MORPHOLOGICAL CHANGES AND THE ABATEMENT OF THEIR NEGATIVE EFFECTS ON A SELECTED PART OF THE DANUBE RIVER: OBJECTIVES, RESULTS AND PROPOSALS

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Abstract

In the Lower Danube reach numerous problems have arisen over the past two to three decades linked to changes of the river morphology and to erosion along the Danube reach between the Iron Gates reservoirs and the Danube delta. To address this issue of river morphology and its consequences for all types of water management activities in this area, a common initiative of all involved countries was launched that led to the definition of a project entitled "Morphological Changes and Abatement of their Negative Effects on a Selected Part of the Danube River". Implementation of this project was made possible by PHARE funding through the EPDRB (Environmental Program for the Danube River Basis).

This paper reports the results on the second phase study that was aimed at developing a common and integrated monitoring of all elements connected to the Danube river morphology in the Lower Danube reach and at developing a common and accorded methodology for planning remedial actions based on a common view and perception on the major processes.

Task 1 was devoted to the sampling of the hydrographical and morphological mapping of this reach and to developing a new surveying methodology. Central to this task was the definition of a new common reference system ("System 2000"). A special study was performed to develop a methodology for the processing of old, "historical" maps and their transformation from the original, in many cases unknown, system to the new common system.

Task 2 focused on the review and unification of the existing monitoring procedures. Monitoring of water and sediments has been performed independently by the countries leading to discrepancies when data were to be compared and exchanged. Based on a careful and broad inventory of all measurement and data handling techniques and on the results of several joint field measurement experiments in the pilot reach, a new unified monitoring methodology has been defined.

Task 3 dealt with the modelling of the morphological processes in the pilot reach. In the absence of recent and accurate river bed surveys and maps the modelling efforts have concentrated so far on the development of empirical relationships between channel parameters and flow and sediment transport variables and on sediment balance computations. Results of these investigations are reported in the paper by Bondar et al. in this conference.

Task 4 finally was directed at the performance of a Recognition Field Trip covering the common BG-RO river reach (km 375 to km 845) to document the state of the river morphology and to prepare an inventory of eventual "hot spots" along the reach. As a result a set of recommendations for global agreements have been derived.

Key words: Lower Danube, fluvial morphology, monitoring, surveying methodology, PHARE, international river study

MORPHOLOGISCHE VERÄNDERUNGEN UND VERMEIDUNG IHRER NEGATIVEN EINFLÜSSE AUF EINEN GEWÄHLTEN DONAUABSCHNITT: ZIELE, ERGEBNISSE UND EMPFEHLUNGEN

Zusammenfassung

In der vorliegenden Arbeit wird über die Ergebnisse eines im Rahmen des PHARE Environment Programmes durchgeführten Projektes zur Erfassung der flussmorphologischen Situation an der Unteren Donau berichtet.

Task 1 hat zum Ziel, eine einheitliche und dem Stand der Technik angepasste Methodik zur Stromgrundvermessung aufzustellen. Im Zentrum der Arbeit stand die Definition eines neuen Referenzsystems ("System 2000"). Ein spezieller Arbeitsschritt war auf die Auswertung der vorhandenen älteren Stromgrundaufnahmen ausgerichtet.

Aufgabe von Task 2 war es, die vorhandenen Methoden zur Wasserstands-, Durchfluss- und Sedimenttransport-Erhebung zu vereinheitlichen. Neben einer umfangreichen Dokumentation und Diskussion der in den verschiedenen Donauländern eingesetzten Methoden und Geräte wurden zwei Feldexperimente zum Abgleich der von rumänischer bzw. bulgarischer Seite verwendeten Methoden durchgeführt.

In Task 3 wurden die bisherigen Methoden zur Modellierung von Flussbettveränderungen im betrachteten Donauabschnitt erfasst und diskutiert. Wegen des Fehlens ausreichender Flussbettaufnahmen und detaillierter Sedimenterhebungen kamen überwiegend empirische Ansätze, auf Basis eines Bezuges zwischen Profiländerungen und hydrologischer Kenngrößen sowie einfache Sedimentbilanzierungen zum Einsatz. Vorschläge für die Entwicklung eines neuen Modellsystems wurden entwickelt.

Task 4 war darauf ausgerichtet, den derzeitigen flussmorphologischen Zustand in der bulgarisch-rumänischen Grenzstrecke zu erheben und Flussabschnitte mit starken Veränderungen in Hinblick auf Bankbildung, Erosion, Furten, Inselbildung und Fahrrinnenänderungen aufzuzeigen ("Hot spots"). In einem zweiten Teil wurden Übereinkommen zur weiteren Vorgangsweise beim Flussbett-Monitoring erarbeitet.

