**XXIst CONFERENCE OF THE DANUBIAN COUNTRIES**
ON THE HYDROLOGICAL FORECASTING AND HYDROLOGICAL BASES OF WATER MANAGEMENT
2-6 September 2002, Bucharest, Romania

# MORPHODYNAMIC ASPECTS OF THE DANUBE RIVER FROM CORABIA TO OLTENITA, IN THE PERIOD OF TIME FROM 1980 TO 2000

**Dan Batuca and Carmen Buta**
National Institute of Meteorology and Hydrology, Bucharest, Romania
71552 Bucharest, Sos. Bucuresti-Ploiesti No 97
dbatuca@meteo.inmh.ro - bcarmen@meteo.inmh.ro

**Florian Ploscaru and Marin Petrus,**
CN Apele Romane, Arges-Vedea-Pitesti District, Romania
Pitesti, Str. Calea Campul Lung No 6-8

***Abstract:*** The main quantitative and qualitative aspects of the Lower Danube River morphodynamic evolution, from Corabia Town to Oltenita City in the period of time from 1980 to 2000, are presented in the paper. The analysis has been carried out by making use of a large amount of hydrologic data collected from 5 permanent hydrometric stations, as well as of some bathymetric data collected at a number of 6 representative sections along the river reach.

***Keywords:*** Danube River, morphodynamic evolution, water flow, sediment transport, river bed processes, cross-sectional changes, thalweg changes, hydrometric station, hydrologic data, bathymetric data.

## Introduction

The Danube River, with a total length of 2857 km and a catchment aria of 817,000 Km$^2$ within 18 countries, is the second largest river in Europe – *the Great Blue Diagonal of Europe* (Fig.1).


*Fig.1. Danube River Bazin.*

The Danube River is a major international watercourse, multipurposes used by riparian countries for power generation, fluvial navigation, water supply, irrigation, fishing and others; it flows through nine countries and crosses four capital cities (Belgrade, Budapest, Bratislava, Vienna) and many other important cities in the region (Liptak, 1993).

The Lower Danube River flows in Romania over 1075 km (37.6% from the total length), from Bazias Town to the Black Sea and collects waters from a 232,000 km$^2$ drainage area (28.4% from the total catchment).

A number of six major tributaries from Romanian territory (Jiu, Olt, Arges, Ialomita, Siret and Prut rivers), one tributary from Serbian territory (Timok river) and other four smaller tributaries from Bulgarian territory (Lom, Ogosta, Isker and Iantra rivers) are discharging in the river reach (Fig.2).

Two great hydrotechnical systems (the Iron Gates 1 and 2) are actually in function for hydro-power generation, fluvial navigation and water supply, as well as two nuclear-power stations (at Kozlodui in Bulgaria and Cernavoda in Romania).

Several fluvial harbours and pumping stations for irrigation and industrial and municipal water supply are presently in operation in the region.

The river reach is actually crossed by the great road and rail bridge at Giurgiu-Russe and will be crossed in the next future by a second great bridge at Calafat-Vidin.

Various social, agricultural and industrial objectives in the region are protected against floods by several dykes along both Romanian and Bulgarian river banks.

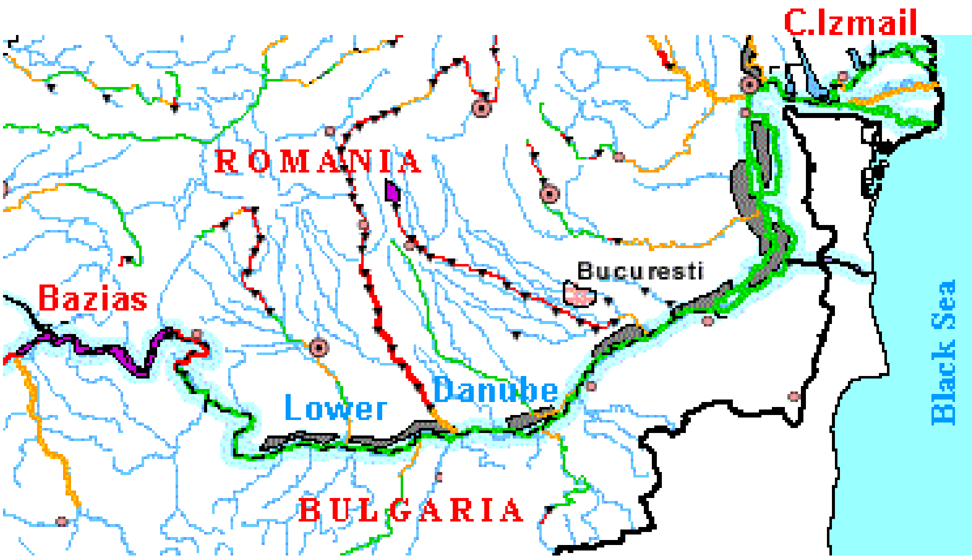


*Fig.2. Lower Danube River from Bazias to Black Sea.*

Water flow and sediment transport regime in the Lower Danube River are non-uniform in space and time (Stanescu et al., 1967, Stancik et al., 1988).

