conditions with “kick and sweep” method, with silt/sediment sampler and with forceps, shovels and by hand. After a visual examination samples were selected/sorted and stored in 70% alcohol in air tight plastic containers. Identified taxa were released immediately.

For the preliminary comparison of the sampling site’s biodiversity, data from the MMCP list were used. Since sampling aimed the determination of water quality, the applied method for diversity calculation did not follow the traditional method, but focused on the determination of probability of cases, when two randomly chosen taxa from the sample belongs to different water quality classes. For the characterization of biodiversity Simpson’s diversity index and evenness were calculated. Samplings were carried out by applying identical methods and time-frame.

#### **2.6. Connections between the applied water classification methods and the applied environmental condition index**

Spencer’s environmental indicator method was used for the comprehensive review of environmental status. I also took into consideration such hydromechanical/hydraulic and hydrologic factors which are excluded from the original method (flow type: supercritical - subcritical, current type: laminar – turbulent).



Water quality classification based on the available water quality parameters and was performed according to the limit values of the different water classes of the Hungarian standard (MSZ 12 749).

I supplemented the list of environmental indicators with such hydraulic factors, which has significant effect on the formation and changes of the river ecosystem, but at the same time difficult to measure. I included the calculated MMCP values into the list (Table 3.).

The environmental status index considers these indicators by breaking down soil – water – biocenosis related parameters. In case of analyzing longer time series water quality classification was based on the 90% permanency of parameter values.

**Table 3: Calculation of the environmental qualitative index**

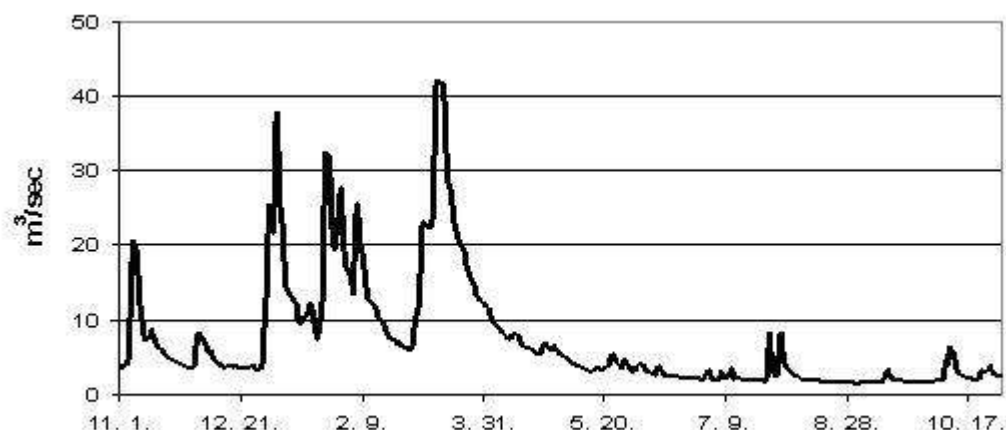
Score of the environmental factor/indicator		1	2	3	4	5	Unit
Soil	Stability of the coast		Soft		Solid		
Water	Shearing stress		>50		<50		N/m <sup>2</sup>
	Stream		Turbulent		Laminar		
			Supercritical		Subcritical		m/s
	Average velocity	>1.00	0,75-1,00	0,50-0,75	0,25–0,50	0–0,25	m/s
	Conductivity	>5.83	2.50-5.83	0.83-2.5	0.29-0.83	0-0.29	mS/cm
	Absolute Oxygen Content	0-4.00	4.10-8.00	8.10-12.00	12.10-15.00	>15.00	mg/l
	5-day Biochemical Oxygen Demand	>15	10,1-15	6.1-10	4.1-6	0-4	mg/l
	H-concentration	<4.5 or >9.5		4.5-6.5 or 8.3-9.5		6.5 – 8,3	
Water quality index	Water-quality indicators (MMCP)	1	2	3	4	5	
	Biodiversity	<0.60	0.60-0.75	0.75-0.82	0.82-0.92	>0.92	
Vegetation	Cover	<5	>95	5-15 or 85-95	15-25 or 76-85	26-75	% (Percent of surface area)
	Heterogeneity of habitats	1	2	3	4	5	Number of habitats

