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# Deep Water Navigation Canal Danube Black Sea

Report to the ESPOO Inquiry Commission

Report

June, 2006

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WL | delft hydraulics

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Jos van Gils, Dirk Schwanenberg, Thijs van Kessel,
Dirkjan Walstra

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# Contents

# 1 Introduction

## 1.1 General

Under the ESPOO Convention (1991), an Inquiry Commission has been established related to the project “Danube-Black Sea Deep Water Navigation Canal in the Ukrainian sector of the Danube Delta”. A Technical Commission, comprising representatives of Romania and Ukraine as well as a number of independent experts has been nominated to investigate the project. Jos van Gils of WL | Delft Hydraulics has been invited to take part in the Technical Commission on subjects of river hydrology, sediment transport and coastal morphology. This report presents the findings presented by Jos van Gils in this matter. The information in this report has been compiled on the basis of contributions by Thijs van Kessel (cohesive sediment expert), Dirkjan Walstra (coastal morphology expert) and Dirk Schwanenberg (river hydraulics expert).

## 1.2 Reader’s Guide

This report starts with a brief project description and an explicit formulation of the objectives in Section 1. Section 2 presents the data collected which will form the basis of the project assessment presented in Section 3.

This report is based on the material provided by the Ukrainian and Romanian representatives in the Technical Commission, Dr. Ludmila Anischenko and Dr. Mircea Staras respectively. Whenever relevant, we will explicitly refer to the documentation provided by both parties as “UA report” or “RO report”. Apart from this material, in some cases external literature was used. These references are explicitly mentioned at the end of the report.

The author of this report is not a native Romanian or Ukrainian speaker. The author apologises for any confusion caused by misspelling or misusing certain geographical names. Such mistakes are made unintentionally, and do not express any judgement.

## 1.3 Project background

The project under investigation concerns the re-opening of the navigation route from the Black Sea to the Danube River via the Bystry branch and the Kiliya branch (see Figure 1-1). Different options for the Black Sea-Danube navigation route were studied; some of these options are mentioned in the UA report. Finally, the option via the Bystry branch was selected. The project was set up to be carried out in two phases. Phase 1 comprises (UA report):

- the dredging of the sandbar section at the mouth of the Bystry Branch (km. –1.898 to km 1.534[1], see Figure 1-2);
- the deepening of shallow areas in the river section between Izmailsky Chatal and Vilkovo (km. 20.555 to km. 116.000);
- the construction of (a part of) a retaining sea dam (see Figure 1-2).

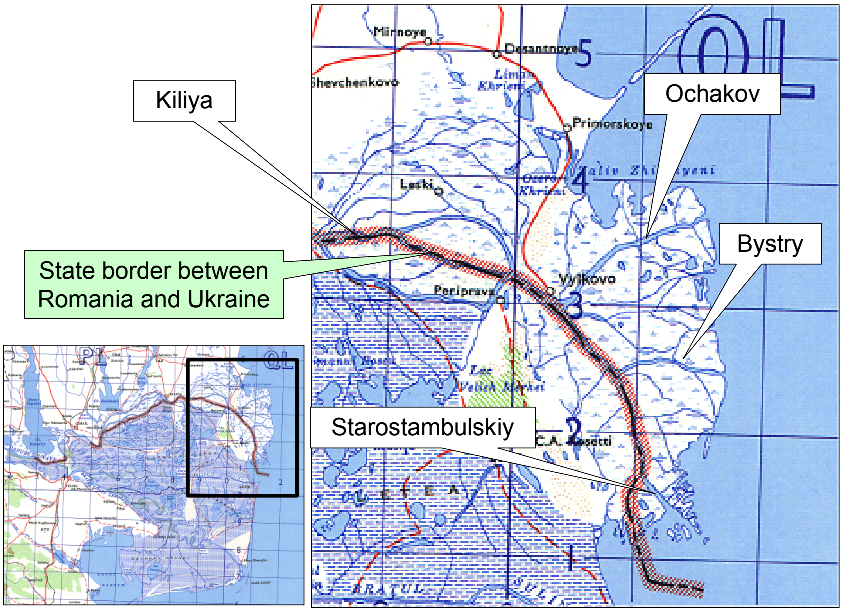



Figure 1-1: Map of the project area.

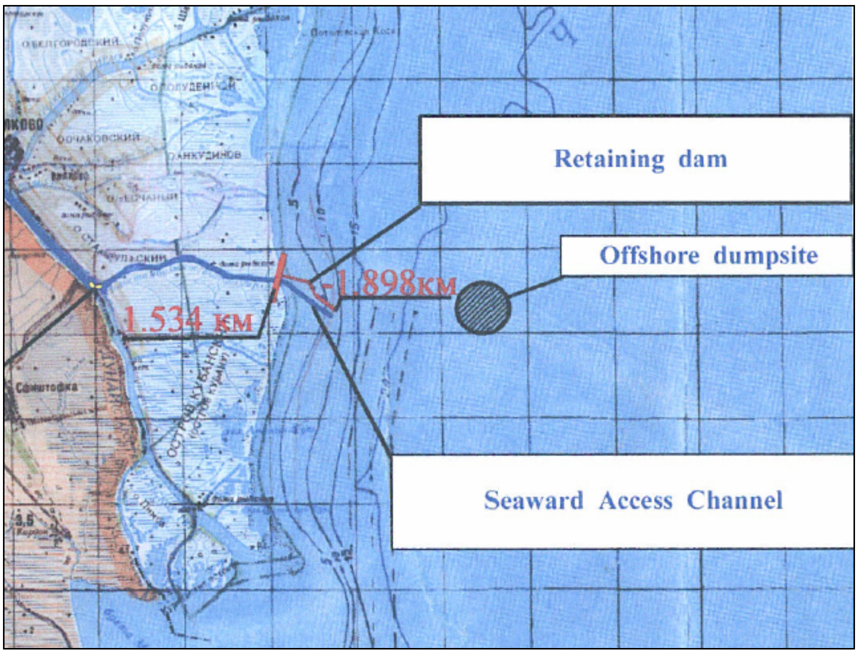



Figure 1-2: Details of the Bystry Branch mouth section.

[1] *River kilometres are indicated from the river mouth (km 0.000) in an upstream direction.*

Phase 2 is planned to comprise (UA report):

- the final adjustment of its elements and parameters in line with existing international standards, up to a navigable depth of 7.2 m;
- and the provision of protective hydraulic facilities designed to ensure its stable operation, including an extension of the retaining sea dam.

Across the Ukrainian-Romanian border, the Danube Biosphere Reserve constitutes a transboundary protected wetlands area, which is jointly managed by both countries. The total surface area of the reserve is about 626,000 ha.