In the period of time from 1931 to 2000 the mean annual flow varies from 5600 m$^3$/s at Bazias (the river entrance in Romania) to 6500 m$^3$/s at Ceatal Izmail (the upstream end of the Danube Delta), with the tributaries' contribution of 900 m$^3$/s in total; a minimum flow of 1600 m$^3$/s and a maximum flow of 15,000 m$^3$/s have been recorded.

The mean annual suspended load varies from 750 kg/s to 1000 kg/s and the bed-load is about 3% to 5% from suspended load.

Several morphological processes and river bed and bank changes (general and local aggradation and degradation, alluvial island formation) have been detected and observed in the river channel. They are determined by natural causes (soil erosion in the catchment, water flow and sediment transport in the river system) and influenced by anthropic works and actions (art and engineering structures, fluvial navigation, water use, hydraulic sand mining); they have numerous environmental, technical and social effects (INMH-PHARE, 1997, Behr et al., 2000, Buta and Batuca, 2002).

### Lower Danube River from Corabia Town to Oltenita City: Case study

A hydro-morphological study has been recently carried out for a 160 km-long river reach, from Corabia Town to Oltenita City (Fig. 3), for the period of time from 1980 to 2000.

The analysis has been conducted by making use of a large amount of data:

- hydrologic data collected at a number of 5 permanent Romanian hydrometric stations, namely Corabia (km 630), Turnu Magurele (km 597.3), Zimnicea (km 554.1), Giurgiu (km 493) and Oltenita (km 429.7), and
- bathymetric data collected during some field campaigns at a number of 6 representative sections along the river (located at km 608 between Corabia and Turnu Magurele, at km 578 and 560 between Turnu Magurele and Zimnicea, at km 504 between Zimnicea and Giurgiu, and at km 476 and 448 between Giurgiu and Oltenita).


*Fig.3. Lower Danube River from Corabia Town to Oltenita City.*

### Water flow regime

Water flow regime recorded at the two hydrometric stations from upstream end (Corabia Town) and downstream end (Oltenita City) of the river reach is shown in figure 4.

For the period of time from 1980 to 2000, the mean annual flow rate varies from 5630 $m^3/s$ at the Corabia station to 5880 $m^3/s$ at the Oltenita station.

An evident increasing tendancy of the mean annual flow rate is to be observed since 1990 at both hydrometric stations.

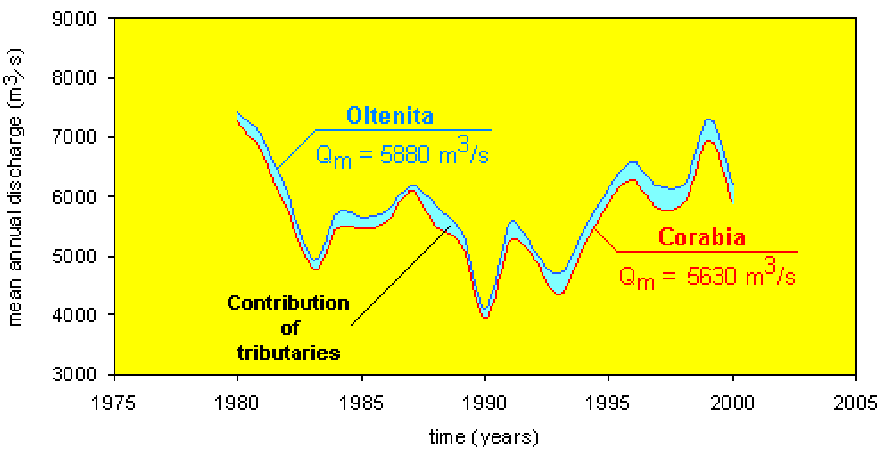


*Fig.4. Water flow regime in the Lower Danube River from Corabia Town to Oltenita City.*

## Sediment transport regime

The existing alluvial materials in the river channel are non-homogeneous mixtures of sand that originate from the upper Danube catchment, river and tributaries.

They are transported by gravity mainly in suspension, the bed-load transportation being relatively small (less than 5%).