### 3. Results and discussion

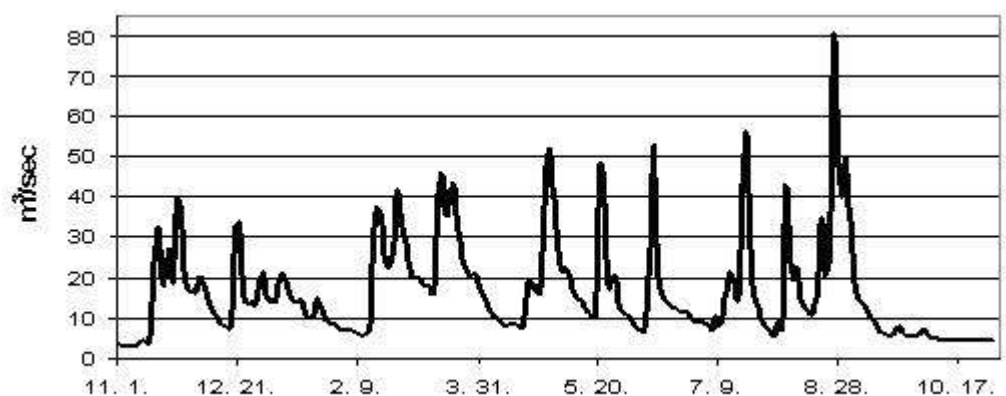
#### 3.1. Results of the hydrologic- hydraulic analysis

Based on the appendix II. of the WFD, the Berettyó River is a lowland small river with calcareous hydrogeochemical type, medium-fine river bottom and medium-sized catchment area: Type 18. Due to river regulations it is considered a highly regulated surface water-body.





3. Figure. Time series of the streamflow of the Berettyó. (Pocsaj, 2002-2003. hydrologic year, November 1 – October 31.)



4. Figure. Time series of the streamflow of the Berettyó. (Pocsaj, 2004-2005. hydrologic year, November 1 – October 31.)

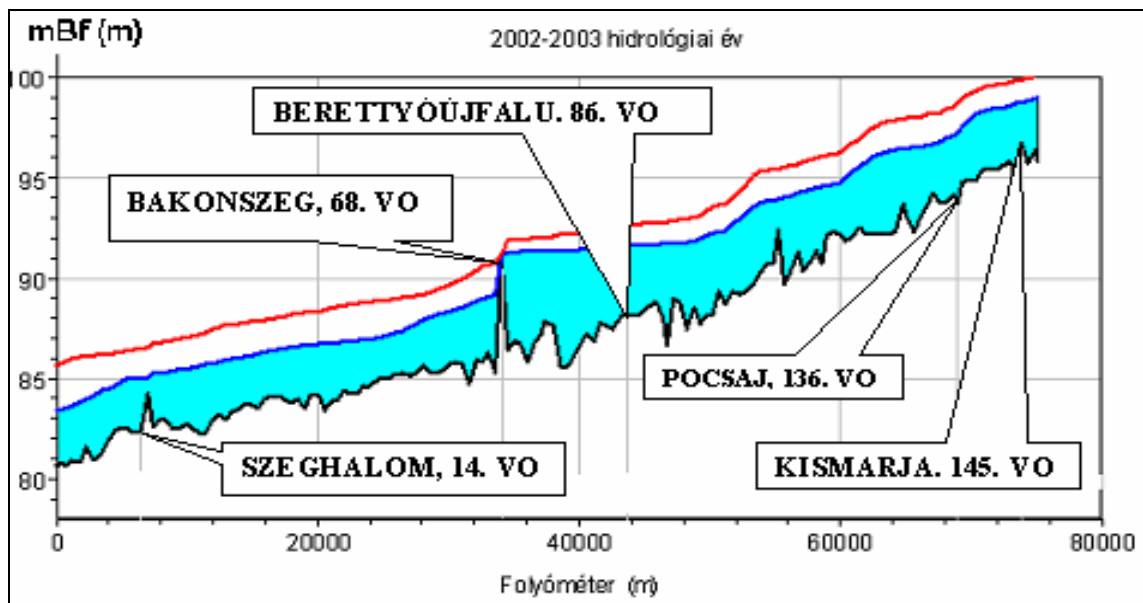
The flow regime of the Berettyó River is fluctuating and extreme. The difference between the lowest and highest rate of streamflow can be 20 – 25 fold. Flood hydrograph can be represented with the extremities of flood waves, which are usually short in time.