## 1.4 Objectives of the present report

The objectives of the Technical Commission are to advise the Inquiry Commission on the likeliness of significant transboundary impacts as a result of the project implementation. More specifically, six aspects of these possible impacts are subject of study (see “Summary of Statements”, compiled by the president of the Technical Commission, Dr. Terwindt). The present report deals with two of these aspects, in particular:

1. Trans-boundary hydrological impact.
2. Trans-boundary impact of sediment discharge and dumping.

Related to aspect (1), a relevant issue is the impact of the project implementation on the discharge distribution over the different Danube branches and the Kiliya Delta branches, as a result of the modification of the river cross sections due to the dredging of the shallow areas in the river and the sandbar section in the Bystry Branch. The impacts on the discharge distribution potentially lead to impacts on the water level dynamics and on the sediment transport in the different branches.

Related to aspect (2), relevant issues are the movement of sediments released during the project implementation from the river mouths to the coastal waters which can have an impact on the littoral system. There could also be an impact from the project implementation on the coastal morphology. This includes the effects from protective structures (see Annexes 5 and 8 from the UA report), e.g. on the so-called Ptichiya Spit.

Near dredging areas, hydro engineering construction activities and dredging spoils storage sites, the formation of a turbid plume could be a factor causing impacts on aquatic organisms and fish stocks.

# 2 Summary of information used

## 2.1 Baseline conditions

### 2.1.1 River hydrology

The average River Danube discharge equals 6570 $m^3/s$ (over the period 1921-1990, RO report). In the Danube Delta, it is distributed over the three main Danube Branches Kiliya, Sulina and St. George in two subsequent large bifurcations near Tulcea. In recent years, the northern Kiliya branch receives about 52% of the Danube discharge. In the past 100 years, a very significant downward trend has been observed in the share of the Kiliya discharge from a maximum of 70% around 1900 to 52% today. Even around 1990, the share of the Kiliya discharge was substantially higher than it is in recent years: 56% or 58% according to different sources (see UA report, Annex 4 and RO report).

The year-to-year variability of the river discharge is significant: the minimum and maximum annually averaged discharges over 1840-2004 are approximately 3600 and 10000 $m^3/s$ respectively. This implies that the annually averaged river discharge varies between 55% and 152% of the average value. The standard deviation over 1921-2000 amounts to 18% of the average value.

Annex 28 to the UA report provides a comprehensive description of the Kiliya Delta formation, historical discharge distribution data of the main Danube branches, historical discharge data of the Kiliya delta, and much other background information. Around the year 2000, the discharge of the Ochakov and Bystry branches is reported at 14.5% and 17.6% of the total Danube discharge respectively. Figure 2-1 provides a schematic overview of the discharge distribution over the key Danube and Kiliya delta branches.

### 2.1.2 Climate

Climate information is collected in Annex 28 to the UA report.

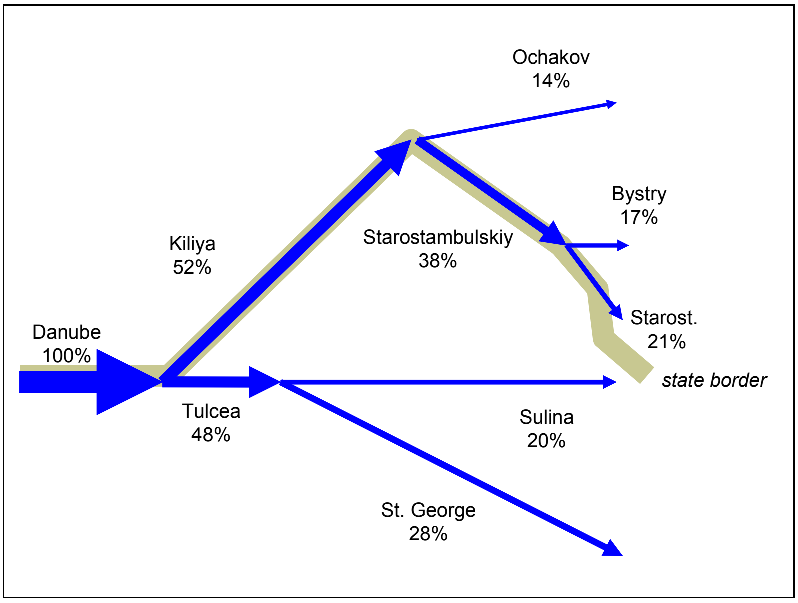



Figure 2-1: Schematic overview of the discharge distribution over the key Danube and Kiliya delta branches (smaller branches are neglected).

### 2.1.3 River sedimentology

Annex 29 to the UA report presents an extended assessment of the Danube River sedimentology, based on a long term hydrological study carried out by the Danube Basin Hydrometeorological Observatory in the Ukrainian part of the Delta between 1961 and 2002, on historical data since 1840, as well as several recent surveys in the area. The main findings are listed below:

- There is a long term trend in the Danube River water and sediment discharges over the period 1840-2000 due to climate changes and geomorphological alterations. If we concentrate on the period since 1985, after the completion of the major Iron Gates I and II dams, an average annual discharge of 201 $km^3/y$ or 6370 $m^3/s$ can be observed. The average suspended sediment transport in this period is 28.6 x $10^6$ t/y. The average concentration of suspended solids is 140 $g/m^3$.

- There is a large interannual variability in the loads of suspended sediments. Since 1961, the range of observed annual loads is between 8.5 and 85 Mt/y. Recent years are characterised by low suspended loads in 2003 (12.3 Mt/y) and 2004 (15.2 Mt/y) and high loads in 2005 (no quantitative data). As this report is written (spring 2006), the lower Danube experiences a major flood, which might indicate another year with high loads of suspended sediments.

- The annual distribution of the suspended sediment load shows a distinct maximum in the spring, under influence of the spring high water period. On average, the high water period (March-July) contributes about 65% to the annual load of suspended sediments.

- The distribution of the Danube River sediment load over the different branches is by very good approximation proportional to the water discharge distribution.

- It is estimated that the average net sedimentation along the Kiliya branch between km 115 and km 20 is 4-10% of the incoming load of suspended solids.

- Quantitative information regarding the sediment bed load at the upper Danube Delta is ambiguous. As a fraction of the suspended load, values between 1% and 25% are encountered in the literature.

- The grain size distribution of the bottom sediments along Kiliya and its sub-branches is as follows: grain sizes of 200-500 µm (20-50%) and 100-200 µm (25-60%) are dominant.

- The sediment density decreases from 1500-1600 kg/m$^3$ in the Danube to 1400-1500 kg/m$^3$ in the Kiliya arm to 1300-1400 kg/m$^3$ in the Ochakov/Starostambulskiy branches to 1100 kg/m$^3$ in the mouth sections.

Panin & Jipa (2002) present historical data on the River Danube sediment load, based on hydrological data collected since 1931 which are stored in the databases of the (Romanian) National Institute of Meteorology and Hydrology (NIMH) and the (Romanian) National Institute of Marine Geology and Geoecology (GeoEcoMar). This source estimates the present average Danube sediment discharge at 25-35 $10^6$ t/y, out of which 4-6 $10^6$ t/y is sandy material. This source therefore confirms the information provided by the UA report.