Schlüsselwörter: Untere Donau, Flussmorphologie, Monitoring, Vermessungsmethode, PHARE, internationale Flussstudie

1 Introduction

In the Lower Danube reach, a significant decrease of suspended sediment load has occurred during the last two decades. These changes are mainly caused by human activities such as the construction of large dams like the Iron Gate I and II on the Danube, but also by numerous similar constructions on the Bulgarian and Romanian tributaries. Climatic changes over the past two to three decades as indicated by diminishing precipitation amounts in large parts of the Danube river basin (Behr, 1994) and a pronounced decrease of runoff at the Lower Danube and its tributaries (PHARE_Environment, 1997) might also have contributed to the observed intensifications of bank erosion and river bed morphological changes.

In a first project (PHARE_Environment, 1997, Behr et al., 2000) a review of all existing data and information sources and a first assessment of the morphological state of the Bulgarian-Romanian Danube river reach was performed (Behr et al., 2000). Based on the results of this project a follow-up project was started in 1998 aimed at providing the necessary preconditions for a common and integrated planning of future remedial actions by the involved countries. Four main tasks had to be preformed by the project group which consisted of experts from Bulgaria, Romania, Yugoslavia and Austria, assisted by experts from Germany, Hungary and Slovakia in the preparation of the final recommendations. The present paper reports on the main results of these tasks.

2 Surveying methodology and processing of existing surveys

The aim of this part of the project was to review and prepare a careful inventory of the existing surveys in a 65 km long "pilot reach" section (km 556 to km 491) of the Danube and to assess these surveys with respect to their suitability to provide information on the morphological changes in the reach. For this purpose all available historical surveys from Romania and Bulgaria were inventoried and classified with respect to the possibility of further processing.

Central to this task was the definition of a new common reference system as the historical surveys and maps were based on different geodetic systems. The selected "System 2000" is based on the EUREF reference frame and the EUVN vertical system and uses conic Lambert projection for planar co-ordinate determination and the Baltic Sea, Kronstad height system for height determination (Valev and Sava 2002; paper to this conference). It is designed to constitute the common basis for all future surveying and mapping activities at the Lower Danube.

Processing of the given historical maps proved to be difficult as for some of the maps neither the co-ordinate system nor the reference system and the projection were known. Fig. 1 gives an overview of the procedure used to establish the necessary transformation equations for the historical maps included in the final analysis: RO1909, RO1956, BG1938, BG1968 (the first two letters designating the country, the figures designating the year of the survey). The transformation equations had to be defined on the basis of "identical points" having co-ordinates in at least two co-ordinate systems. To provide these points has proven to be a difficult task as the historical maps do not contain many identifiable points. Considerable efforts had to be undertaken by the Bulgarian and Romanian teams to identify and define the necessary number of identical control points which were needed to establish the transformations.