The mean size of suspended sediment ranges from 0.017 to 0.024 mm while the size of bed-load sediment ranges from 0.21 to 0.25 mm.

Sediment transport regime recorded at the Corabia and Giurgiu hydrometric stations is shown in figure 5 (sediment data at the Oltenita station are not available).

For the period of time from 1980 to 2000, the mean annual suspended-load rate varies from 390 kg/s at the Corabia station to 520 kg/s at the Giurgiu station.

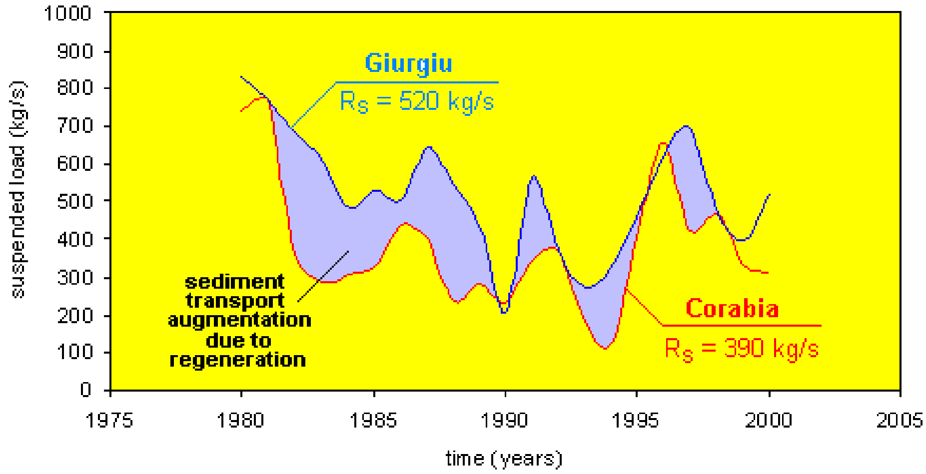


*Fig.5. Sediment transport regime in the Lower Danube River from Corabia Town to Giurgiu City.*

A general decreasing tendancy of the sediment transportation in suspension is evident for the entire period of time at both hydrometric stations, that could be explained by:

- the general changes of climatic and hydrology conditions in the region,
- the anthropic influences in the catchment and river system of the Middle and Lower Danube River,
- the important retention of sediment in upstream Danubian reservoirs (the Iron Gate 1 completed in 1972 and the Iron Gate 2 completed in 1985),
- the severe reduction in sediment contribution of the major Romanian tributaries (the Jiu, Olt and Arges rivers, with reservoirs in cascade that have been drastically silted up during last few decades), and others.

Based on a large number of direct measurement data at three hydrometric stations (Corabia, Zimnicea and Giurgiu), the following relationships expressing quantitatively the transportation of sediment (in suspension and bed-load) have beed developed for various engineering and environmental purposes in the region:

- at the Corabia station:

$$Q_s = 0.26\times10^{-5}\,Q^{2.100} \quad (1)$$

- at the Zimnicea station:

$$Q_s = 0.23\times10^{-5}\,Q^{2.136} \quad (2)$$

- at the Giurgiu station:

$$Q_s = 4.60\times10^{-5}\,Q^{1.805} \quad \text{and} \quad Q_b = 4.08\times10^{-7}\,Q^{1.911} \quad (3)$$

where $Q_s$ is suspended-load discharge (in kg/s), $Q_b$ = bed-load discharge (in kg/s) and $Q$ = water discharge (in m$^3$/s).

For the Lower Danube River reach from Corabia Town to Giurgiu City the following two generalized empirical relationships have been produced:

$$q_s = 5.41\times10^{-3}\, q^{2.067} \qquad \text{and} \qquad q_b = 1.62\times10^{-4}\, q^{1.995} \tag{4}$$

as shown in figure 6, as well as a relationship expressing the ratio of sediment discharges:

$$\frac{q_s}{q_b} = 33.4\, q^{0.072} \tag{5}$$

where $q_s$ is the specific suspended-load discharge, per unit of river channel width (in kg/s.m), $q_b$ = specific bed-load discharge (kg/s.m) and $q$ = specific water discharge (m$^3$/s.m).

