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THE HIDROLOGICAL RELATIONSHIP BETWEEN DANUBE ARMS AND LAKE COMPLEXIS IN THE DANUBE DELTA

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Abstract

The Danube Delta, which is an open system, is permanently exchanging matter and energy with the external environment. The hydrological sub-system, basically the water circulation represents the vital component of the existence of the delta space. In view of the ecological requirements of this delta space, of the present and prospective situation of various managements, of the present legal framework and the future of the Danube Delta Biosphere Reserve, it is advisable to make some changes to the water circulation system within the Letea unit as follows: to close down or undersize the Mila 35 Canal and the Mila 22 Canal, to reduce the Crânjală Canal flow section or close the canal, to secure the ecological reconstruction of inefficient dammed enclosures (e.g. Pardina) by ensuring normal water circulation inside them, to reopen the Sireasa Canal at its junction with the Chilia Arm. The fact is that the water circulation system throughout the Caraorman unit will suffer essential changes, so that is recommendable to: revitalise the Litcov Canal and close the Filat canal, downsize the Crişan-Caraorman flow section, open up the Gorgova and Ceamurlia canals, revigorate the Ivancea and the Erenciuc canals (between the Puiu and the Erenciuc lakes, respectively), make 2 – 3 openings in the littoral dam and in the Împuțita Backwater, placing the weir level at + 70-80 cm, in order to facilitate the depression water outflow into the sea.

Keywords: the Danube Delta, the Danube Delta Biosphere Reserve, water circulation.

A **systems** approach made by Prof. *Petre Gâştescu* in 1985, provided arguments to the effect that, geographically speaking, the Danube Delta and the Razim-Sinoie lake complex are two distinct units, because neither genesis nor specificity render them similar. *Two old gulfs* are separated by the Tulcea Hills Spur: a *liman-type gulf* in the north, an outlet for the Danube, which corresponds to the present delta, and a *lagoon-type gulf* in the south (the ancient *Halmyris*) which is a lacustrine complex today (lagoons and fluvio-marine limans).

The total Danube Delta area is 4,455 kmp, 82 % of which (3,510 kmp) lies on Romanian territory. The delta proper, which stretches between the Chilia and the Sfântu Gheorghe arms, covers 2, 540 kmp.

The formation of the Danube Delta was favoured by the existence of a large continental shelf, a liman-type gulf between the Dobrogean horst and the Bugeac Platform, the big volume of alluvia deposited by the Danube, the configuration of the littoral sea currents, the low tides (9-12 cm) in the north-east of the Black Sea, together with the major climatic conditions which triggered the Black Sea level oscillations, and the tectonic (epirogenetic) movements suffered by the neighbouring areas.

All the hypotheses on the genesis and evolution of the Danube Delta river sector fall into two large categories: one admitting the existence of a liman enclosed by littoral bars, pierced through in several points, and later evolving into the fluviatile delta (*Murgoci, Antipa, Vâlsan, Panin*); the other admitting the formation of the delta by the gradual advance of the river levees as far as the littoral sea current, fact that led to the formation of the coastal bar (*Brătescu*).

The structure of the delta space comprises both natural and anthropic elements that form fairly numerous and large sub-systems in terms of the complexity of the delta. Some of the natural sub-systems studied and quantified are: morphometric, hydrographic, climatic, soil, and vegetation. The anthropic sub-systems are more difficult to assess than to identify; however, our study focussed on such aspects as human settlements, management works (fish-farms, forestry and agriculture), transport, tourism and nature reserves.

Having all of a system's attributes, the Danube Delta can be viewed as a complex and open system gravitating around two main components, namely, the water circulation and human intervention. In terms of genesis, hypsometry, water relations between the Danube arms and the inland areas, climatic conditions and landscape, two large delta sectors can be distinguished: *the fluviatile delta* and *the fluviatile-marine delta*. The first sector, which is the oldest, begins at Ceatal Chilia and ends up at the Letea-Caraorman-Crasnicol alignment of sea levees. The second sector extends between the Letea-Caraorman-Crasnicol marine levees in the west and the sea coast in the east, including, besides the Letea, Caraorman and Sărăturile levees, an important lake complex (Roşu-Puiu), and suffers important changes at the contact with the Black Sea.