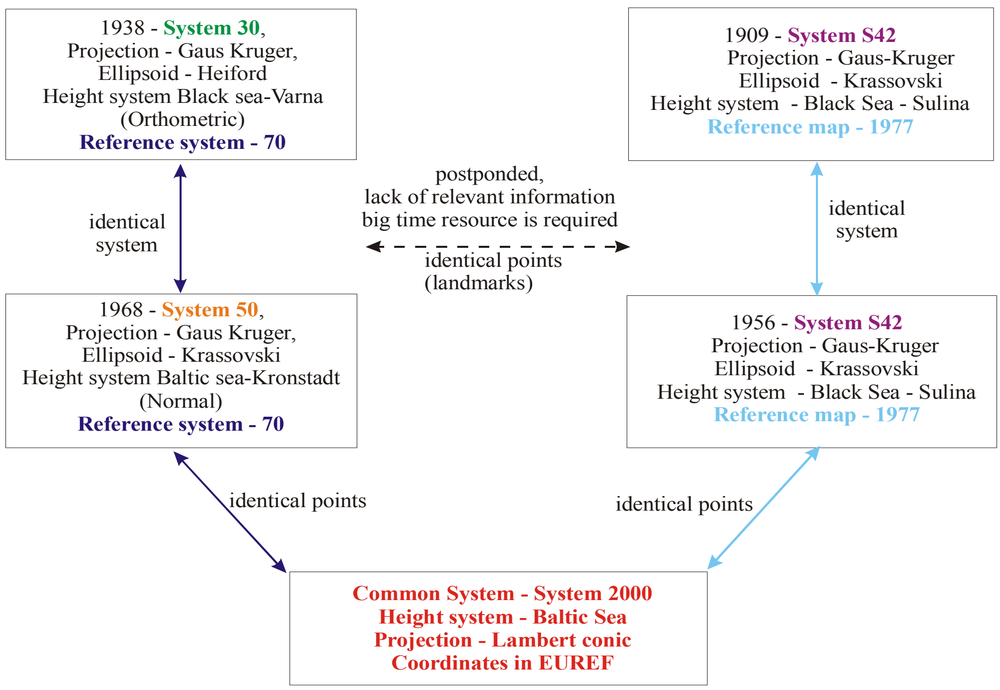


Fig. 1: Transformation to a common system

Processing of the derived data was done by application of the software SCOP (developed by the Institute of Photogrammetry and Remote Sensing, TU Vienna, Austria and INPHO GmbH, Stuttgart, Germany) designed specially to calculate and manipulate digital terrain models for river morphology purposes (http://www.ipf.tuwien.ac.at/produktinfo/scop/englisch/scop_e.html). The main input data are either digitised contour lines or cross-sections. The results of the computations can be presented in contour line, z- or colour coding and profile presentation. To compare the DEMs of the different epochs "intersections" of different models are built. As an example the contour line presentation of a sub-section of the pilot reach based on the maps RO1909 and RO1956 is given in Fig. 2.

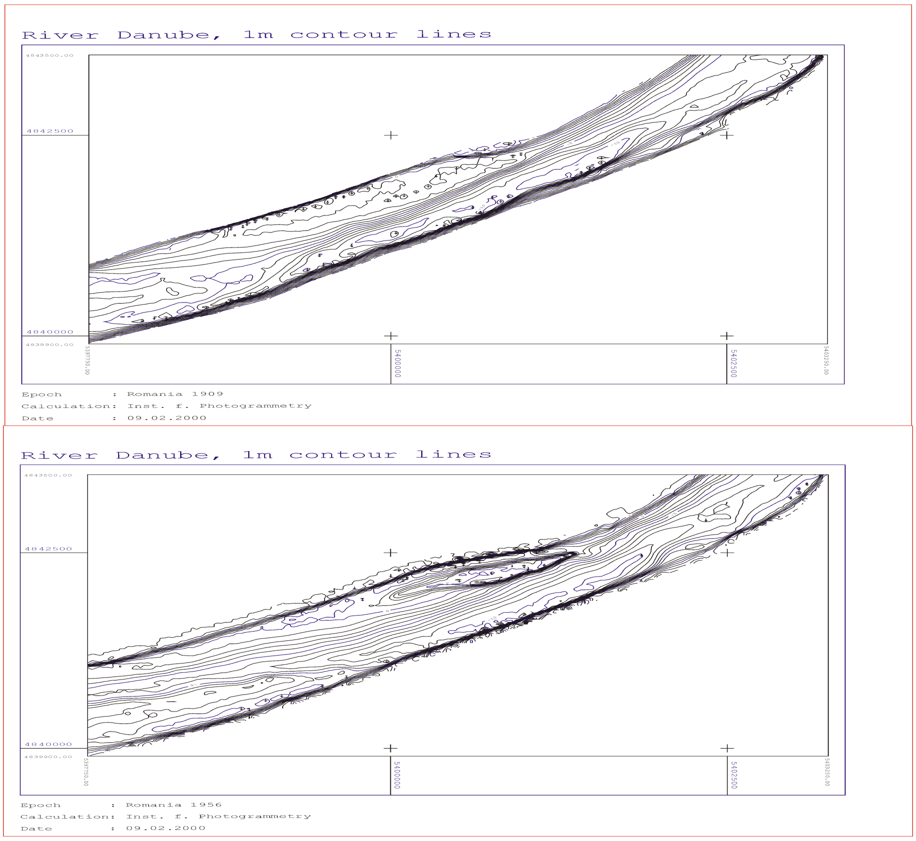


Fig. 2: Contour lines from Romania 1909 and 1956

The results obtained in this project have shown that valuable information on the structure and the morphological parameters (e.g. channel width, depth, cross-section, longitudinal profiles, islands, crossings etc.) of the river channel can be extracted from the old maps.

3 Review and unification of existing monitoring procedures

The review of the monitoring practice comprised the analysis of the existing monitoring network, the standards and rules applied, the measurement procedures and data processing methods. Table 1 gives an overview of the network of stations and the observations obtained at these stations. Water discharge and sediment load measurements in Bulgaria and Romania are performed in compliance with the standards and rules set by various international organisations such as Danube Commission, WMO, IHP-UNESCO and with ISO standards and national rules.

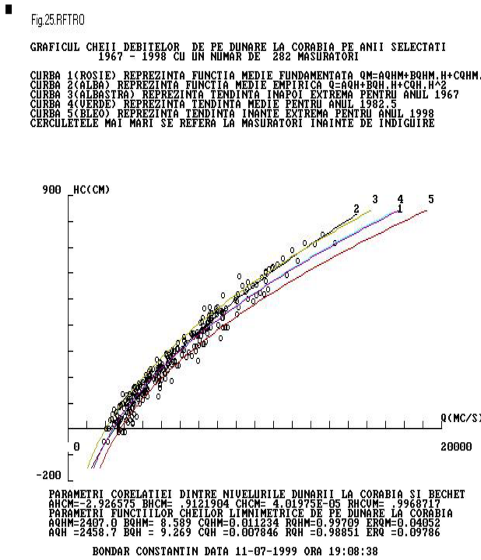
Table 1: List of the RO and BG gauging stations, included in the Field Trip