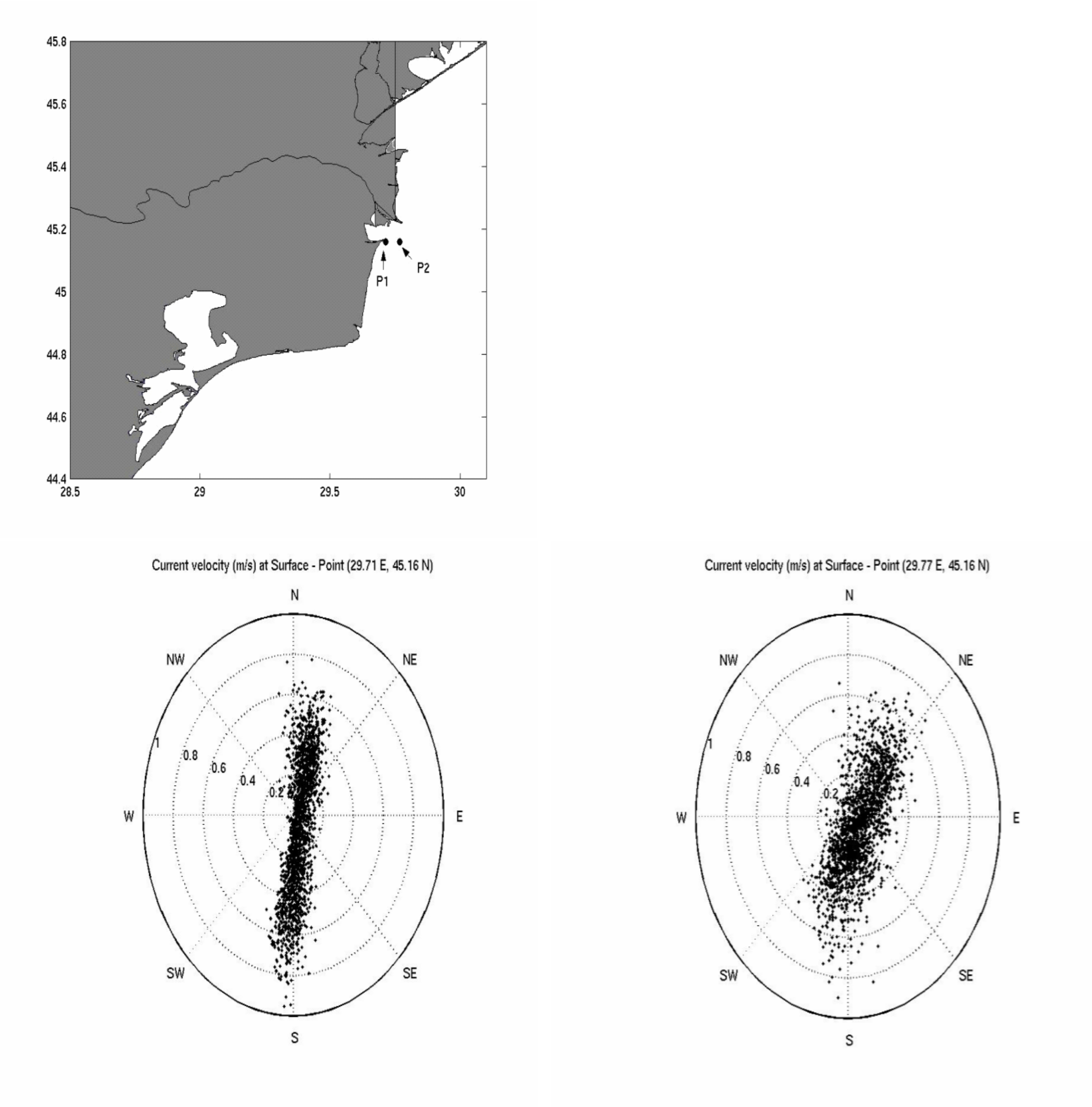
### 2.1.4 Tides, marine currents and waves

Tides are of negligible importance in the project area, with the spring tidal range amounting to about 10 cm in the Western part of the Black Sea (British Navy, 1969). Water level variations are controlled by river discharges and variations in atmospheric pressure and wind. The range of the fluctuations varies between 0.5 and 1.5 m.

The currents in the Black Sea are generally weak and variable, under influence of variations in the discharge of the rivers and the wind direction and speed. This also holds for the marine currents in the study area, which are mainly determined by the Danube discharge and by the winds. The average southward current found in front of the Danube Delta amounts to 0.25-0.35 m/s (British Navy, 1969). In the approach to Sulina the current is 0.15-0.25 m/s.
The streamflow velocity in the Danube branches varies between 0.25 and 2.6 m/s (typically below 1.5 m/s).

An impression of the variability of the marine currents in front of the Danube Delta can be obtained from simulations carried out in the *daNUbs* research project (for a description we refer to Kourafalou et al. 2005). The simulations take into account the day-to-day variations of the weather conditions (e.g. wind, air pressure) as well as the variation of the river discharge. The results are presented in Figure 2-2.

Information about waves is available from Gosian et al. (1999) for the waters off Constanta, along the Romanian coast some 60 km south of the Danube Delta area (Figure 2-3).




**P1** **P2**

Figure 2-2: Simulated marine surface currents in front of the Danube Delta (locations P1 and P2 indicated in the map.

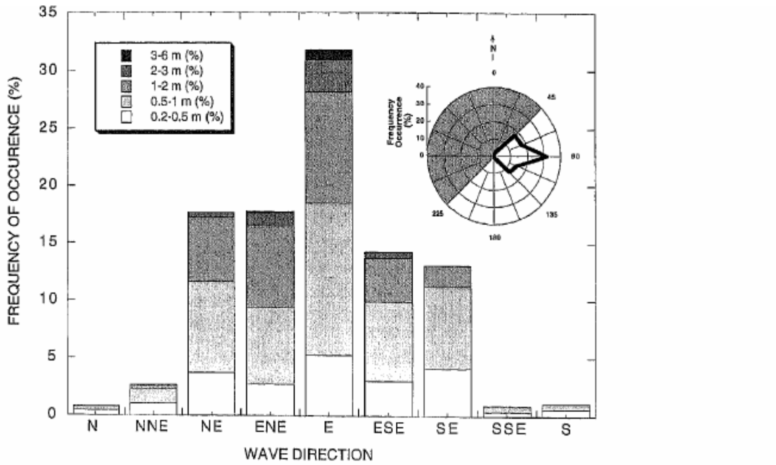



Figure 2. Frequency of occurrence of wave height as a function of approach direction at the coast. A wave rose is also shown for all waves available, along with the average orientation of the coast.

Figure 2-3: Graphical overview of wave statistics off Constanta (Gosian et al, 1999).

### 2.1.5 Coastal sediment transports and morphology

#### Coastal sediment transport

Panin & Jipa (2002) provide a clear overview on the issue of coastal sediment transports in the area of the Danube Delta and on the North-western Shelf of the Black Sea.