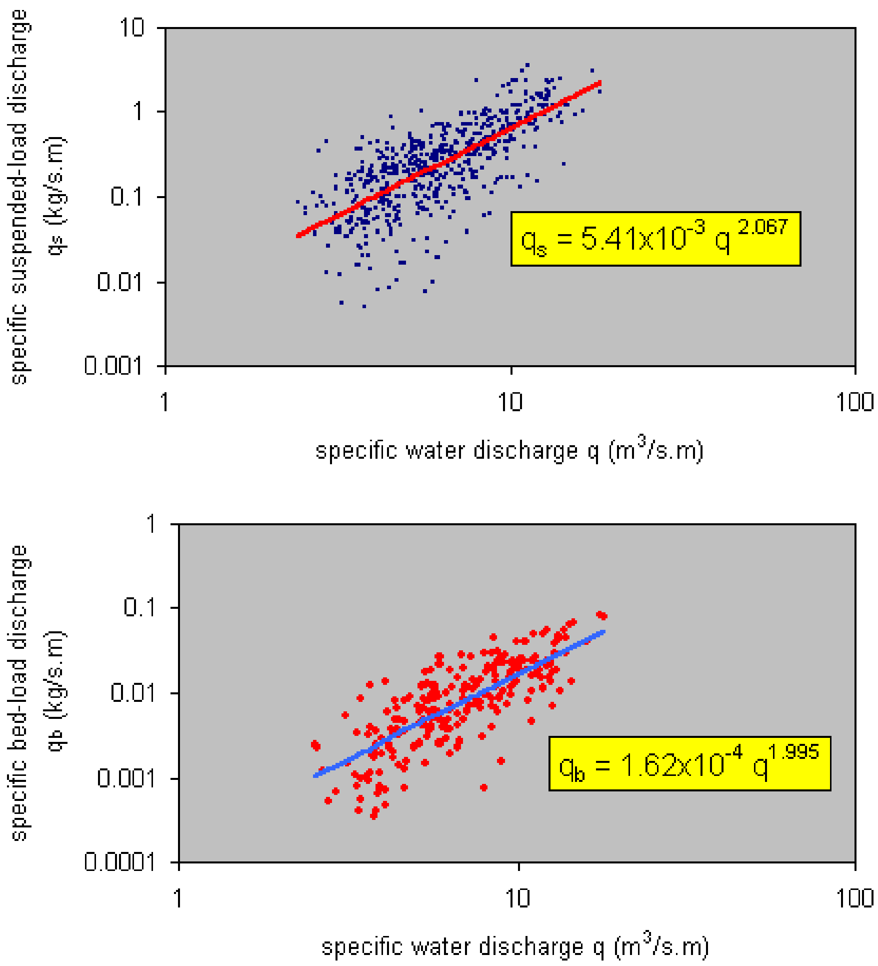


*Fig.6. Suspended-load and bed-load transportation in the Lower Danube River from Corabia Town to Giurgiu City.*

The analysis of these relationships has led to some general conclusions as follows:

– the sediment transport, developed in the river channel either in suspension or as bed-load, has an unique character given by the single value of the flow rate exponent, of about 2,
– the suspended-load to bed-load ratio has a small variation with water discharges, namely about 36.5 during low flows, 38.5 during medium flows and up to 40 during high flows, and
– the bed-load is about 2 - 3% from the suspended-load.

The above characteristics of sediment transportation are valid only for the particular reach of the Lower Danube River from Corabia Town to Giurgiu City; some limited extensions to other upstream or downstream reaches are acceptable only as informative.

Many other semi-empirical equations for transportation of suspended sediment have been derived from “*stream power theory*” and “*gravitational theory*” at various hydrometric stations along the Lower Danube River, as recently reported by Buta and Batuca (2002).

**River bed processes and changes**

Several morphological processes (river bed and bank changes) have been observed in time along the Lower Danube River from Corabia Town to Oltenita City, such as:

- river bed alluvial aggradation,
- formation of new alluvial deposits and islands, or migration of the existing ones,
- change of thalweg line (affecting fluvial navigation conditions),
- river bed erosional degradation (general or local),
- river bank erosion, and others.

Aiming to investigate these processes and changes a number of field campaigns have been carried out in the period of time from 1980 to 2000, when some bathymetric (ultrasonic) measurements have been performed and relevant data have been collected.

**Thalweg changes**

The longitudinal profile of the Lower Danube River thalweg from Corabia Town to Oltenita City is irregular, of “chut-and-pool” type, as shown in figure 7. This is a live line, changing in time its vertical position (by general aggradation and/or degradation), with possible migration across the channel (important for fluvial navigation).