	Name	Position on the Danube	Altitude of the "zero"			Start of Measurem.	Elements of the Measurement and observation
			Black Sea Sulina	Black Sea Varna	Baltic Sea Kronstadt		
Ro	Dr.T.Severin	931	34.130			1879	H,Q,T,SSC, R,CSC
Ro	Tiganasi	878	31.320			1982	H,Q,T,SSC, R,CSC
Ro	Gruia	851	29.146		28.07	1898	H,Q,T,SSC, R,CSC
Bg	Novo Selo	833.6		27.00	26.75	1937	H,Q,T,SSC, SOC,R,CSC
Ro	Cetate	810.7	27.786		26.46	1898	H,T
Ro	Calafat	794.6	26.683		25.94	1879	H,Q,T,SSC, R,CSC
Bg	Vidin	790.2		24.81	24.55	1920	H,Q,T,CSC
Bg	Archar	770.6		24.00	23.76	1937	H,Q,CSC
Bg	Lom	743.3		22.89	22.65	1911	H,Q,T,SSC, SOC,R,CSC
Bg	Tcibar	717.6		22.50	22.27	1937	H,CSC
Bg	Kozloduy	703.5		22.00	21.77	1937	H,CSC
Ro	Bechet	679.0	22.083		21.31	1880	H,Q,T,SSC, R,CSC
Bg	Oriahovo	678.0		21.56	21.34	1924	H,Q,T,CSC
Bg	Vadin	653.6		20.00	19.78	1937	H,CSC
Bg	Baikal	640.8		20.00	19.78	1927	H,CSC
Ro	Corabia	629.5	20.123		19.49	1879	H,Q,T,SSC, R,CSC
Bg	Somovit	607.7		17.86	17.64	1921	H,CSC
Bg	Nikopol	597.5		17.23	17.02	1927	H,CSC
Ro	Tr.Magurele	597.0	19.125		18.34	1879	H,Q,T,SSC, R,CSC
Bg	Svistov	554.3		15.10	14.89	1913	H,Q,T,SSC, SOC,R,CSC
Ro	Zimnicea	553.5	16.218		15.29	1879	H,Q,T,SSC, R,CSC
Bg	Russe	495.6		11.99	11.80	1878	H,Q,T,CSC
Ro	Giurgiu	492.8	13.060		12.58	1879	H,Q,T,SSC, R,CSC
BG	Tutrakan	433.0		8.89	8.70	1943	H,CSC
Ro	Oltenita	429.7	10.010		9.53	1879	H,Q,T,SSC, R,CSC
Bg	Silistra	375.5		6.50	6.27	1941	H,Q,T,SSC, SOC,R,CSC
Ro	Calarasi	364.5	7.31		6.79	1879	H,Q,T,SSC, R,CSC

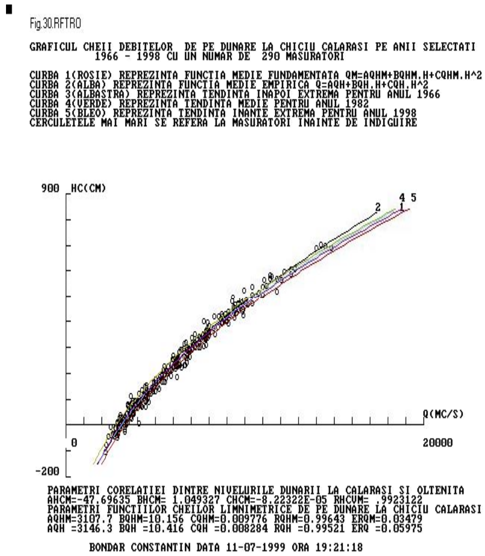
*) elements of measurements and observations:

H	gauge water stage
Q	Discharge
T	water temperature
SSC	concentration of suspended sediments
SOC	concentration of organic matter
R	runoff of suspended sediments
CSS	cross-section geometry

Central to the success of these methods is the determination of accurate discharge rating curves and empirical suspended sediment relationships. Discharge rating curves exhibit significant variation over time in nearly all stations. Fig. 3 shows as examples the rating curves of a relatively stable (Chuchiu-Calarasi) and a relatively unstable hydrometrical profile (Corabia). Considerable shifting of the curves had been necessary to fit the measurement data of different years. Also considerable deviations of the data from the fitted curves are to be seen indicating changes in river bed morphology within relatively short time spans. These observations are in line with the general experience that there are only a few sections of the Lower Danube where a stable riverbed exists, e.g. the section of Turnu Magurele where rocks form the river bed. Most of the other sections experience frequent morphological changes as can also be detected by an analysis of the morphometric parameters of a cross-section such as river width, depth etc. The observation that the rating curves seem to follow a tendency of shifting into the direction of higher discharges accompanied by a slight clockwise rotation made at several hydrometric cross-sections coincide with the observation of a tendency of channel widening in some of the investigated profiles.