The Danube River is the main supplier of sediments to the North-western Shelf of the Black Sea. The sediment input from the Ukrainian rivers Dniepr, Dniestr and Bug is negligible, because these rivers flow into lagoons which are separated from the Black Sea by sandy spits. This implies that coastal sediment transport is primarily determined by the sediment inputs from the Danube River.

The sediment transport in the littoral zone near the Danube Delta is characterised by a longshore (southward) sediment drift along the delta, generated by the wind-wave longshore current system, with potential values varying in different places from 0 to 1.2 $Mm^3/y$, or approximately 0-1.0 x $10^6$ t/y (Gosian et al., 1999).

The littoral transports are strongly affected by 8 km long jetties built at the mouth of the Sulina Branch (which can be observed for example through Google Earth, http://earth.google.com/). The Sulina mouth sandbar is continuously dredged, and the dredged sand (approximately 800,000 $m^3/y$) is being dumped off-shore, and thus removed from the littoral sediment budget.

#### Development of coastline (spit formation).

Annex 11 to the UA report presents satellite images of the Ukrainian Danube Delta coast for the years 1988 and 2001. The formation of the Ptichiya spit within this period can be clearly observed (Figure 2-4). It should be pointed out that a spit like the Ptichiya spit is an intermediate stage in the process of land formation. Eventually the spit will become part of the delta mainland.

Annex 28 to the UA report provides an overview of land advances and bank/coast recession over the periods 1975-1988 and 1988-2001 respectively, presumably derived from satellite images like the ones mentioned above for the period of 1988-2001.
Annex 27 to the UA report provides details of the formation and development of the Ptichiya spit by comparing satellite images of 1998-2001, 2001-2002, 2002-2003 and 2003-2004 respectively.

#### Suspended matter concentrations in the coastal waters

On the basis of satellite images, it can be observed that the silts carried by the Danube River are transported in the coastal waters over considerable distances (10 km and more). Monitoring data for the suspended matter concentration are available for the Romanian coastal waters (Cociasu et al. 2004). They are summarised in Figure 2-5. The data in that figure refer to river-borne inorganic suspended matter (clays and silts) excluding organic suspended matter (phytoplankton and related organic matter).

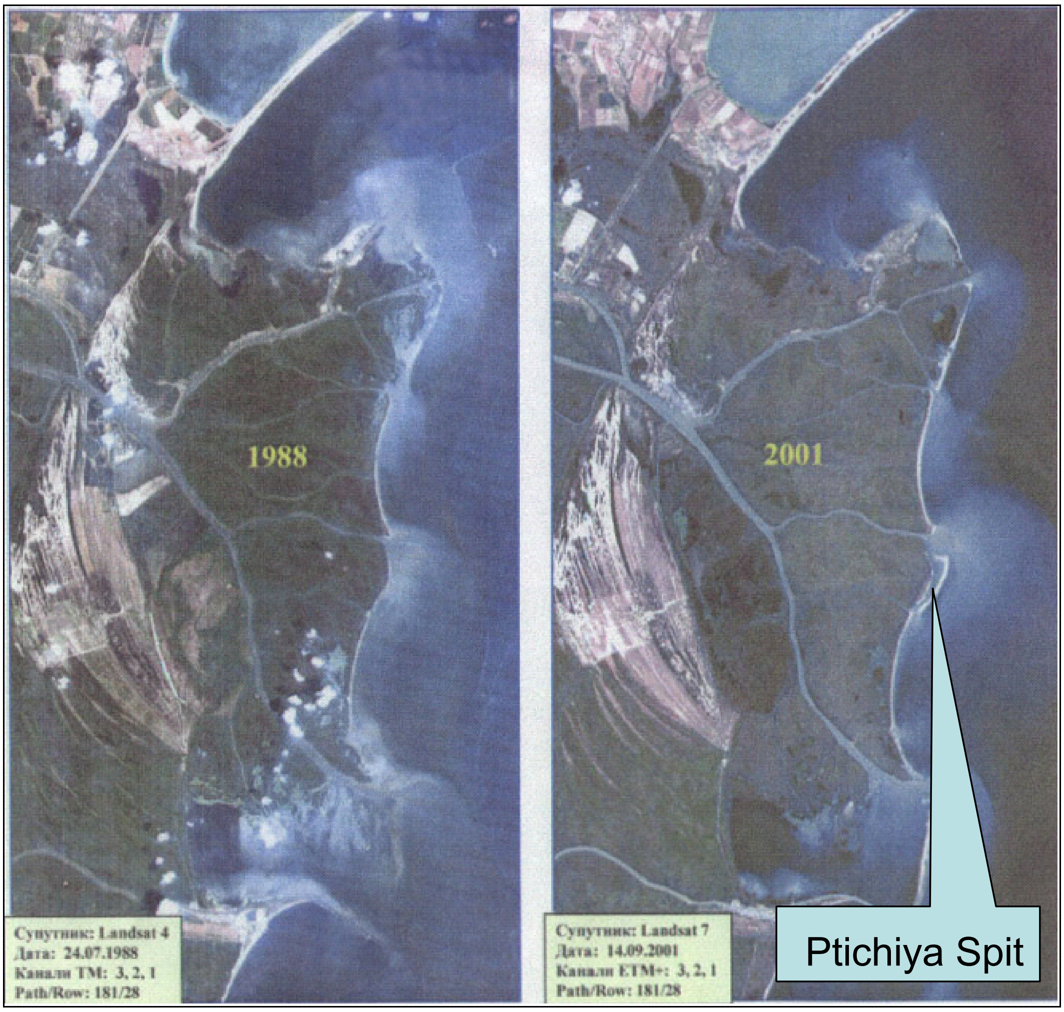



Figure 2-4: Landsat images of the Danube Delta in 1988 and 2001 respectively, showing among other things the Ptichiya Spit which was formed between 1988 and 2001.

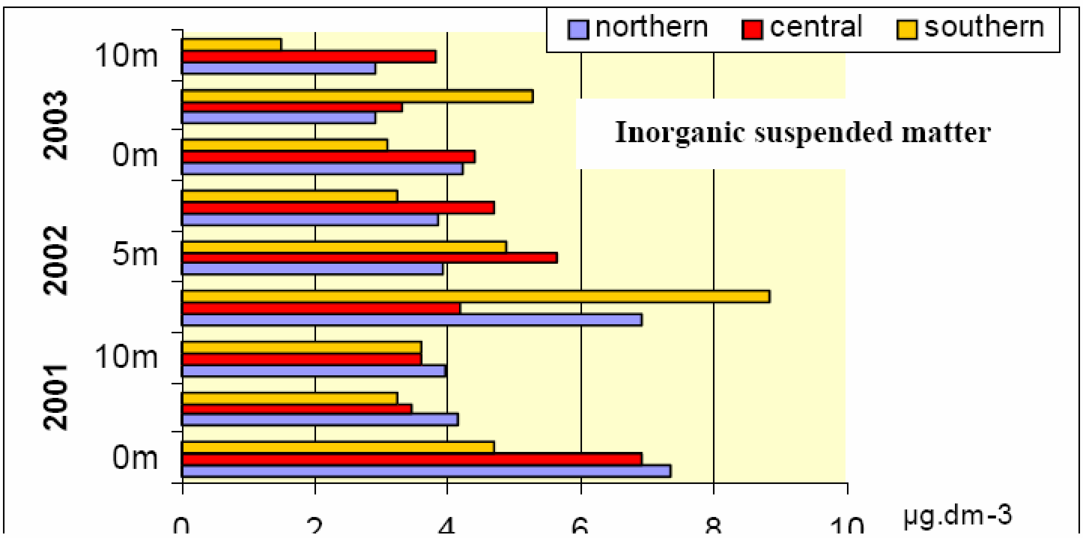



Figure 2-5: Annual averages of inorganic suspended matter on the Romanian Shelf during 2001, 2002 and 2003, at different depths (unit is mg/l, despite what the picture mentions).