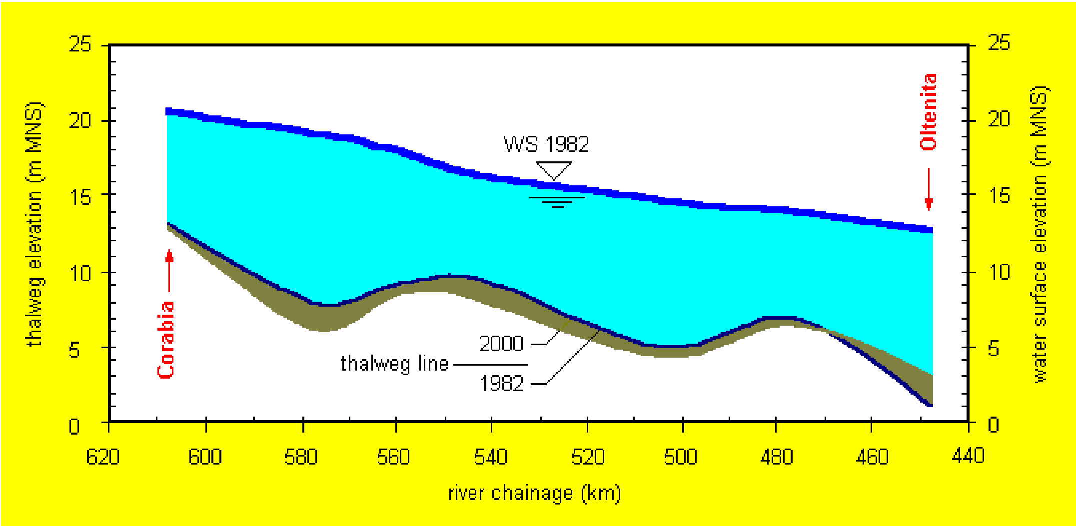


*Fig.7. Longitudinal variation of the Lower Danube River thalweg from Corabia Town to Oltenita City.*

The variation in time of the thalweg line in various locations along the river is shown in figure 8.

In two decades, a general falling down of the thalweg line due to river bed degradation has been detected at Tr. Magurele, km 578 (up to 2.15 m from 1983 to 1990 and to 0.90 m from 1995 to 2001), Zimnicea, km 560 (up to 1.25 m from1980 to 1999) and Giurgiu, km 504 (up to 0.65 m from 1980 to 2000), while a general rising up of the thalweg line due to river bed aggradation has been observed at Oltenita, km 448 (up to 0.50 to 0.75 m from 1983 to 2000).

An alternate (up and down) variation of the thalweg line has been observed at Corabia, km 608, with an aggradation of 0.85 m maximum depth from 1982 to 1995, followed by a degradation of 0.65 m maximum depth from 1995 to 2000.

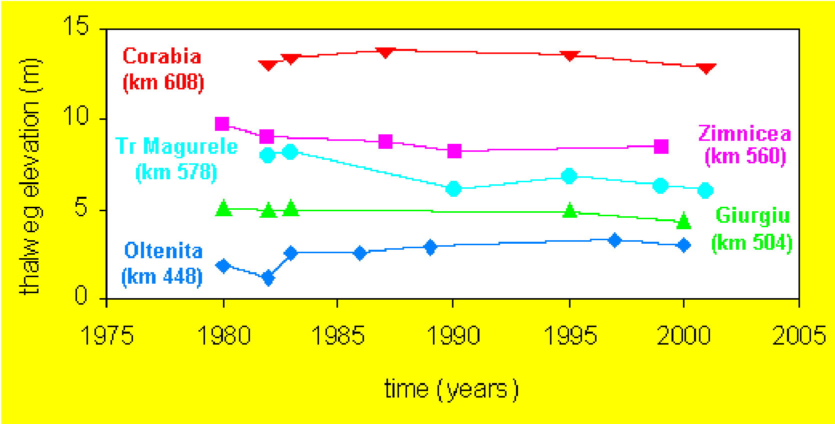


*Fig.8. Time variation of the Lower Danube River thalweg from Corabia Town to Oltenita City.*

**Cross-sectional changes**

The Lower Danube River channel from Corabia Town to Oltenita City is subject in time to important cross-sectional morphological changes, including river bed and banks erosion and deposition, that are caused by variation of water flow and sediment transportation regimes, by fluvial navigation, sand mining and many other human activities in the region.

In the region of Corabia Town (km 608) a progressive erosional degradation process occurred from 1982 to 2001 at the left side of the river channel, while an alternance of alluvial deposition and erosion has been observed in the middle of the channel, as shown in figure 9. The cross-sectional areas affected by erosion or/and deposition are relatively small (up to 500 $m^2$), except the erosional area recorded from 1995 to 2001 (up to 800 $m^2$).