a) Corabia (km 624.2)



b) Chiciu-Calarasi (km 379.6)

Fig. 3: Discharge rating curves at two selected hydrometric stations – Time Period 1966-1998

The central points for an accurate assessment of suspended sediment discharge data are an appropriate measurement scheme and an appropriate data processing method. Fig. 4 gives examples of the relationships that are used in analysing sediment-water discharge relationships. Fig. 4a shows the relation between the suspended sediment concentration in the vertical 1 nearest to the bank (C1) and the mean concentration derived from detailed measurements and averaged across the whole cross-section (Cav). The relationship can be studied based on 3 to 5 detailed measurements annually and derived to estimate the suspended sediment discharge from single-vertical measurements. Fig.4b shows the rather irregular relationship between water Q and suspended sediment R discharge. Specially marked are the two situations observed during the field experiment. The wide variation of the points with high deviations in each class of discharge and the occurrence of high R-values also for low discharges indicate that suspended sediment discharge is mainly controlled by sediment supply which itself is strongly linked to input from the tributaries. It can be concluded that a proper understanding of the sediment transport process can only be achieved if also reliable estimates of the sediment input from the Danube tributaries are available. It, therefore, is strongly recommended to include sediment measurements at the nearest upstream stations of the main tributaries in the monitoring system.

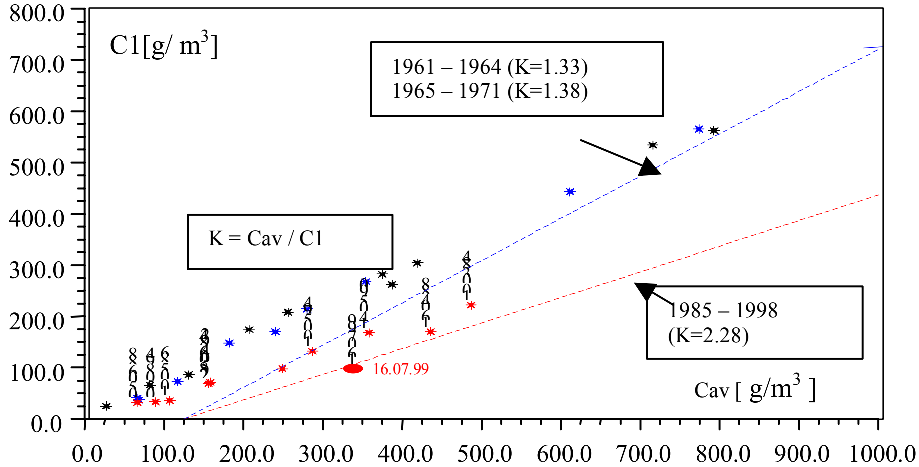


Fig. 4a: Relation between average (Cav) and the single sample (C1) suspended sediment concentration

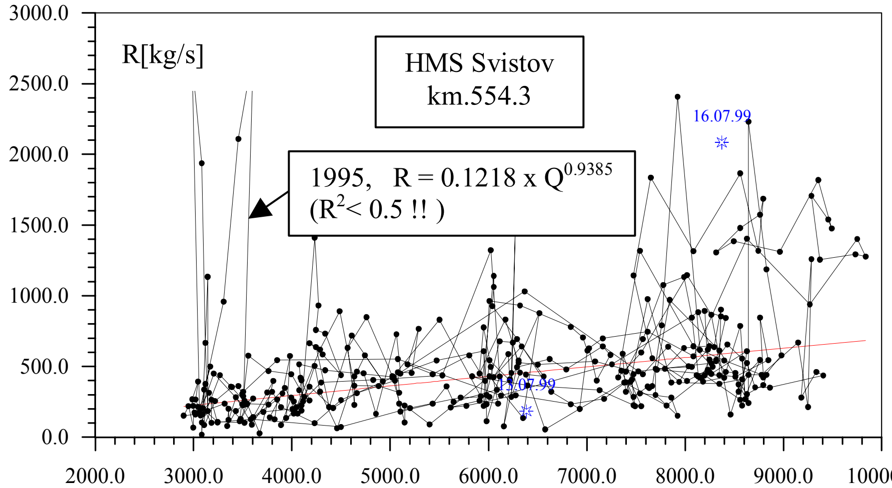


Fig. 4b: Relation between water and suspended sediment discharge at Svistov

To assess the methods applied in both countries and to compare the results obtained by the methods applied presently in both countries, field experiments were planned. Two measurement campaigns were performed. The first experiment from July 13 to 16, 1999, was carried out in connection with the surveying experiment in the 10 km river section in the Svistov/Zimnicea area. The second experiment was carried out in the Ruse/Giurgiu section on September 26 and 29, 1999. An overview of the measurements performed, the equipment applied and the laboratory methods used in given in Table 2.