## 2.2 Project details

### Overview

Phase 1 of the project comprises (UA report):

- the dredging of the sandbar section at the mouth of the Bystry Branch;
- the clearance of shallow areas in the river section between Izmailsky Chatal and Vilkovo;
- the construction of (a part of) a retaining sea dam (see Figure 1-2).

Phase 2 is planned to comprise (UA report):

- the final adjustment of its elements and parameters in line with existing international standards, up to a navigable depth of 7.2 m;
- and the provision of protective hydraulic facilities designed to ensure its stable operation, including an extension of the retaining sea dam.

### Sandbar Bystry Branch mouth

The removal will involve in Phase 1 a volume of 1.7 $Mm^3$, in the river section km. –1.898 to km 1.534, see Figure 1-2.

In Phase 2 the Seaward Access Channel (SAC) will involve the removal of 1.2 $Mm^3$ (Annex 40).

### Deepening of shallow areas along the river[2]

Shallow areas are deepened at a number of rivers sections, over km 20.555 to km. 116.000, see Annex 15 for maps indicating shallow areas, and Annex 17 for details of the dredging operations[3]. On the basis of the available information we estimate for Phase 1 a volume of removed sediments of 1.9 $Mm^3$, an affected surface area of about 113 ha. With the shipping channel having a width of 120 m, the length of the affected river section is 9400 m, and the average thickness of the removed layer is about 1.7 m.

Approximate representative cross-sections of the Lower Danube and the main Danube Delta branches are provided by Vituki et al. (1996).

For Phase 2, the volume of sediments to be removed is 4.5 $Mm^3$ (Annex 40).

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[2] *Shallow sections in the river are referred to as "rifts" or "reefs" in the UA and RO reports.*
[3] *The vertical reference level for these data is the "Baltic Datum" (Annex 40).*

## Construction dredging volumes and associated storage[4]

Annex 2 to the UA report defines the sediment removal during Phase 1 as 3.6 $Mm^3$ (from both the sandbar section and the shallow areas in the river). Out of this total volume, 1.7 $Mm^3$ has been disposed on land (see Annex 18 for site indications on the map) and 1.9 $Mm^3$ has been dumped in the sea. Most of the material removed from the river shallows is disposed on land sites, while most of the material removed from the sandbar section is disposed in sea.

Annex 25 presents the "current status", after stopping the Phase 1 construction activities on 1 October 2005. It also discusses the amounts of river-borne sediments deposited in the seaward access channel during the 2005 river flood, which is estimated at 1.1 $Mm^3$.

Annex 8 to the UA report specifies the volume to be dumped in the sea during phase 2 as 1.7 $Mm^3$.

Annex 36 estimates the losses of soil during dredging in Phase 1 (appr. 160,000 $m^3$, or about 10% of the dredged volume) and estimates the "small fractions" therein (5% of the losses, or 0.5% of the dredged volume).

## Operational dredging volumes and associated storage

According to Annex 8, about 1 $Mm^3$/year of sediments, produced by operational dredging activities, will be disposed of at the marine dump site till it reaches its design capacity of 5.361 $Mm^3$.[5] This estimate was obtained on the basis of the following considerations:

- On the basis of historical data, the average sedimentation in the Kiliya branch between Izmailsky Chatal and Vilkovo is estimated at 1.3 $Mm^3$/y (range 0.3-4.4 $Mm^3$/y, annex 29 UA report).

- On the basis of historical data, the average deposition of river borne sediments in the Bystry branch sandbar section is estimated at 2.4 $Mm^3$/y (range 0.6-6 $Mm^3$/y, annex 29 UA report).

- The average sedimentation in the seaward access channel is estimated at 20-30% of the deposition in the sandbar section, so about 0.5 to 0.7 $Mm^3$/y (annex 29 UA report), which is without the protective dam. With this dam, the volume is expected to go down to 0.25-0.35 $Mm^3$/y (Annex 38). Note that during the 2005 flood period 1.1 $Mm^3$ have been deposited (Annex 25, UA report).

[4] *The design data mentioned in this text are derived from the UA report, having noticed the comments from the Romanian side and the responses in Annex 8 to the UA report.*
[5] *Note that the design capacity will be reached after no more than 2 years of operational use!*

### Off-shore dump site

The offshore site selected for dumping of dredging spoils is situated at a distance of 8 km from the coast, at a depth of over 20 m (Annexes 34 and 44, UA report).

The selected site for offshore spoils storage is reported as not representing a valuable habitat for benthic communities; the dumpsite lies within the intensive sediment deposition zone, especially during floods. (UA report).[6]

Annex 24 to the UA report presents physical properties of the seafloor around the dumping site. The seafloor consists of silt, with the size fraction <50 μm representing 79% and the fraction <5 μm representing 36%. The density is reported as 1580 kg/m$^3$.

### Nature of the dredged material

The grain size properties at a number of sampling sites at the shallow areas in the river section have been compiled from Annexes 21, 22, 24 and 26 of the UA report, see Table 2-1.

Table 2-1: Summary of dredged sediment properties.

| **Area** | **Km** | **Dominant GEU[1]** | **Fraction < 50 um (%)** | **Fraction < 5 um (%)** | **Density (t/m$^3$) or porosity (%)** |
|---|---|---|---|---|---|
| Maikan Island | 35.5-38.0 | 2 | 80 | 32 | 25% |
| Katenka/Mashenka Island | 47.0-53.1 | 2 | 80 | 32 | 30% |
| Bolshoy Daller Island | 63.4-69.7 | 1/3/4 | *35* | *16* | *n.a.* |
| | | 2 | 80 | 32 | 40% |
| Kislitsky | 70.2-74.5 | 1 | <3.5 | <3.5 | 1.32 |
| | | 5 | 72 | 23 | 45% |
| Kislitsky Arm | 75.6-76.8 | 5 | 72 | 23 | 31% |
| Bystry sandbar | | 3 | 17 | 8 | 1.26 |
| | | 6 | 49 | 20 | 33% |
| | | 7 | 37 | 12 | 28% |
| Sandbar section (annex 24) | | | 10-50 | 3-23 | 1.8-1.9 |
| Sandbar section (annex 26) | | | | 1 | 1.4 |
| Staromstambulski branch (annex 26) | 11.0 | | | 14 | 1.3 |

1. See Annex 21 (UA report).

From this table we conclude that the dredged material has a variable composition.