The Danube Delta space contains three large units: *Letea* between the Chilia and the Sulina arms; *Caraorman* between the Sulina and the Sfântu Gheorghe arms and *Dranov* between the Sfântu Gheorghe Arm and the Razim Lake (including the Dranov Lake), as well as a separate sub-unit – the Sacalin Island. Morphological, hydrographic and landscape particularities in the Letea unit made us separate 16 sub-units, 7 in the Caraorman unit and 3 in the Dranov unit.

The hypsometric sub-system governs the specific distribution of all the other sub-systems, indicating that 21 % of the delta territory lies under sea level, 55 % at 0 – 1 m and only 18 % between 1 and 2 m, otherwise said, 94 % of the delta area is + 2 m below the Black Sea level.

The water sub-system contains both dynamic and relatively static elements. Dynamic elements are the liquid and sediment flow (minerals and biotic substances), the water refreshment coefficient, type of water circulation, etc. The static elements consist of a network of canals and backwaters (over 3,500 km) and lakes (9.2 % of the delta area). This sub-system supplies most of the matter and part of the energy to the delta area.

The climatic sub-system is a main supplier of energy rather than matter to the flow of inputs, and is less involved in outputs. The solar energy (125-135 Kcal/cm^2/year) received by the delta accounts for the high annual air temperature means (> 11^{o} C), the lowest quantities of precipitation (400-450 mm/year) in Romania, and the extremely high evaporation and evapotranspiration values (950-1,000 mm/year, depending on biotopes).

The vegetation and fauna sub-system is extremely rich, diverse and azonal in terms of the main climatic conditions. The five major formations (reed, floating reed isles, forests, meadows and sands partly fixed by arenicolous vegetation) are estimated.

The rock and soil substrate is represented by the soil texture sub-system and includes 10 soil types over 97 % of the delta area, from the gley-salt soils to the young hydromorphic, organic and psammitic soils.

Human intervention has changed the natural organisation pattern of the delta space, limiting its natural evolution, or even changing it in a radical way in certain sub-units. From the very beginning, major changes affected the drainage network and hence the circulation of water which is the essential factor of natural evolution. These changes began with the corrections made to the Sulina Arm (1862-1902) to render it navigable. Thus in the early 20th century, they cut the Dranov and Dunavăţ canals after the studies and designs of Prof. *Grigore Antipa*. In the 1920-1940 period several more canal diggings (Litcov-Caraorman, Sireasa, Pardina, Eracle and others) were aimed at facilitating inland navigation and fishing; over the past decades, economic reasons, and total disregard for ecological requirements, created a very dense drainage network to supply fish-farms, agricultural terrains, reed and forest exploitations, etc. Many canals (e.g. Crişan-Caraorman, Mila 35) have completely disturbed the natural water circulation system, with severe consequences for the entire normal evolution of the area. Unlike anthropic influences on the drainage network elsewhere, the works made here for various purposes and on well-delimited surfaces affect now 31 % of the delta area.

In 1993 the *Danube Delta Biosphere Reserve* (5,800 kmp), encompassing beside the delta proper also the Danube and its floodplain as far as Cotul Pisicii, the Razim-Sinoie lagoon complex up to Cape Midia and the marine domain delimited by the 20 m isobath, had a wide range of uses. The *strictly protected area* covered 506 kmp (8.55 % of the Reserve), the *buffer zones* 2,233 kmp (37.60 %), and the marine buffer zone 1,033 kmp (17.42 %).

The delta, which is an open system, is permanently exchanging matter and energy with the external environment. Inputs consist largely of the Danube liquid flow and sediment discharge (containing also natural and anthropic chemical and biological components), precipitation and solar radiation. The natural and anthropic sub-systems take over these inputs and process them in their own way. As a result, the delta system produces and releases cyclically quantities of matter and energy, which differ in quality from those it receives. Thus, the output of energy and matter includes a component specific to the delta, more precisely its product, and another component which is transitory in the area and suffers no substantial changes (e.g. much of the Danube discharge – liquid, sediment, chemical, caloric). The major result of the processes going on within the delta system is the cyclic biological output – vegetal and animal – which is potentially utilisable by man.