The difference between the 2002-2003 and 2004-2005 hydrologic year is most apparent in the second half of the year (3. and 4. figure).

The Berettyó River belongs to the small, medium and large category regarding the rate of streamflow, however on the basis of annual average it is considered a medium discharge river. The same conclusion can be drawn on the basis of the 90% permanency of discharge.

Several bottom drops can be found in the longitudinal profile of the Hungarian section of the Berettyó River, among which the most distinctive is the Bakonszeg 68 profile.





5. Figure. **The longitudinal profile of the Hungarian section of the Berettyó River**

The U shaped cross-section of Bakonszeg has the mostly geometric és hydraulic circumstances.

The watercourse is subcritical all year in trapezoid and V shaped cross-sections (Szeghalom, Berettyóújfalú, and Pocsaj), the Froude-number less than 1, the relationship of the average velocity and the Froude-number is described by linear regression in every occasion.

The critical flow statuses are produced by the hydrological conditions in the low water periods of trapezoid-U shaped transitional cross-section of Kismarja. The Froude-number equal or more than 1, and the average velocity is more than 1 m/s.

There isn't coherency between the Froude-number and the average velocity in this period.

Only here can be observed reciprocal relation between the runoff rate and the average velocity among in examined cross-sections, whereas their relationship is the weakest. The average velocity and streamflow were in direct proportionality in the other cross-sections.

In the U shaped cross-section of Bakonszeg the watercourse was critical or supercritical in both of examined years.

In the 2002-2003-as hydrologic year the strength of regression was only  $R^2 = 0,1$ , between the Froude-number and the average velocity, because of permanent critical streamflow.



During the hydraulic year of 2004-2005 – when the Froude-number fluctuated between 0.96 and 2.89 with 0.3 standard error – the determination coefficient increased to  $R^2 = 0.9$  because of the long supercritical flow.

The flows were included in the laminar and light turbulent category in each section. The permanency of the laminar type reached or exceeded 80% in the examined period except cross-section 138. of Pocsaj, where the flow was 60% light turbulent in the hydraulic year of 2002-2003.

The cross-section of Bakonszeg has special hydraulic sessions because of the hydraulic radius and depth is relatively small so the top width and the wetted perimeter are large. This is the reason of the laminar and light turbulent characteristic of the watercourse in spite of supercritical character.

Extreme water velocity conditions featured in the cross-section of Bakonszeg, too (68. VO). This section of the Berettyó River behaves like a mountain stream and makes an ecological barrier not just for the rheoxen species – typical in still waters and slow watercourses – but also for the rheofil species which can be found in middle river sections.

According to the 90% permanency and the averages of water velocity the section Berettyóújfalu is slow, the section Szeghalom is slow and moderately speedy, the section Pocsaj is moderately speedy, the section Kismarja is accelerating and the section Bakonszeg is speedy.

The variance analysis of hydraulic time series of cross-sections in the 2 examined years, gave the next results:

- There is not significant difference among runoffs, except the cross-section of Szeghalom. The Kiskörös-channel, which runs in between Pocsaj and Berettyóújfalu, does not change the characteristic of water level fluctuation notably, because of their behaviours are determined by the hydrologic processes, which come on the same partial watershed. The situation is the same at the case of Kutas-channel which runs into the Berettyó River at Szeghalom. The significant difference is caused by the Keleti-channel, which runs in the Berettyó under Bakonszeg; because it is used for water-control activities, which are partly affected by hydrological conditions of the upper reach of the Tisza, and makes the connection between two partial watersheds. This is the reason of the runoff variance at Szeghalom compared to other cross-sections in both examined years.



In the representative cross-sections the variance of the hydrologic data was different except the next ones:

- In the hydraulic year of 2002-2003, – when in the summer and autumn were low water conditions – there were significant similarity between the hydraulic radius and depth of the 2 trapeze shaped cross-sections (Berettyóújfalu and Szeghalom). The U-shaped cross-sections (Bakonszeg and Kismarja) can be grouped by the energy gradeline and the shearing stress, though the P value of the stress (0.034) is less than the significant level (0.05).
- In the 2004-2005. hydraulic year there were great flood waves at the Berettyó River. According to this the variances changed. There was similarity in the wetted perimeter and the distribution between cross-sections of Szeghalom and Berettyóújfalu, the hydraulic radius and hydraulic depth in the cross-sections of Szeghalom and Pocsaj, the wetted perimeter and top width in the cross-sections of Szeghalom and Bakonszeg were similar significantly.