### Retaining sea dam

Details of the planned retaining sea dam are provided in Annex 3 (UA report). The length of the dam is planned at 1040 m after Phase 1 and about 2830 m after Phase 2 (Annex 40 to

[6] *It should be noted that the information on the location of the dump site is ambiguous. Annex 7 to the UA report for example, suggests that the site is only 2 to 3 km offshore, at a depth of about 7 m.*

UA report). Annex 23 to the UA report presents a drawing of the retaining dam for the seaward access channel, including phasing.

According to Annex 25 to the UA report, up to October 2005 the protection dam has been completed for 360 m, or 1/3 of the planned Phase 1.

### Results from surveys to investigate project impacts

The available documentation provides information on a number of surveys which have been conducted by the Ukrainian side (e.g. Annexes 6, 26 and 30) to assess the impact of the project implementation. The documentation is mostly a qualitative description of findings and conclusions which are based on the data collected. Concrete, quantitative summaries of these data are however not provided.

# 3 Discussion of impacts

The main subject of the Inquiry Commission is the question whether the proposed project is likely to have a significant adverse transboundary impact. Key notions in this respect are “adverse”, “likely” and “significant".

The significance of an impact will be judged against quantitative criteria, which will be based on (1) the observed system characteristics, and (2) experience. Such criteria will be clearly stated so that they can be explicitly discussed.

The degree, to which a certain impact is likely to occur, will be classified as follows:
- unlikely;
- hardly likely (inconclusive);
- likely;
- very likely.

The judgement whether an impact is adverse or not is omitted in the present chapter. This is mainly done because changes in the physical environment can only be classified as being positive or negative if one judges them from a certain ecological or socio-economical perspective. Such an assessment is outside the scope of the present document. Therefore, we will concentrate on any likely significant impact, regardless of its nature.

## 3.1 Hydrological impact

### 3.1.1 Transboundary impact on the discharge distribution over Kiliya, Sulina and St. George branches

The quantification of the impact of the project implementation on the discharge distribution over the different river branches can very well be done by mathematical modelling, provided that an accurate description of the water system and the changes therein as a result of the project implementation is available. The information provided by the Ukrainian and Romanian representatives comprises results from different modelling studies. These studies address the impacts from the removal of the sandbar section in the Bystry mouth and the dredging of shallow areas along the river during Phase 1 of the project separately.

#### Dredging in the sandbar section of the Bystry channel

The results of mathematical modelling of the flow distribution between the Danube Delta branches, conducted at the Faculty of Geography of the Moscow State University by a team led by Dr. Prof. V.N. Mikhailov, indicate that during low water conditions, the increase in the flow discharge rates in the sandbar section after the completion of a 9 m deep sandbar cutting will be 1-2 $m^3/s$, which is about 0.05% of the Danube low water discharge (3000 $m^3/s$) or about 0.3% of the estimated low water discharge of the Bystry channel (17.6% of the Danube discharge) [UA report]. The result allows the conclusion that there will be no detectable impact of the measures regarding the flow distribution between the main branches Kiliya and Tulcea.

An additional modelling study is presented in the Romanian report [Annex 1]. This analysis also concludes that no impact is expected regarding the flow distribution between the main branches Kiliya and Tulcea. Therefore, the results from both modelling studies are consistent in this respect.

The above assessment concerns Phase 1 of the project. The Phase 2 impact has not been quantitatively assessed. On the basis of the available information regarding the Phase 1 impact, we do not expect a significant impact of the further deepening of the sandbar section in the Bystry Branch mouth during Phase 2 on the discharge distribution between the Kiliya and Tulcea branches.

#### Dredging of shallow areas along the river section of the shipping canal

According to the mathematical modelling presented in the UA report, the deepening of shallow areas along the whole course of the deep-water navigation route would result in an increase of the flow discharge in the Kiliya branch by 24 $m^3/s$ (which is 0.8% of the Danube flow in the low-water period of about 3000 $m^3/s$). Since we had only access to the summary of the modelling study [UA report] referring to a report in Russian/Ukrainian, we can not evaluate the assumptions made, the modelling approach and the uncertainty of results.

The RO report presents in Annex 1 an assessment of the impact from the dredging of shallow areas along the river. It is concluded that the measures will cause a 7% increase of the discharge in Kiliya channel during low water conditions. If applying a low water discharge of 3000 $m^3/s$, the absolute increase will be about 109 $m^3/s$, which is 4.5 times the estimate given in the UA report. The outcomes are computed by applying a simple extrapolation assuming that the channel cross section increases by 240 $m^2$. We think that this approach does not yield correct results because of three reasons:

- The amount of dredged sediment is overestimated: with the length of the Kiliya branch from the bifurcation of Kiliya and Tulcea to the bifurcation of Bystry channel being about 95 km, the equivalent dredged sediment volume would be 22.8 $Mm^3$, which is one order of magnitude higher than the reported actual dredging volume. (This argument is equivalent with the reasoning provided in Annex 8 to the UA report).
- The assessment does not take into account the flow distribution between the branches Kiliya and Tulcea. Because of the approximately 50%-50% distribution between the two channels, the impacts will be reduced by approximately a factor 2.
- An averaging of the measures over the complete length of the branch may underestimate the impact of the measures on the flow distribution. The removal of hydraulic bottlenecks, i.e. the dredging of sand bars, could have a larger impact on water levels and discharge distribution than assessed with the given approach.

Based on the available information we estimate the impact of the dredging of shallow areas along the river on the redistribution of flow between Kiliya branch and Tulcea branch to be in the order of 25 $m^3/s$ or about 1 % of the total discharge of the Danube during low water conditions. The redistribution under flood conditions is estimated to be in the same order in terms of the discharge (25 $m^3/s$), assuming that most of the dredging is done in the deep part of the cross section, and primarily affects the low water discharge.

The above assessment concerns Phase 1 of the project. The Phase 2 impact has not been quantitatively assessed. On the basis of the estimated dredging volume for Phase 2 (4.5 $Mm^3$) the impact of Phase 2 may be expected to be larger than that of Phase 1 (1.9 $Mm^3$). A linear extrapolation on the basis of the dredging volume would provide an estimated redistribution of the flow between the Kiliya branch and the Tulcea branch in the order of 60 $m^3/s$.

The significance of these changes has been judged against the background of the natural variability of the Danube discharge which also causes year-to-year variations in the discharge per branch, with a standard deviation of 18% of the average annual discharge. Against this background, it is unlikely that Phase 1 and 2 will have significant impacts.