The *climatic flux of matter* to the delta consists of inputs – mainly precipitation, and outputs, namely the water released through evaporation and evapotranspiration, with annual mean values for the whole Delta area of 386.4 mm precipitation and 1,344.7 mm evaporation and evapotranspiration, revealing the acute moisture deficit in the region. The *climatic flux of energy* is represented mainly by the solar radiation (direct, diffused, reflected, absorbed, etc.) materialised in the caloric energy accumulated but lost through evaporation and diffusion. Applying the above values to the 27 natural delta sub-units in a differentiated manner, it appears that the whole delta space receives 4,382,709 * 10^9 Kcal./year. The caloric energy losses through reflexion represent 744,197 * 10^9 Kcal/year, which means 14.7 % of the quantity received, more precisely 55.6 % of the global radiation received. Since there are low altitude variations in the delta, the territorial distribution of precipitation was estimated by Thiessen's polygonal method. The value yielded showed an annual average of 386.4 mm, or 1,283.3 * 10^6 m^3 throughout the delta, that is 28-29 % from the quantity of water lost through evaporation.

The hypsometric interval for the Danube Delta approximates only 15 m (+12.4 m on the Letea levee and –3 m in the lake areas, excepting the depth of the Danube arms). In 1983, average altitude stood at +0.52 m as against +0.31 m on Vidraşcu's map; this difference cannot be assigned only to the silting processes which occurred in the meantime, but also to possible errors of calculation and mapping. A global analysis of the delta area reveals that 79.5 % of its surface stands above the 0 m Black Sea level, while 20.5 % lies below this level; most of the emersed surfaces are found within the interval of 0 – 1 m (54.6 %), followed by those at 1 – 2 m (18.2 %) and 2 – 3 m (16.8 %). According to Vidraşcu's map (1911), over 42.4 % of the delta surface was below 0 m Black Sea level, which means that until 1983 the delta area had diminished by over 50 % (at a rate of 1,150 ha/year).

The hydrological sub-system, basically the water circulation (Figure 1), represents the vital component of the very existence of the delta space. Since the water volume transported by the Danube to Ceatal Chilia is 204.5 km^3/year at a multiannual mean of 6,473 m^3/sec (1921-1980) and with it a quantity of alluvia of 58.75 million t/year (the average for the same period), and 90 million tons of salts/year corresponding to a mineralization of 350 mg/l and 2,576.1 * 10^{12} Kcal., this sub-system is undoubtedly playing a basic role within the configuration and evolution of the delta space. Of the matter and energy transported by the Danube, 95 % reaches the three arms and flows into the sea, and only 5 % is taken over by the network of backwaters and canals. Characteristic flow values: mean discharge 6, 473 m^3/sec; maximum discharge 15,500 m^3/sec (June, 1970), and minimum discharge 1,350 m^3/sec (October, 1921). The yearly Danube flow variations registered at Ceatal Chilia record a winter minimum and maximum, a spring-summer maximum and a much higher minimum in autumn, the cycle ending in a low autumn maximum. The highest discharge was registered in May (11.46 % of the annual value) with lowest rates in October (5.51 %); it can be estimated that nearly 33 % of the annual discharge takes place in the April-June interval, while September-November is left with only 17-18 %.

The distribution of discharge on the main Danube arms (Chilia and Tulcea, the latter branching out into Sulina and Sfântu Gheorghe) is uneven, with more or less significant variations over the last 150 years. Until 1890, values on the Chilia Arm seemed to increase (from 63 % to 70 %), remaining constant (7 %) on the Sulina Arm, and decreasing on the Tulcea and the Sfântu Gheorghe arms (from 30 % to 23 %). The Chilia Arm registered steady decreases, from 72 % in 1910 to 66.1 % in 1928/1929; 62.5 % in 1958/1960; 58.6 % in 1970; 57.8 % in 1985; 56 % in 1990 and 56.4 % in 1992. Correction works, permanent dredging and consolidation of the banks (required by maritime navigation) made the Sulina Arm record increases, from 7 % in 1893 to 13.8 % in 1928/1929, 15.4 % in 1970 and 19.5 % in 1978, stabilising at these value (19.7 % in 1992); a maximum of 20.2 % was reached in 1990. No significant evolutions on the Sfântu Gheorghe Arm, discharge values fluctuating between 23.0 % in 1893 and 24.1 % in 1992, with a minimum of 18.7 % in 1910 and an estimated maximum of 30.0 % in 1856. After corrections to this arm are made, a percent change in the distribution of the Danube flow on the three arms is expected with beneficial effects for the Sfântu Gheorghe Arm.