### **3.2. The results of the principal component analysis of the hydraulic data**

The main differences were from May till October. In 2003 the water was low according to the experiences. During the spring of 2005 there were several flood waves because of the extreme precipitation conditions.

#### **Summary**

- The value of the prime principal component at low water conditions is high at the kismarjai (U-trapeze shaped), pocsaji (V-shaped) and bakonszegi (U-shaped) cross-sections and decreases at higher water level when the value of the secondary principal component increases. The situation is reversed in the trapeze-shaped cross-sections of Berettyóújfalu and Szeghalom. The slope of the water level, which is represented by the energy gradeline of the subcritical flow, is the lowest at these 2 sections.
- Geometric data were in the prime principal in each case with significantly, so its role in the hydraulic character is changed with the component. The runoff also belongs to this, except the bakonszegi cross-sections where in permanent running case the factor weight beings minimal.
- The dynamical hydraulic factors (the parameters connected to the energy of the water, the velocity, etc.) at Kismarja, Pocsaj and Bakonszeg changed to the second component and increased its role against the first one.



- The same situation can be found in the case of the berettyóújfalui and szeghalmi trapeze-shaped cross-sections at low water period, but only the independence of the friction and energy loss is significant at Berettyóújfalu. In this case the derivative geometrical data (hydraulic radius and depth, distribution) moves to the second component with a negative sign and the top width and the perimeter appear. This indirectly indicates the inverse proportion between the average depth and the energy losses in low runoff. In the case of high-water stage the average depth does not influence the energy status. At cross section of Szeghalom the average depth is always large enough to be neutral in this aspect.
- Various strength connections are realized between the geometrical and dynamical factors at different types cross-sections at given runoffs, for example the average velocity and geometric factors are constant independent in cross-section of Bakonszeg, and in the cross-section of Kismarja permanently independent in the supercritical and critical flow circumstances. The coherences decrease at low water situations at Szeghalom.
- According to the things mentioned above if we would like to change the conditions of the flow positively we should consider not just the geometric water bad regulation, but those solutions which influence the water flow (hydraulic structures, levees, chutes, spur, etc.) or change the runoff (storage areas, pump stations, etc.).

### **3.3. The environmental condition of the river**

#### **3.3.1. Results of the analysis with many variables**

Summarizing the principal component analysis of examined water quality and hydraulic factors it is found out that the hydraulic parameters (runoff, energetic and geometric attributes) influence the water quality with an effect on the physical and chemical parameters of the water. They affect the dilution process at high water situations and the temperature at low water cases. The obverse connection between the temperature and the pH shows the dependence of biological degradation processes on temperature. The increase of the degradation is connected to acidification.

The trophity (chlorophyll-content) is connected to the conductivity at summer time (low water conditions) and to the Total Organic Carbon (TOC) in winter time (high water floods). This may refers to pollution sources at the flood plain of the upper sector.



### **3.3.2. Yearly changes of the water quality**

According to the permanency of the water quality data we can conclude the followings:

- The water according to the pH was perfect (neutral) or good (slightly alkaline) in both hydraulic years.
- The conductivity (salt-content) in hydraulic year 2002-2003. was perfect or good in 67%, middle in 24% and low in 9%. The middle and the low states were realized in low runoff cases. In the hydraulic year 2004-2005, there were not low water periods so the conductivity was perfect or good in 83% and middle in 17%.
- By the dissolved oxygen content in the first year the water was perfect or good in 18%, middle in 42%, low in 34% and bad in 6% during the low water states. In the second hydraulic year the water was good and perfect in 93% and middle in 7%.
- The water quality of the Berettyó River is most endangered by Total Organic Carbon (TOC) content. In the first year the category was middle or low in 31%, and in 19% (50% in total). In the second year it was 37% and 22% and bad in 6% (65% in total). The increasing TOC attracts attention to the point or diffuse pollution sources in the upper sector which become more dangerous during the risings.
- The rate of the ammonification progresses was low. Medium quality period evolved in 10% at the summer of 2003. The concentration was lower in the second year.
- The quality of the water was mostly perfect or good and medium in 3% according to the trophity.
- The toxicity of the water was always better than class II. But the quality was worse in the lower runoff periods because of floated organic pollutants.