### 3.1.2 Impact on the discharge distribution over the Bystry and Starostambulskiy branches

The dredging in the sandbar section of the Bystry channel will have an impact on the distribution of the discharge at the bifurcation of the Bystry and Starostambulskiy branches. According to the mathematical modelling presented in the RO report (Annex 1), the implementation of Phase 1 of the project will result in an increased discharge in the Bystry branch. From the figures presented in this Annex, we estimate the relative increase at 12% of the local discharge. This implies that the share of the Bystry in the total Danube discharge increases from about 17% to about 19%. Consequently, the share of the Starostambulskiy branch downstream of the Bystry branch of the total Danube discharge will decrease from about 21% to about 19%. Since we had only access to the summary of the modelling study, we can not evaluate the assumptions made, the modelling approach and the uncertainty of results.

This impact of 12% is likely significant for the Bystry and Starostambulskiy branches, since it is of the same order as the natural variability.

The impact is also transboundary, since it concerns a river which coincides with the state border.

### 3.1.3 Impact on water level dynamics (riparian water bodies and flood plains)

The impact of the changes in the river hydrology on fish and bird fauna is primarily determined by the changes in the water level dynamics of the rivers; this determines the frequency of flooding in the floodplains and riparian wetlands. In this paragraph, the impact of the project implementation on the water levels will be assessed. We will consider this impact representative for the impact on floodplains and riparian wetlands. The physical destruction of floodplains and riparian wetlands, e.g. by bank protection measures, is extremely relevant for assessing the impact on birds and fish life, but will not be discussed in this report.

The present assessment is done on the basis of mathematical modelling and is of a quantitative nature. However, the results are indicative only, since only an approximate representation of the river geometry has been used. A full scale mathematical modelling exercise using a precise geographical representation of the study area is beyond the scope of the present report.

The adopted methodology assesses the annual frequency distribution of the water levels, by means of a curve showing the number of days per year that the average water level is below a certain value. The natural variability of this frequency distribution is studies by compiling the distribution for 8 different years (1995-2002). The "band width" of these 8 distributions tentatively quantifies the natural variability[7].

For one of the years, 1998 which has an average discharge, the frequency distribution before the implementation of the project ("baseline") is compared to the distributions after implementation of Phase 1 and Phase 2 of the project, still assuming the same 1998 hydrology.

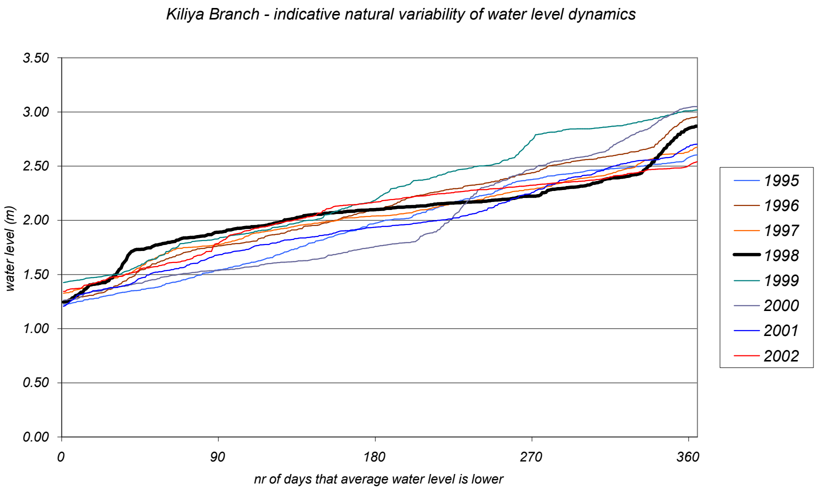
This exercise has been done for the Kiliya river (between Izmailsky Chatal and Vilkovo) and for the Bystry branch. For the former, both Phase 1 and Phase 2 could be assessed and for the latter, only Phase 1. The assessment was done by the program Sobek (www.sobek.nl)

[7] *Actually we underestimate the natural variability because neither extreme dry years (e.g. 2003) nor extreme wet years (e.g. 2005, 2006) are present in this period.*

which solves the one-dimensional shallow water equations. The assessment was based on the following information:

- Daily discharge series for the Danube River at Isaccea, upstream of the Danube Delta, derived from Constantinescu et al. (2005).
- An approximate representative cross-section of the Kiliya branch provided by Vituki et al. (1996).
- An approximate representative cross-section of the Bystry branch derived from Annex 17 of the UA report.
- The impacts on the discharge distribution described in sections 3.1.1 and 3.1.2.

The results are presented in Figure 3-1 and Figure 3-2.



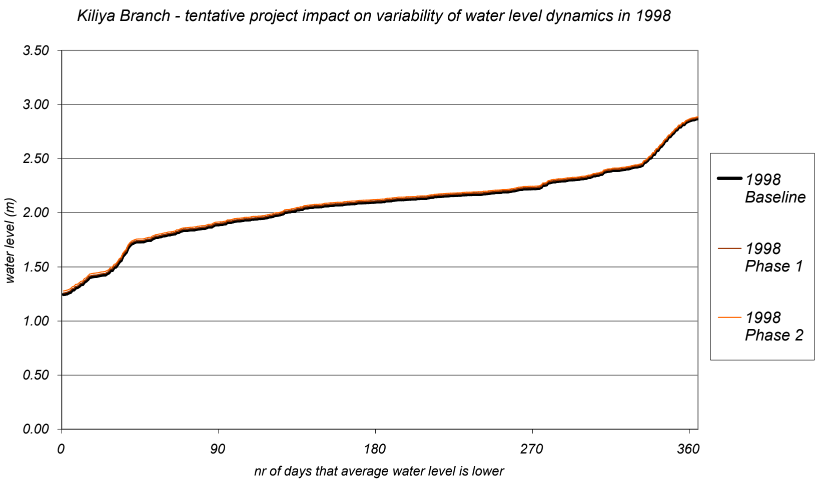
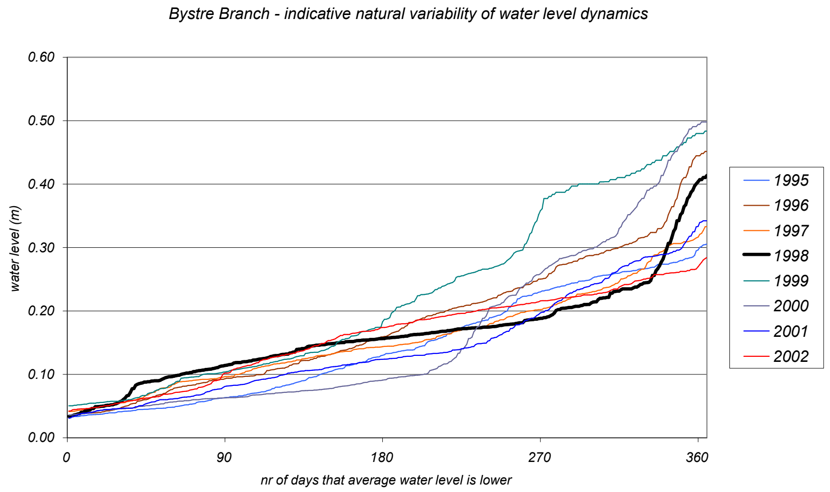




Figure 3-1: Natural variability of water levels (top) versus project impact on water levels (bottom) for the Kiliya branch.