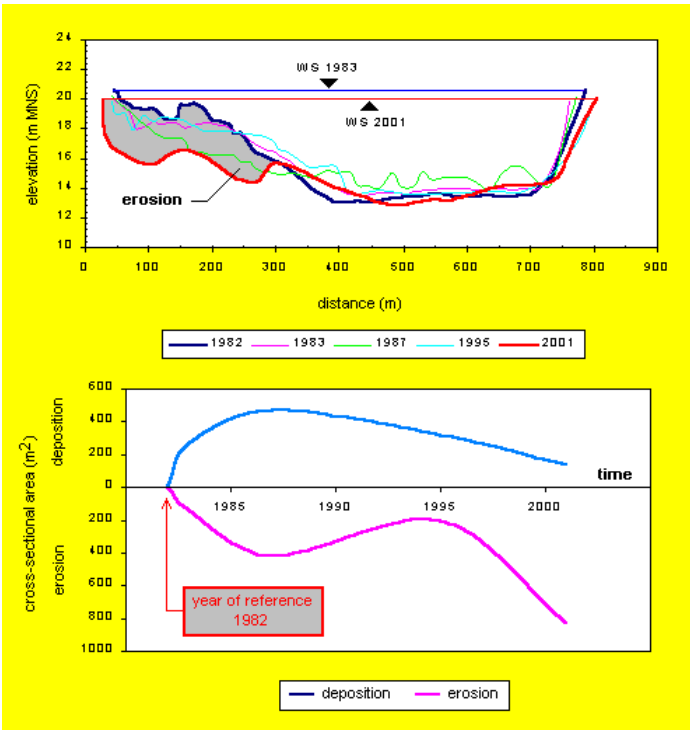


*Fig.9. Cross-sectional morphological changes in the Lower Danube River at Corabia (km 608)*

In the region of Tr Magurele and Zimnicea Towns, upstream (km 578) and downstream (km 560) of the great Belene Island, the river channel is subject to:

- severe erosional degradations at the right side of the channel (upstream of the island) and the left side of the channel (downstream of the island),
- significant deposition at the left side of the channel (upstream of the island), as shown in figure 10.

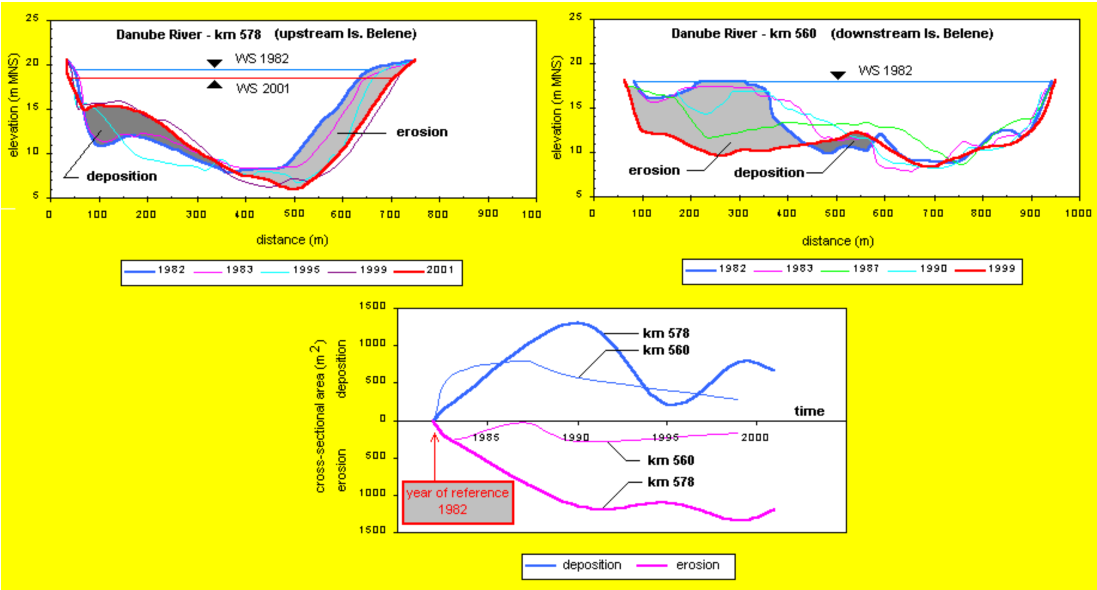


*Fig.10. Cross-sectional morphological changes in the Lower Danube River at Tr Magurele and Zimnicea, upstream (km 578) and downstream (km 560) of the great Belene Island.*

In the region of Giurgiu City, upstream (km 504) and downstream (km 476) of the great road and rail bridge, the river channel is subject to:

- important erosional degragation of the right bank (upstream) and of the middle of river channel (downstream), as well as to
- small deposition of alluvial materials in the central part of the flowing cross-section (upstream), as shown in figure 11.