Most of the Danube discharge on the three Danube arms flows directly into the Black Sea and only a small quantity passes through the network of backwaters, canals and the lacustrine complexes. This water flow, estimated at 100 – 450 m^3/sec (including the quantity of water that reaches the Razim Lake at an average flow rate of 90 m^3/sec), represent 2.2 – 7 % of the Danube discharge at Ceatal Chilia; the quantity of sediment is about 1.5 million tons/year. The water volume from the Danube arms running through backwaters and canals stagnates in the lacustrine complexes between 2 months (1921) and 10-11 months (1926, 1940), changing from river water into lake water. In order to assess the process of eutrophication, it is important to know the refreshment rate of the water volume from the lake complexes.

In 1983, the total length of the backwater and canal networks in the whole delta space was approximately equal (1,742 km and 1,753 km, respectively), at an average density of 0.53 km/km^2 backwaters and 0.58 km/km^2 canals. In 1964, there were 661 lakes of over one hectare, totaling 31,493 ha (9.49 % of the delta area). Draining and damming works in the Pardina and Sireasa agricultural sub-units left only 479 lakes and 25,794 ha, that is 8.06 % of the delta area; a number of 120 lakes (3,660 ha) in Pardina and 40 lakes in Sireasa (cca. 600 ha) were drained.

After 1960, **professor Petre Gastescu** (1966), made assessments for certain delta lacustrine complexes using the general **water balance equation: $X + Y_1 + U_1 + W_1 - (Z + Y_2 + U_2 + W_2) = \pm \Delta V$**. Variations were found with the geographical zone and the genetic type of lacustrine depression. Precipitation (X) and evapotranspiration (Z) depend on geographical zone; surface inflow (Y_1) and outflow (Y_2) are related to the drainage basin of the lake; ground inflow (U_1) and losses (U_2) depend on the local groundwater; human consumption (W_1) and waste water spills (W_2) mirror the anthropic impact.