### **3.3.3. Water quality of the Hungarian section of Berettyó River in summer, at low-water period**

#### **A. The upper section (Kismarja, 145. VO).**

During summer the velocity of this river section was between 0,68-1,37 m/s, which means moderately rapid, rapid water flow. The temperature of the water near the surface was varied between 19,9-28°C, it was moderately warm, warm.

According to the standard for changes of specific electric conductivity, the salt content is moderately changing, and the electric conductivity of this river section is high, or rather moderately high (670-950 $\mu$ S/cm, II-III. class).

The pH of the river section was changed between 7,28-7,80, which means neutral or mildly alkaline according to the standard for proton activity values (I-II. class).



The oxygen content of this river section was changed between 3,2-7,65 mg/l, with the mean of 5,98 mg/l, which means high oxygen content according to the standard for dissolved oxygen content (II. class).

The oxygen saturation of the water was varied between 60-92,4 % which is moderate, moderately changing oxygen saturation.

The organic content (saprobies) was changed 8-12 mg/l BOI<sub>5</sub> so that this river section mainly fell under alfa-mezosaprobe zone, and III. (tolerable), and IV. (polluted) category correspond to the water qualification method.

#### **B. The middle section (Berettyóújfalu, 86. VO).**

This section is the most exposed part of the river due to different water uses and the organic content is at the highest level, which can be modified significantly by partially cleaned joining waste water, especially at low water period.

During summer the velocity of this river section was between 0,33-0,34 m/s, which means medium, moderate rapid water flow.

The temperature of the water surface was varied between 22,5-26,3°C in summer during sampling, it was moderately warm.

According to the standard for changes of specific electric conductivity, the salt content is moderately changing and the electric conductivity of this river section is high (1080-1953 µS/cm, III-IV. class).

The pH of the river section was changed between 7,40-8,17, which means mildly alkaline according to the standard for proton activity values (I-II. class).

The oxygen content of this river section was changed between 4,76-7,65 mg/l, which means higher oxygen content than middle values according to the standard for dissolved oxygen content (I. II. III. class, fine based on their means).

The oxygen saturation of the water was varied between 71,4 – 95,5 % which shows moderate, moderately changing oxygen saturation.

The organic content (saprobies) was changed 11-18 mg/l BOI<sub>5</sub> so that this river section mainly fell under alfa-mezosaprobe and poli saprobe zone, and III. (Tolerable), IV. (Polluted), and V. (extremely polluted) category.

#### **C. The present lower section of the river (Szeghalom, 14 – 15. VO)**

The water flows in artificial riverbed in this section. The cross-sections of the whole lower reach are trapezoid shaped.

During summer the velocity of this river section was between 0,13 – 0,42 m/s, which means slow, moderately rapid water flow.



The temperature of the water surface was varied between 23,3 – 26,1 °C in summer during sampling, it was moderately warm.

According to the standard for changes of specific electric conductivity, the electric conductivity of this river section is high (970 – 2180 µS/cm mean: 1444,60 µS/cm).

The change of pH was between 7,5 – 8,08 in the river section, which means mildly alkaline according to the standard for proton activity values.

The oxygen content changed between 4,76-7,61 mg/l, which means moderate, fine oxygen content according to the standard for dissolved oxygen content.

The oxygen saturation of the water was varied between 59,00 – 65,4 % which shows moderate, moderately changing oxygen saturation.

The organic content (saprobity) was changed 7-11 mg/l BOI<sub>5</sub> so that this river section mainly fell under alfa-mesosaprobe zone, and III. (tolerable), IV. (polluted) category, based on MSZ (Hungarian standard) water qualification method (Felföldi 1987, MSZ 12749:1993, Németh 1998).

Summarizing: The Berettyó River is markedly regulated stream with trapezoid cross-sections, low inclination and extremely variable hydrological and hydraulical conditions in time and space. Point of views of water management, the river is a lower section ruled main recipient of undrained runoffs, where most of the channels are joined in the middle and lower section of the river.

The organic content of the river is high, so it fell mainly under the 4. category (polluted water; 10,1 – 15 BOI<sub>5</sub>) during summer at low water period. At middle and high water period it reached 2. category (fine quality water). The water was mainly mesosaprobe based on saprobity categories. If weather circumstances are steady, the river will fall under beta – mesosaprobe zone, which means good quality, but in extreme low water periods the water quality may fall under alfa-oligosaprobe and polisaprobe zone. Furthermore beside transborder and inland pollution the low water discharge and serious warming are also contribute to the increasing of organic content.