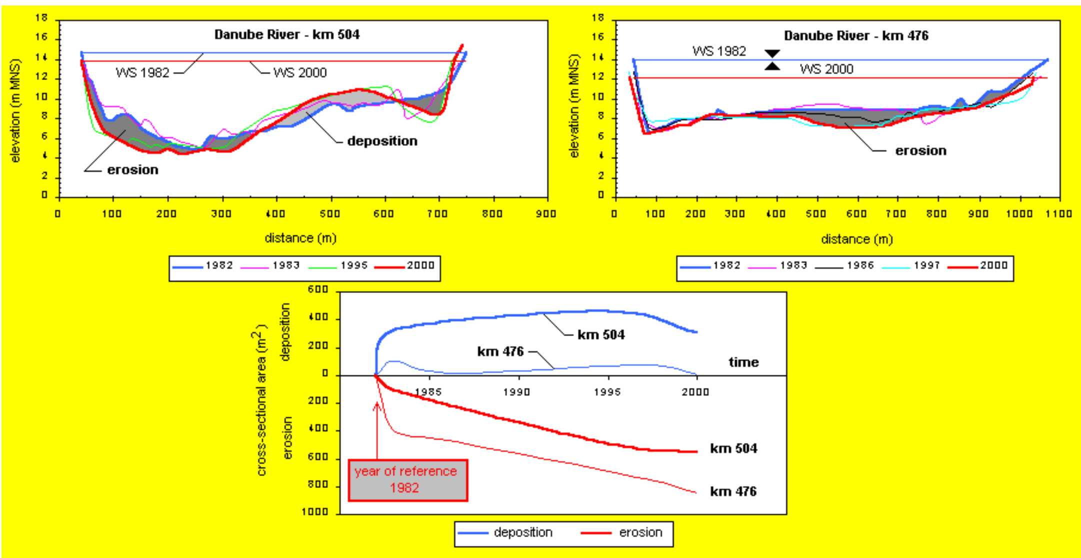


*Fig.11. Cross-sectional morphological changes in the Lower Danube River at Giurgiu, upstream (km 504) and downstream (km 476) of the great road and rail bridge.*

In the region of Oltenita City (km 448) a continuous process of erosional degradation has been recorded at the right side of the channel, combined with a large deposition of alluvial materials at the left side of the channel, as shown in figure 12.