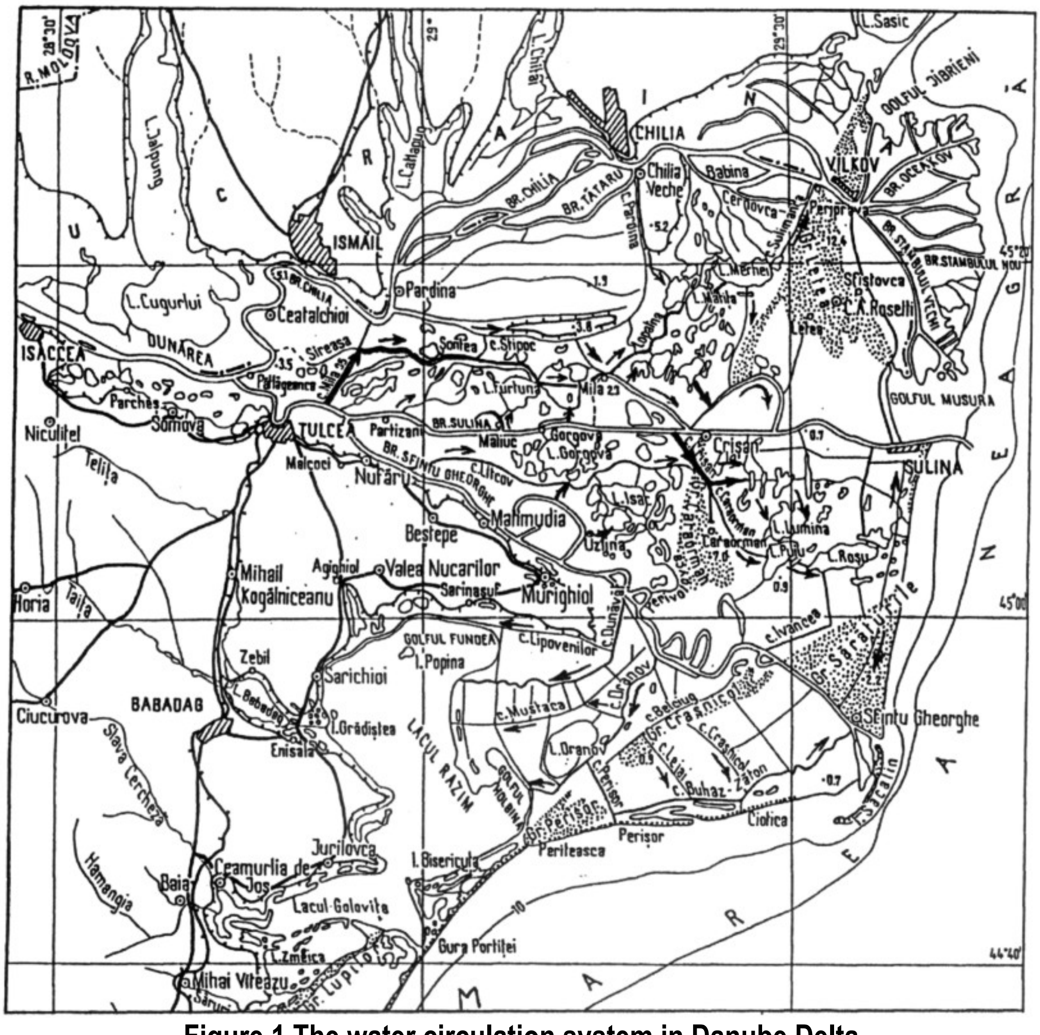

Figure 1 The water circulation system in Danube Delta

The water balance of one lake alone, considering its perimeter to stretch as far as the reed plots or floating reed isles on the edge of the lake, has but a theoretical relevance for practical purposes, the water balance should be estimated for the whole depression, which contains several lakes, that is a lake complex, e.g. Matiţa-Merhei, Roşu-Puiu, Furtuna, Gorgova and Isac-Uzlina.

Making quantitative assessments of the real flow exchange between the Danube arms and the lacustrine depressions is a difficult task; so, while at low or moderate levels these exchanges, irrespective of sense, are easily visible on the network of backwaters and canals, at high levels the river inflow into the inner delta areas no longer follows that network, it covering the whole surface beginning even from the delta tip. In the Letea unit, the water inflows from the Chilia and Sulina arms into the inland areas run through the Mila 35, Şontea, Eracle-Lopatna, Babina, Rădăcinoasele and Căzănel canals and many temporary backwaters, outflowing through the Bogdaproste, Dovnica and Sulimanca canals. Our working methodology consisted in the hydrological interpretation of the statistical analysis of the gauge level variations dynamics within various time-intervals and the field measurements of discharges made by the Institute of Geography researchers (1982-1993), field mapping, observations, and consultation of bibliographical references.

The water refreshment flow expressed in l/sec yielded by the (X + Y1) ratio and by the area of the lacustrine complex, is particularly important for establishing the abiotic water variables of lakes, canals and backwaters (heat regime, hydrochemistry, etc.) which influence biological productivity and the state of the aquatic ecosystems. For example, when the water level inside the lacustrine depression was above +130 cm at Matiţa (fisheries station), the refreshment flow exceeded 0.720 l/sec/ha, which was sufficient to have good quality water in the lacustrine depression. The refreshment rate is usually assessed by *the specific water exchange index* (P) yielded by the water input to the lake / lake volume ratio corresponding to the medium level in the studied period. The mean monthly refreshment coefficient / year in the Matiţa-Merhei lacustrine depression ranged between 11.6 % (1964) and 17.5 % (1980), signifying that the whole water volume is replaced within a 5 – 7-month interval. The generally accepted solution is for inflows to come from several small hydrographic arteries, directed as far as possible along the steepest slope, without flowing right into the lakes after branching from the Danube arms.

Before the Sulina-Sfântu Gheorghe littoral dam and the parallel canal had been built, the water system had an acceptable balance, given that the main lakes, the floating reed isles and the reed plots from the north of the depression had a good drainage system.

Of all the hydrographic changes that had an impact on the water regime and the area's ecological condition, two were of major consequence: the building of the Crişan-Caraorman Canal commissioned in 1982 and the dam and littoral canal erected between Sulina and Sfântu Gheorghe.

In 1970-1972 the oversized Sonda Canal (30-40 m wide and 5-6 m deep) was opened, and since the Împuţita Backwater was undergoing a natural process of enclosure which was completed by 1990-1992, the Sonda Canal remained the only lake water outflow route. In 1982, the main Crişan-Caraorman Canal was dug between the Sulina Arm and the Caraorman Village and connected to the Litcov-Caraorman Canal, thus becoming the main route of water and sediment inflow into the lacustrine complex. In 1994, when the Sulina-Sfântu Gheorghe littoral dam was commissioned, all outputs to the sea through the Sonda Canal and the temporary backwaters were completely closed, so that the lacustrine depression water could flow into the sea only at over + 130 cm weir level; if waters are below this level, they flow to the north (through the Sulina Arm) and to the south (through the Sfântu Gheorghe Arm).