#### **3.3.4. Assessment and results of the Hungarian Macrozoobenton Family Point-system (MMCP)**

The water quality of the Berettyó River in the Table 4., the taxons and taxon-scores in the Table 5.can be finding.



**Table 4.: The water quality of the Berettyó based on the point system of the Hungarian macrozoobenthos families and other taxons**

	<b>Szeghalom</b>	<b>Berettyóújfalu</b>	<b>Kismarja</b>
<b>Number of taxons</b>	24	18	17
<b>MMCP Total score</b>	99	73	72
<b>Quality index by the total score (QI<sub>MMCP</sub>)</b>	5	4	4
<b>Mean score of taxons</b>	4.125	4.05	4,23
<b>Quality index by the mean score of taxons (QI<sub>TÁP</sub>)</b>	5	4	5
<b>Qualification (QI<sub>MMCP</sub>+ QI<sub>TÁP</sub>)/2</b>	5 – Prime quality	4 – Good quality	4,5 – Good quality
<b>Water quality class</b>	I/C	II/B	II/A

### **3.3.5. A környezeti állapot-index, a vizsgálati helyek környezeti állapota**

According to Spencer environmental qualification system, which uses biotic and abiotic environmental factors, structural and taxonomic diversity indices, in summertime the Berettyó River is in moderate and fine environmental conditions (Table 6).

Environmental qualification factors based on different methods match each other. However, bioindicators show better environmental conditions than physical – chemical properties. Neither the long term water qualification data represent such wrong environmental conditions, than the monthly sampling data (Table 7).

At section of Szeghalom (below the entrance of Keleti main channel), depending on water flow control operations, the good water quality of Felső – Tisza River remedy the environmental conditions. Kutas joins ecological corridor between Bihar plane and the lower section of Berettyó River. There is no significant bottom drop between research area and Sebes – Körös in 6,5 km distance. This two way of relationship together with natural self-purification of the river result excellent environmental conditions of lower river reach which is based on MMCP qualification system.



Table 5. **The examined Hungarian macrozoobenthos families and other taxons**

	Kismarja	Berettyóújfalú	Szeghalom
QI	Family Taxon	Family Taxon	Family Taxon
6	Ephemeridae – Burrowing Mayflies Libellulidae – Skimmer Dragonflies	Leptoceridae – Longhorned Caddisflies Leptophlebiidae – Common Mayflies	Ephemeridae – Burrowing Mayflies Leptoceridae - Longhorned Caddishflies Leptophlebiidae – Mayflies
5	Haliplidae – Crawling Water Beetles Unionidae – Freshwater Molluscan Shells Hydropsychidae - Spotted Sedges Limnephilidae – Caddisflies Pisidiidae – Pea Mussels )	Caenidae – Small Squaregill Mayflies Dytiscidae – Water Beetles Haliplidae – Crawling Water Beetles Hydropsychidae - Spotted Sedges Pisidiidae – Pea Mussels	Dytiscidae – Water Beetles Haliplidae – Crawling Water Beetles Hydrophilidae – Water Lover Hydropsychidae – Spotted Sedges Limnephilidae – Caddisflies Pisidiidae – Pea Mussels
4	Baetidae – Small Minnow Mayflies Calopterygidae – Broad Wing Damselflies Gerridae – Water Striders Nepidae – Waterscorpions Coenagrionidae – Pond Damselflies Notonectidae – Backswimmers	Baetidae – Small Minnow Mayflies Calopterygidae – Broad Wing Damselflies Nepidae – Waterscorpions Gerridae – Water Striders Pleidae – Pigmy Backswimmers	Baetidae – Small Minnow Mayflies Calopterygidae – Broad Wing Damselflies Gerridae – Water Striders Nepidae – Waterscorpions Pleidae – Pigmy Backswimmers
3	Asellidae Platycnemididae – White-legged Damselflies. Corixidae – Water Boatmen	Bithyniidae – Mud Snails Corixidae – Water Boatmen Lymnaeidae – Swamp Snails Tipulidae - Crane Flies	Asellidae Bithyniidae – Mud Snails Corixidae – Water Boatmen Erpobdellidae - Leeches Hirudidae - Leeches Lymnaeidae – Swamp Snails Tipulidae - Crane flies
2	Culicidae - Mosquitoes	Culicidae - Mosquitoes Diptera – Flies	Culicidae - Mosquitoes Diptera – Flies