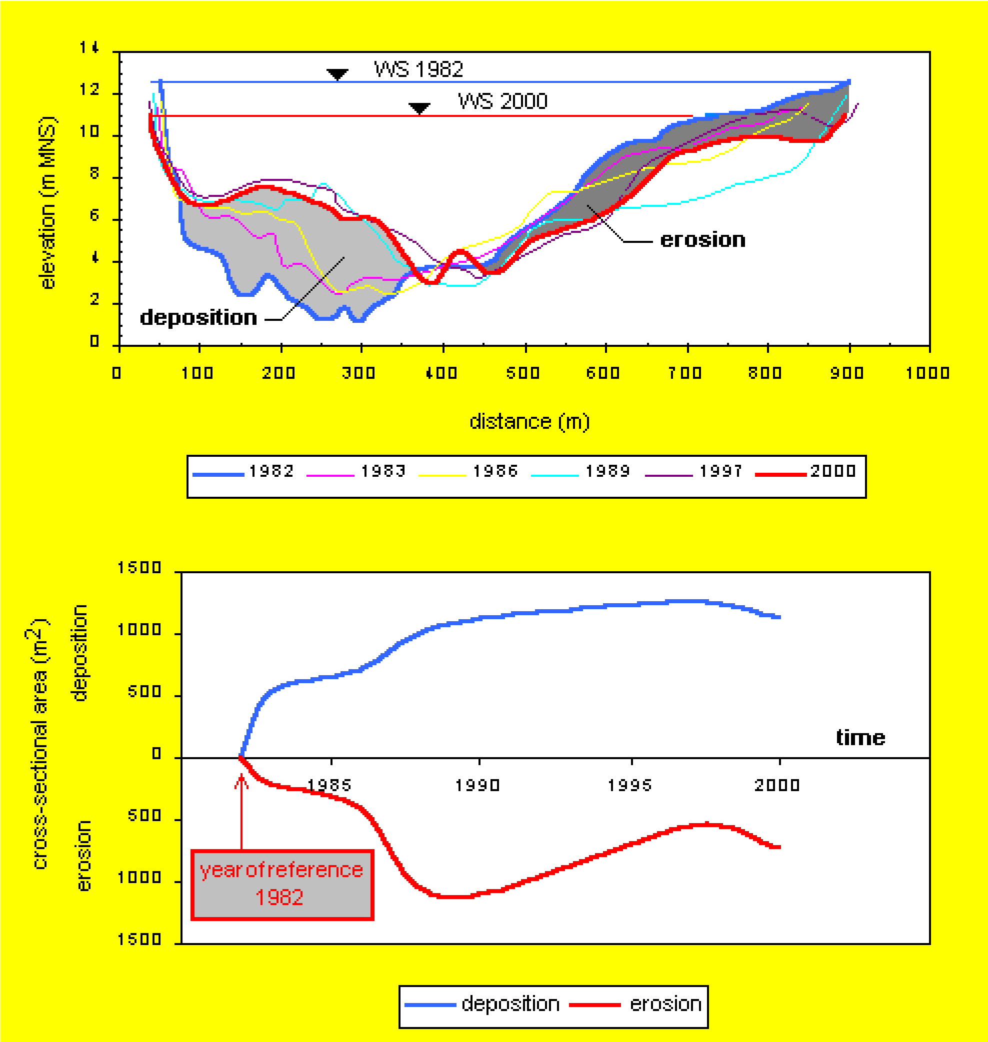


*Fig.12. Cross-sectional morphological changes in the Lower Danube River at Oltenita (km 448).*

## Conclusion

The paper presents some results of a recent study carried out for a selected 160 km-long reach of the Lower Danube River, from Corabia Town to Oltenita City, along the common Romanian-Bulgarian border.

The research study made use of a large amount of hydrologic and bathymetric data collected in the period of time from 1980 to 2000 at a number of 5 permanent hydrometric stations and other 6 representative sections along the selected river reach.

The main aspects of the water flow, sediment transport and river bed morphological changes have been investigated, as summarized below:

- The mean annual water flow and sediment transport regimes have been defined at the upstream and downstream ends of the river reach under study, as follows:
  - flow rate varies from 5630 $m^3/s$ at Corabia to 5880 $m^3/s$ at Oltenita,
  - suspended-load varies from 390 kg/s at Corabia to 520 kg/s at Giurgiu.
- The grain size analysis of alluvial materials transported in the river channel has indicates for suspension (reprezenting more than 95% from the total load) a mean

size of 0.017-0.024 mm and for bed-load (less than 5% from the total load) a mean size of 0.21-0.25 mm.

- Several empirical (power-type) and semi-empirical (stream power and gravitational theory) relationships for sediment transportation (suspension and bed-load) have been derived at different locations along the river channel, for various engineering, technical and environmental purposes in the region.
- The time and spatial variation of the river thalweg line has been put in evidence, mainly for fluvial navigation purposes.
- The major cross-sectional changes due to aggradation-degradation morphological processes in the river channel have been identified in the region, including:
  - erosion of the river bed at its left side (at Corabia, downstream of Belene Island and Giurgiu), right side (upstream of Belene Island and Oltenita), and central part (downstream of Giurgiu), and
  - deposition of alluvial materials at the right side of the channel at Giurgiu and the left side of the channel at Oltenita.

Similar research studies would be developed in the near future for other important reaches of the Lower Danube River in Romania.

**References**


Behr, O. et al. (2000) – "Danube River morphology: a common initiative was taken", Danube Watch no.1, Vienna.

Buta, C. and Batuca, D. (2002) – "Actual regime of water-sediment flow in the Lower Danube River", The XXIst Conference of the Danubian Countries on the Hydrological Forecasting and Hydrological Bases of Water Management, 2-6 September 2002, Bucharest.

IHP-UNESCO (1986) – "*Die Donau und ihr Einzugsgebiet–Eine hydrologische Monographie*" Vol. 1,2,3.

IHP-UNESCO (1993) – "*Die Donau und ihr Einzugsgebiet–Eine hydrologische Monographie: Schwebstoff- und Geschieberegime der Donau*".

INMH-PHARE (1997) – "Schimbari morfologice si diminuarea efectelor lor negative pe un sector selectat al Dunarii", Bucuresti.

Liptak, J. (1993) – "*The River Danube of Europe*", NVK International, Bratislava.

Stancik, A. et al. (1988) – "*Hydrology of the River Danube*", Priroda Publishing House, Bratislava.

Stanescu, V. et al. (1967) – "*Dunarea intre Bazias si Ceatal Izmail – Monografie hidrologica*", Bucuresti.