In view of the major changes suffered by the configuration of the water network in the Roşu-Puiu lacustrine depression over the last few decades, the water circulation system presents substantial modifications. If in 1962 there were several inflow and outflow arteries (especially the Litcov Canal), after 1985 the main input and output routes were the Crişan-Caraorman and the Sonda canals, respectively. At that time, the hydrological system was in an acceptable state, having a high water refreshment coefficient. What had suffered alterations was the structure and functionality of the water circulation system, in that the water circuit in the northern compartment was faster (Crişan-Caraorman Canal – Vătafu and Iacob canals and thence towards the Lumina Lake – Roşu Lake) than in the southern compartment where water circulation had another trajectory. Preliminary analyses showed that the quantity of water refreshment flow (l/sec/ha) was not essentially changed, inputs and outputs registering approximately the same values although the surface of the lacustrine depression became larger. On the other hand, the specific water exchange index decreased as the water volume stored in the lake substantially increased. That decrease was the consequence of the longer water volume replacement time in the depression and, in the conditions of a deficient water circulation structure, it may prejudice the abiotic variables of the aquatic ecosystems. In other words, *the increase and maintenance of high water levels in the lacustrine depression does not necessarily imply a good water circulation*.

The construction of the Sulina-Sfântu Gheorghe littoral dam and canal, which began in 1988, has and will have untoward effects over the whole delta area between the Sulina and the Sfântu Gheorghe arms. All along the length of the littoral dam and canal (cca. 29 km) there is only one link (outflow) between the lake complex and the sea, namely the Sonda Canal. The dam was designed to protect against littoral erosion, to ensure vehicle transport between the localities of Sulina and Sfântu Gheorghe and to have an electric power line mounted to Sfântu Gheorghe.

In our opinion, building the dam as a defence against erosion was simply a pretext, because the intense ongoing erosion process in front of the Roşu Lake cannot be stopped. A first consequence of the building of the dam, foreseen also in the design, was the artificial rise of the water level in the lacustrine depression. On the whole, the additional water volume to the Roşu-Puiu lacustrine depression is estimated at some 100 million m^3. We consider that the weir threshold of + 130 cm on the Puiu Canal is far to high. The annual average level with 50 % assurance on the Puiu Canal is + 67 cm, minimum + 34 cm and maximum + 111 cm; *a weir level at + 70…+ 80 cm would have been more efficient, reducing the water volume refreshment time in the lacustrine depression*.

The weak points of water circulation in the Caraorman unit are the Crişan-Caraorman, Filat and Uzlina canals, whose limitrophe areas get silted (the Uzlina, Gorgovăţ, Roşuleţ and Roşu lakes). The reopening of the Litcov Canal has a possitive effect because, by supplying the western compartment of the unit it counterbalances the negative impact of the Filat and Uzlina canals. As far as outputs are concerned, it is imperative to decrease the littoral dam weir level, and create several secondary outflow passages to the sea.

Overflowing is a complex hydrological process, which is particularly important for the delta space and the evolution of its natural system components. Flooding, which is closely dependent on the Danube water regime, is a source of alluviation on the surface (when waters are high), and through the network of canals and backwaters (when waters are low) and of water supply to the lacustrine depressions, thus ensuring rhythmical water refreshment within an optimum water circulation system and the normal evolution of terrestrial and aquatic ecosystems.

The Danube Delta flooding map, which was elaborated at the Institute of Geography in 1993, is based on the morphohydrographic map worked out at the same Institute in 1983 and updated in 1991. It represents the average hydrological levels: at 3-hg, 57.6 % of the delta area was flooded (190,870 ha), accumulating a water volume of 1,814 million m^3. At 6-hg, 83 % of the delta area (275,265 ha) was covered by waters, the water volume stored being 4,332 million m^3. At these values flooding proceeds from downstream to upstream, englobing also some fluviatile delta sectors, while in the fluvio-marine sector waters are stored progressively and pushed by the Danube flow into the Danube arms. At 10-hg 93.4 % (309,470 ha) of the delta area is flooded, accumulations being of 6,888 million m^3. At these levels only 6.6 % of the delta area (cca. 6,200 ha), corresponding to the highest levees – Letea and Caraorman, and to a lesser extent to Sărăturile levees and the Chilia and Stipoc fields, are water-free, as are 0.3 % (961 ha) of the Dranov unit.