Table 6: The modified Spencer-index of the studied spaces and water spaces

Environmental factor/indicator		Szeghalom	Berettyóújfalú	Kismarja
Soil	Stability of the bank	4	4	4
	SZUBINDEX(7)	4	4	4
Water	Shearing stress	4	4	2
	Stream	Turbulent – Laminar	4	4
		Supercritical - Subcritical	4	4
	Average velocity	5	4	2
	Conductivity	3	3	3
	Absolute Oxygen Content	5	5	5
	5-day Biochemical Oxygen Demand	3	2	3
	H-concentration	5	5	5
	SZUBINDEX(7)	4.13	3.88	3.50
Water quality index	Water-quality indicators (MMCP)	5	4	4
	Biodiversity	3	3	3
	SZUBINDEX(7)	4.00	3.50	3.58
Vegetation	Cover	3	1	4
	Heterogeneity of habitats	4	3	4
	SZUBINDEX(7)	3.50	2.50	4.00
INDEX(21)		3.91	3.47	3.77

This fact emphasizes the role of excess water channel network in nature conservation. The Hungarian section of Berettyó River is divided ecologically from the upper section of the river by the oil processing industrial site at Berettyószéplak; from hydrological point of view the presence of bed rise at Bakonszeg make a barrier from 68. VO up the river. Supplement of these taxonomic groups and genetic refreshment of degraded biotic communities could be possible mainly through the interior, near-natural parts of Bihari plane (Kutas, Kiskörös, Ér). The role of ecological corridors is partly supplied by the excess water channel network at this area. Depending on water flow control operations, at the entrance of Keleti main channel, the water in Berettyó river is mixed with the water with good quality from Felső – Tisza river.

Based on the results, if the Körös Berettyó system achieves good ecological status and the possibility of natural genetic refreshment and exchanging is provided, the natural flora and fauna of main water-courses can be restored.



Table 7: **Water quality of the Berettyó**

	<b>SZEGHALOM</b>	<b>BERETTYÓÚJFALU</b>	<b>KISMARJA</b>
<b>H-concentration</b>	Mildly alkaline	Mildly alkaline	Mildly alkaline
<b>Halobe - LF (mS/cm)</b>	$\beta$ -mesohalobe	$\beta$ -mesohalobe	$\beta$ -mesohalobe
<b>Saprobe - BOI<sub>5</sub> (mg/l)</b>	$\alpha$ -mesosaprobe	$\alpha$ -mesosaprobe	$\alpha$ -mesosaprobe
<b>Water Qualification (Hungarian Standard 12749)</b>	Tolerable water III.	Polluted water IV.	Tolerable water III.
<b>Water Qualification -MMCP</b>	Prime quality V.	Good quality II.	Good quality II.
<b>Simpson-index of bioindicators</b>	Middle status 0.82 – III.	Middle status 0.82 – III.	Middle status 0.79 – III.
<b>Spencer-index</b>	Good status 3.91	Middle status 3.47	Good status 3.77

#### 4. CONCLUSIONS, RECCOMANDATIONS

- The results of researches at partial watershed shall be integrated to a transborder Watershed Management Plan concerning the whole watershed.
- From altering point of view, the monitoring station at Pocsaj works properly. However, the riverbed geometry and hydrological – water flow conditions of the cross section are not representative in the case of Hungarian part of Berettyó River. It would be essential to establish monitoring station at every inflow point of the water network, or at least at Ér, Kiskörös, Kálló, Keleti Main Channel, Kutas area.
- During monitoring, besides measuring of total organic carbon content (TOC), chemical oxygen demand (COD) and biological oxygen demand (BOD) should be also measured regularly in order to assess the rate of natural and artificial organic content with the aim of better indication of artificial contamination.
- The channel network of Bihar plane has a gene bank role, since it protects the relictum species of the original flora and fauna. These species should be necessary to survey from the environment and nature conservation point of view. Based on the results, rearranging agricultural water flow control operation is also valid.
- Amendment of cross section survey is essential to the ecologically revitalization process. This completion is recommended at low-water period. The number of the examined cross sections should be increased at significant river part of the river from hydrologic, environmental management and water management point of view. In the case of sections, relevant in water flow control operation, riverbed morphology and water flow mechanics, surveying cross sections are essential. (now the surveys are in 500m distances)



- Exact surveying channel roughness value is not yet resolved Therefore introduction of remote sensing technologies is strongly recommended in the future besides conventional surveys. These methodical changes are allowing us to assess changes of large areas and optimize the possibly applied technology.