An assessment of the field experiments led to the conclusion that the Bulgarian and Romanian discharge measurements differed only within common limits (less than 2.5 %), the suspended sediment load measurements were also in good agreement, differing in two cases by less than 7 % and in the third case by 21%, the possibility to apply GPS-technology for positioning during the measurements greatly enhanced the efficiency and the accuracy of the measurements.

From the review of the monitoring practices and the field experiments some conclusions were drawn:

- For future monitoring a combined network of stations is proposed including four pairs of BG-RO "coupled" stations defined as common measurement sites, namely: Oriahovo(BG) – Bechet(RO), Nikopol(BG) – Turnu Magurele(RO), Svistov(BG) – Zimnichea(RO), Ruse(BG) – Giurgiu(RO).
- New equipment, including measurement vessels, current meters, samplers for the collection of suspended sediment, bed load and bed material, and laboratory equipment is necessary.

- To assure comparability between the measurement data prepared in each of the countries, the harmonisation of the monitoring methods is necessary. To achieve best results, it is recommended to use the same methodology, the same equipment and the same data analysis software in both countries.
- The first performance of a series of really joint measurements of the BG and RO team is considered a very promising start for the future. The performance of a series of joint measurements is recommended to test the selected methods, equipment and data analysis procedures to be applied in the future.

Table 2: Summary of data on the hydrometric field experiments

MEASUREMENT HYDROMETRICAL ELEMENTS	Units	13.07.1999		16.07.1999		29.09.1999	
		Ro results at Zimnicea	Bg results at Svistov	Ro results at Zimnicea	Bg results at Svistov	Ro results at Giurgiu	Bg results at Ruse
Water level at hydrometrical gauge	H(cm)	285	320	425	464	38	109
Water discharge	$Q(m^3/s)$	6405	6344/6387	8876	8215/8376	3470	3314/3445
Surface of wetted area	$A(m^2)$	6726	6958	8020	7887	4528	4568
Width of river bed at water level	B(m)	721	721	740	740	766	-
Mean velocity of water current	Vm(m/s)	0.952	0.943	1.107	1.099	0.765	0.726
Maxim velocity of water current	Vmax(m/s)	1.153	1.169	1.422	1.457	0.952	-
Mean depth of bed	hmean(m)	9.33	9.65	10.84	10.66	5.91	-
Maxim depth of bed	hmax(m)	11.15	11.6	12.85	12.85	11.0	-
Suspended sediment discharge	R(kg/s)	185.4	180.4/181.9	2662	1991/2083	23.8	30.4/39
Mean concentration of suspended sediment	$Cm(g/m^3)$	30	28.4/28.5	300	242.3/248.6	6.85	9.2/11.3
The median diameter of suspended particles	ds50%(mm)	0.0104	-	0.00471	-	0.0179	-
Bed load	G(kg/s)	-	-	-	-	3.67	-
The median diameter of bed load particles	dg50%(mm)	-	-	-	-	0.779	-

EQUIPMENT		13.07.1999	16.07.1999	29.09.1999
Discharge measurements	BG	OTT-current meter	OTT-current meter	OTT-current meter
	RO	Biotron flow meter	Biotron flow meter	Jestovskii-current meter
Suspended sediment measurements	BG	Self sealing sampler Any level bottom sampler	Self sealing sampler Any level bottom sampler	Self sealing sampler Any level bottom sampler
	RO	Bottle sampler	Bottle sampler	Marine riversible bathometer
Bed load measurements	RO	-	-	OTT-bed load bathometer
Laboratory equipment	BG	filtering, drying	filtering, drying	filtering, drying
	RO	filtering; DR/2000 HACH photospectrometer	filtering; DR/2000 HACH photospectrometer	DR/2000 HACH photospectrometer

4 Modelling of morphological processes in the pilot reach

The Lower Danube constitutes a typical example of a large, lowland river with a wide channel, a slope of only approximately 0.05 ‰ and well developed alluvial plains especially on the left bank on the Romanian side. The channel morphology is characterised by sequences of alterations of uniform and divided channel reaches with predominantly straight or only slightly sinuous main channel and sinuous side-channel branches. Following flood protection measures starting in the 19th century and being strengthened around the 30-ies and after the Second World War the total floodable area has decreased considerably.

A simplified scheme of the general morphological features of the river channel in the pilot reach between km 556 and km 491 is given in Table 3, summarising the bulk characteristics of channel morphology in terms of the channel planform, channel parameters width and depth and the occurrence of islands.

The current state of modelling is characterised by empirical approaches due to the lack of reliable river bed survey data. Several empirical modelling attempts have been made to derive some quantitative results on the dynamics of the morphological processes in the pilot reach. Two approaches are distinguished: (a) where the morphological changes from changes in the channel and flow parameters and (b) models based on sediment balance equations.