At present, 31.2 % of the delta area is dammed and no longer flooded, a situation that resulted in quantitative and qualitative changes. The areas overflown at hg 3 and 6 were referred to the total surface of sub-units and to the surfaces lying outside the enclosures. A significant difference was found between the water volume stored in the delta left in natural regime and the enclosed areas. So, the maximum volume that can be stored at hg 3 is by some 30 % lower (1,60 million m^3), the same at 6 hg, but the difference is somehow smaller (19 %). What should be remembered is that the deltaic ecosystems have now a lower quantity of water, because higher flow rates make larger amounts of Danube water trasit the delta. This situation has both beneficial and detrimental effects, namely a better water refreshment coefficient but also alluviation and erosion, respectively.

Summing up we would say that the main hydrographic axis of the water circulation system within *the Letea unit* in 2007, ensuring water links between the Danube arms and the inner depressionary areas, was the Mila 35 – Sireasa – Şontea – Eracle – Lopatna Canal with several secondary lateral connexions for inputs (Păpădia, Mila 22, Crânjală, Chilia-ocolitor, etc.) and outputs (Sulimanca, Bogdaproste, Dovnica, etc.). The quantity of circulated water was generally satisfactory, securing the necessary water refreshment flow. However, there are great territorial disparities in this respect. Among the most serious ecological effects is intense silting on the Mila 35, Crânjală (for the Furtuna Lake), and Mila 22 canals and the poor water circulation in the north-eastern compartment of the Matiţa-Merhei lacustrine depression, where eutrophication is an alarmingly constant phenomenon. Dealing with this situations requires the following measures:

- *To close or redimension the Mila 35 Canal in order to reduce the fast silting rate in the numerous lakes of the Sireasa and Şontea sub-units (Meşter, Lung, Tătaru, Rădăcinoasele, etc.);*
- *To close the Crânjală and Mila 22 canals;*
- *To dradge and redimension the Sulimanca, Dovnica, Căzănel and Bogdaproste canals in order to optimise the redistribution of waters;*
- *To open the Sireasa Canal at the junction with the Chilia Arm;*
- *To partly renaturate the Pardina enclosure by reactivating 2 – 3 old backwaters or canals (Batac, Pardina and Repedea) at the junction with the Chilia Arm;*
- *To reactivate the backwaters with reversible water flow in the east of the Chilia fish-farms (Gârla Satului, Poliacova, Brătuşca, etc.).*

In the *Caraorman unit*, the digging of the Crişan-Caraorman and Sonda canals, in disregard of any ecological criteria, has changed the water circulation system in a radical manner: while in the past water inputs to the Roşu-Puiu lacustrine depression used to come through the Litcov-Caraorman canals – Puiu Lake – Roşu Lake, now the inflow was reverted to the Crişan-Caraorman Canal with very high discharges, and farther to the Iacob and Vătafu canals located in the north of the lacustrine depression, waters flowing back into the Puiu and Roşu lakes and farther into the sea through the Sonda Canal. Simultaneously, silting in the Puiu and the Roşu lakes took on an alarming turn; a similar process is going on in the Uzlina and the Gorgovăţ lakes after the Uzlina and Filat canals were opened. In the absence of adequate water circulation, some sectors of the Uzlina, Isac, Gorgova, Puiu, Roşu and other lakes undergo intense eutrophication. The building of the Sulina-Sfântu Gheorghe littoral dam has a negative impact on water circulation. According to preliminary estimations, the inflow of the Caraorman unit waters adds some 100 million m^3 to the Roşu-Puiu lacustrine depression. The design provides for outflows towards the Sulina and the Sfântu Gheorghe arms below the + 130 cm level of the 200 m-wide weir attached to the littoral dam through the canal parallel to the dam.

The Dranov unit is largely an embanked enclosure and has a relatively simple water circulation system compared to the other units. There a two main canals (Dranov and Dunavăţ) through which the waters from the Sfântu Gheorghe Arm flow into the Razim

Lake; a part of these waters supply the unit's fish-farms (some of them renaturated because the peat substrate made them low-productive).

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