## 5. Summary

In the course of my researches I developed the virtual hydrologic – hydraulic model of the Berettyó River and its environment, based on the Berettyó's conceptual model.

The developed conceptual model served as a basis for the establishment of a dynamic spatial decision-making support system taking into consideration the recommendations of the EU Water Framework Directive.

The objective of monitoring and modelling of hydroecological processes aimed at providing a tool, which facilitates the natural, self-supporting river-environment, which is less risky for his milieu.

I analyzed the relationship between the important hydroecological and water-quality significant factors according to the recommendations of the EU Water Framework Directive.

In the course of the hydraulic analysis I investigated the hydrological and morphological character of the river, and the conditions of the flow in the examined cross-sections. I concluded that the cross-section of Bakonszeg is an ecological barrier, because of the extreme hydraulic conditions.

I demonstrated that under normal circumstances the bed-geometrical and flow coefficients were in correlation in case of given run-off, but this relationship weakens or breaks off in extreme low-water and high-water conditions.

Both hydroecological and water-quality status give reason for the application of environmental stream regulation methods, or the bed regulation in the last resort. I analyzed the relationship of the indicator-groups of water quality with bivariate and multivariate statistical methods, and investigated connections among environmental indicator groups determined primarily by physical-chemical factors, and determined principally by biotic factors, and determined by the collective effect of abiotic and biotic factors.

I completed the environmental assessment and water qualification of the Berettyó River and its surrounding area in the examined periods.

I appointed that the water pollution origins mostly from transborder sources.



The self-purification capacity of the ecosystem of the Berettyó is significant; its environmental status improves toward the downstream.

I framed an environmental qualification method based on the Spencer environmental rapid tests, which includes some elements of the four accepted Hungarian water-qualification systems.

This method is adaptable for streams of the Hungarian Great plain, can be completed and customized for special instances.

In the course of the research it was proven that in case of physical, chemical and biochemical examinations long term monitoring is needed, the occasionally sampling is not appropriate.

The used MMCP-index (the point-system of the Hungarian macrozoobenthos family taxons) was more applicable than other short term evaluation methods, which use results of other occasionally samplings. This method summarizes and averages the environmental quality conditions for the life cycle of the macroscopic invertebrate biomes till the time of sampling.

On the basis of these results the MMCP proved to be more effectively comparable with the results of the long term physical, chemical and biochemical analysis which were achieved according to the MSZ 12749 standard.

### **5.1. New or novel scientific results**

1. I generated the digital hydrologic-hydraulic model of the partial watershed of the Berettyó River. The model is appropriate for real time and predictive estimation of processes which are connected to environmental management. The model can be expanded, and can serve as a basis for the realization of the comprehensive mapping of the river basin.
2. I established the environmental qualification typology of the Berettyó River with the purpose of handling environmental management issues.
3. I proved that the environmental quality status of the waterspace is influenced by hydraulic parameters, which has been adversely affected by bed regulation.
4. I proved that the ecological status of the waterspace is determined by the runoff, the average water velocity, and the type of the stream and the flow, by numeric evaluations.
5. I demonstrated that the common, multivariate analysis of the hydrologic, physical, chemical and biological factors provides site specific data for the planning of water quality protection and stream rehabilitation.



6. I contracted the different aspects of water qualification methods in a uniform environment qualification test, according the recommendations of the EU Water Framework Directive. I adapted and expanded the Spencer environmental rapid test to the conditions of the Hungarian plains.

## **5.2. The applicability of scientific results**

1. I adapted the HEC-RAS hydrologic-hydraulic programme for the Berettyó River which allows the more accurate estimation of the planning variables.
2. I introduced the annual permanency likelihoods of ecologically relevant hydrologic, physical, chemical and biological factors, similarly to run-off permanency used in hydrology. With this method water quality factors can be analysed in any optional period.
3. I assessed the characteristics, functions, and intensity of relationships among hydrologic-hydraulic factors in the examined cross-sections. In this way the values of immeasurable or hardly measurable factors can be estimated based on calculated data.

## **SCIENTIFIC PUBLICATIONS IN THE SUBJECT MATTER**

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