Table 3: Mean morphological features of the Danube river channel in the pilot reach

km	Islands	Channel planform		width (m)	depth (m)
553,2	Zimnicea (g.st)				
		Uniform	sinuous	1239	5,6
547					
	Vardim isl. (r)	divided, 1 side-channel	slightly sinuous highly sinuous	700 (m.ch) 280 (s.ch)	
542					
	Gasca isl.(l)	divided, 1 (small) side-channel	highly sinuous	1000	
538	538-536	bank protection (BG)			
		uniform	(slightly) sinuous	1150	4,73
530					
	Batin isl. (r)	divided,	sinuous	1250	
		1 side channel	sinuous	280 (s.ch)	
522					
		uniform			
511					
	Kamadinu isl. (r)	divided,		1250	
		1 side channel		280 (s.ch)	
504,6					
	Liulak isl. (r)	divided,	straight slight sinuous	600	
		1 side channel	sinuous	300 (s.ch)	
501					
		uniform		861	5,3
497,3					
	Slobozia isl. (l)	divided, 1 side channel	straight to sinuous		
495,8					
493	Giurgiu - g.st.	uniform	straight, v. slightly sinuous	650	4,7
489					
	Mocanu isl. (l)				

m.ch. – main channel
s.ch. – side channel
— - recommended bank protection
g.st. – gauging station
r, l – right, left side
— - recommended river works

Inference on morphological changes from channel and flow parameters:

Extensive research efforts and studies exist in the attempt to analyse morphological changes of the river bed (Bondar et al., 1991, Bondar et al., 1994, Bondar, 1996). Based on the evaluation of cross-section profile data as surveyed during discharge measurements at the four hydrometrical cross-sections (Zimnicea, Svistov, Giurgiu and Ruse) in the time period of 1965-1997, a model for the evaluation of the time variation of channel parameters was applied in the pilot reach, the main parameters being the channel width and average riverbed depth. Another approach is to investigate the variation of the river bed elevation at crossing sites based on the idea to concentrate on the most critical navigational impact, the minimum available depth.

Results of these empirical models show that considerable morphometric changes occur in the various cross-sections and that crest elevations at crossing sites exhibit a highly dynamic behaviour. When assessing the navigation conditions in the pilot reach, the average number of days per year with critical navigation situations has increased from 30-40 days/yr. in the period 1956-1970 to an average of 85-95 days/yr. in the 1985-1995 period.

Modelling morphological changes in the pilot reach on the basis of the sediment balance equations:

Based on the available data a balance between input and output data could be performed. All sediment data collected at the Romanian stations for the time period 1956-1995 have been analysed on a yearly and a monthly basis and differences between the input and output terms computed and interpreted in terms of river bed changes. Also empirical relationships relating the computed net-transport change to the corresponding flow conditions have been derived.

The results obtained point to the important role of river width. Some indications can be found that sections with "over-width" – as an estimate a width of around 1,000 to 1,100 m has been derived for the pilot reach section in the Romanian study – may be prone to bar formations in the analysed single-threaded channel sections. The Romanian investigations further address the differences obtained when total suspended sediment loads or coarse sediment loads, respectively, are considered. Also differences between different time periods of the whole observation period have been detected. The observation of a reduction in total sediment transport in the last two decades is paralleled by the results of the Bulgarian investigation into the flow transport ability that show a reduction of approx. 34 to 37 percent in transport ability when the more recent period is compared with earlier ones, the turning point being located in the year 1971.

To improve the situation in the field of modelling at the Lower Danube it is of paramount importance to improve the prerequisites. This means:

- To provide a new river bed map as a basis for all modelling tasks.
- To establish a new monitoring system to monitor the channel (river bed and channel banks) regularly and necessarily detailed over the whole considered reach.
- To improve sediment monitoring, particularly to direct attention to the bed load measurement and the observation of grain-size distribution.

5 Remedial action planning

Past remedial actions in the pilot reach:

Remedial action activities have been directed in the past mainly to the consolidation (stabilisation) of banks at specific sites and the local improvement of navigation conditions through local dredging. Main emphasis has been on the protection of harbour areas, whereas most other areas with natural bank lines have remained in their natural unprotected state. Starting with a substantial investigation on the stability of the embankments along the entire Bulgarian - Romanian border river reach in 1971 various studies have been performed in Bulgaria since then, among them an elaborate investigation for the river section from km 600 to 550 based on a comparison of maps of 1971 and 1980. Engineering design studies and actual measures have remained restricted to some limited sections of the Danube reach. (Modev, 1980)

Some positive effects on bank stabilisation have been expected in Romania from the systematic planting of trees (Canadian poplars) on the floodplain banks along the Danube. However, as is evidenced by tens of kilometres of river banks with fallen uprooted trees, the poplar plantations have more likely diminished rather than increased bank stability.

Dredging has always been part of the works to maintain the navigation waterway, both in harbour areas and at river sections with over-width. However, dredging activities are not seen as a solution to the problems at crossings in over-width river sections since their result has only a transitory effect and the need to repeat the work again and again after high flow periods have generated high costs and the demand for proper remedial action measures that assure a long-term solution and reduce maintenance costs.

Review of river engineering works to improve navigation conditions:

Based on the experience gained in the past and on the observations made during the Recognition Field Trip the situations that need proper consideration in the planning of remedial actions have been defined as follows:

- High erosion intensity sections,
- Over-width sections,
- River stretches with repeated shifting of the waterway,
- Narrow and deep channel stretches with highly unsymmetrical cross-sections.

A closer inspection of the observations on these situations and the sites where they occur reveals that in many cases more than one of the above mentioned features can be found at one site. This may point to an internal relationship between them governed by the morphological processes generated at "over-width" river cross-sections.

6 Preparation of global agreements and development of main recommendations

A main part of the implementation of this task was the Recognition Field Trip (RFT) covering the whole common Bulgarian-Romanian river reach (km 375 to km 845). It was carried out between September 20 and 25, 1999, involving members of the Austrian, Bulgarian, Romanian and Yugoslavian expert teams.

During the RFT the joint team performed a detailed assessment on the observed river phenomena which were documented on the basis of navigational river maps (Carte de pilotage du Danube 1969, and 1994, Lotsmanska Karta, Ruse 1980), augmented with hand written notes by the team members, and by photo and video documentation.

In a second phase the gathered information was compared, compiled, unified, and also augmented with observed field data on erosion rates (m/yr) which were supplied by the country experts. Comparative studies on the channel width changes over time, based on navigation maps from different years, were carried out by the country experts. All this information led to a very detailed qualitative assessment of the problem. Trying to define the "Hot Spots" and endangered reaches, where remedial actions have to be taken, the following six aspects were considered: (a) river width, (b) erosion intensity, (c) in-channel bar formation, (d) islands, (e) crossings and (f) shifting of the navigation channel. The results of all investigations and studies were summarised in a comprehensive list of observations on these aspects. Fig. 5 shows an extract of hot spot stretches in the pilot reach.

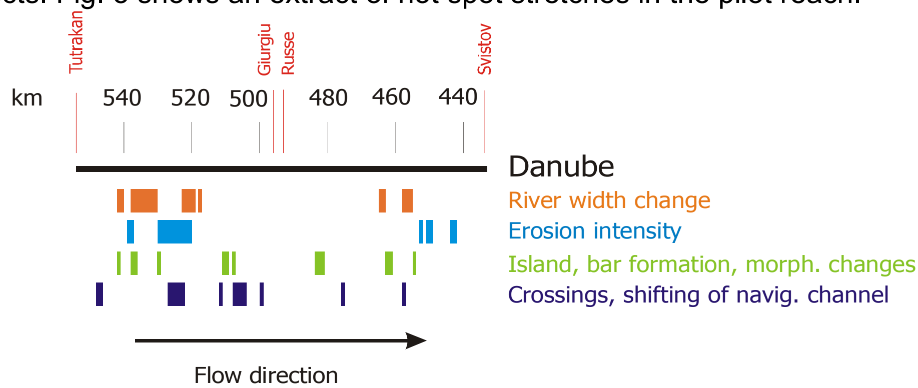


Fig. 5: Hot spot stretches in the pilot reach

The results of the RFT can be summarised as follows:

- The Recognition Field Trip was the first international expedition in modern history of the Lower Danube where experts from four European countries observed and recorded the morphological conditions and development of the Danube river morphological process.
- The Danube river morphological process can be classified as a process in progress. In the upper part of the surveyed section (km 845 – km 730) the intensity of erosion and accumulation is less than in the middle section (km 730 – km 500) or at the lower part of the reach (km 500 – km 375).
- More than 200 kilometres of the Danube river show bank erosion on both sides.
- Some of the crossings at the lower part of the section (km 375 – km 500) have a tendency to become a limiting factor for navigation within the coming years.

Main recommendations:

- Development of a **joint topographic-geodetic network** for both Lower Danube river sides (km 848 – km 375).
- Establishment of a joint cartographic basis for the assessment of the morphological and ecological processes; development of a **new common Danube river map** in the common geodetic system for both countries.
- Development and construction of a **joint hydrological network** at the Lower Danube.
- Establishment of an **ecological-hydrological experimental section** at the Lower Danube (km 581 – km 493) to provide the basis for: (a) the harmonisation of the

monitoring methods between the involved countries, comprising the performance of a series of joint measurements including laboratory analysis, data analysis and data exchange and (b) the development and verification of a computer model for the simulation of the morphological processes on the Danube river.

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