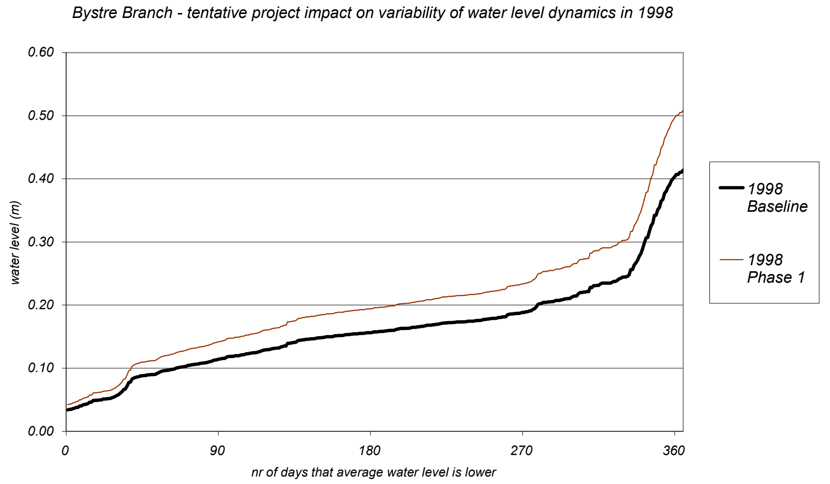




Figure 3-2: Natural variability of water levels (top) versus project impact on water levels (bottom) for the Bystry branch.

The conclusion is that the impact on the Kiliya branch is much smaller than the natural variability, for both phases. Therefore, the impact is unlikely to be significant. The impact on the Bystry branch turns out to be of the same order as the natural variation, and therefore is considered likely significant. A similar observation can be made for the Starostambulskiy branch downstream of the bifurcation with Bystry, which makes the impact transboundary. Note that in the Bystry, the frequency of high water levels will increase, while in the Starostambulskiy branch downstream of the bifurcation, the frequency of high water levels will decrease.

## 3.2 Sediment discharge / dumping of spoil

### 3.2.1 Turbidity of river waters and marine waters as a result of dredging operations (construction and maintenance)

#### "Near field" impacts

During and immediately after dredging operations, a part of the dredged material will be spilt to the environment and either be redeposited or be transported downstream, depending on the particle size, which determines the settling velocity. This will locally and temporally lead to clouds / plumes of elevated turbidity.

On the basis of modelling, the UA report estimates that in the Kiliya Branch downstream of dredging works, the average increase in the background concentration of suspended matter will be about 0.4 mg/l, and that in the centre of the plume the increase in concentrations of suspended solids will be about 10-25 mg/l. Annex 46 provides additional information about these calculations. This Annex mentions the following assumptions for these calculations:

- a dredging volume of 1200 $m^3$/hour;
- a soil density of 1.6 g/$cm^3$ or 1600 kg/$m^3$;
- a fine sediment content (= loss fraction) of 5%;
- settling is neglected;
- a river discharge of 1350 $m^3$/s.

Assuming complete mixing over the cross-section and steady state, we calculate a concentration of 20 mg/l rather than 0.4 mg/l. Therefore, we can not accept the simulation results mentioned above as a quantification of the near field turbidity impact.

Also, the available information does not provide water quality monitoring data during dredging.

In view of the fact that the state border between Ukraine and Romania is situated along the Kiliya branch, exactly where the dredging is taking place, it is likely that the impacts are of a transboundary nature. Since the natural variability of the river concentrations of suspended matter is very large, typically between 20 mg/l and several hundreds mg/l, the concentration increase needs to be in the order of 100 mg/l or higher in order to be significant. On the basis of the available data we can not estimate the extent of such impacts. Therefore we qualify them as "hardly likely (inconclusive)".

It should be mentioned that extensive experience is available from all over the world to mitigate the type of impacts discussed in this section.

#### Impacts over larger distances and time scales

As a result of the dredging along the river, a part of the dredged material will be lost to the environment. This material would otherwise have remained in the river sediments. Annex 36 to the UA report estimates the losses of soil during dredging in Phase 1 as appr. 160,000 $m^3$, or about 10% of the dredged volume. In order to estimate the significance of this extra load of sediment in the river, the volume of lost material needs to be converted to a sediment mass. This is done using a bulk density of 1500 kg/$m^3$, which is equivalent to 833 kg/$m^3$ dry sediment density.

The extra load of sediment is evaluated against the background of the total river sediment loads and the variability therein. On the basis of the available data, the annual (suspended) sediment load of the Kiliya branch is estimated at about 15 x $10^6$ t/y (range 5-50 x $10^6$ t/y). Table 3-1 summarises the sediment losses for the different project phases, assuming that all losses remain in suspension (worst case assumption). The losses turn out to be small in relation to the average annual load in the Kiliya branch, and well within the natural variability (-70% to +230%), and is therefore unlikely to be significant.

Table 3-1: Overview of dredging losses during different project phases.

| **Project phase** | **Dredging volume ($10^6$ $m^3$)** | **Lost sediment mass ($10^6$ t)** | **Lost sediment mass (% of average Kiliya load)** |
|---|---|---|---|
| Phase 1 Construction | 3.6 | 0.54 | 4% |
| Phase 2 Construction | 5.7 | 0.86 | 6% |
| Annual maintenance | 1.0 | 0.15 | 1% |

### 3.2.2 Turbidity of marine waters as a result of dumping

The dumping of dredging spoil potentially causes a turbid plume that affects the marine waters up to the state border with Romania. The likeliness and significance of such impacts are assessed semi-quantitatively, under influence of the following factors:

- The volume of dumped spoil.
- The duration of the dumping.
- The composition of the spoil (size fractions).
- The losses to the marine environment following a dumping event.
- The magnitude and direction of the marine currents.
- The water depth.
- The settling rate of the different fractions of sediment in the spoil.
- The distance between the dump site and the state border with Romania.

For estimating the volume of dumped spoil and the different size fractions therein, the following assumptions have been made. First, the overall dumped volume for the different project phases has been derived from the available information. This has been converted to a sediment mass assuming a bulk density of 1500 kg/$m^3$. The dumping works are assumed to take place over a certain period, in this case 30 days. This allows us to calculate an average rate of dumping during this period. On the basis of the available dredged sediment composition data (see Table 2-1); an estimate has been made for the fraction fine silt (< 5 µm): 10% of the total mass (range 1-23%). The results are summarised in Table 3-2.

Table 3-2: Overview of dredge spoil dumping activities and characteristics.

| Project phase | Dumped volume ($10^6$ $m^3$) | Dumped sediment mass ($10^6$ t) | Period of dumping (d) | Average dumping rate (kg/s) | Dumping rate fraction <5 µm (10%) (kg/s) |
|---|---|---|---|---|---|
| Phase 1 Construction | 1.9 | 1.6 | 30 | 611 | 61 |
| Phase 2 Construction | 1.7 | 1.4 | 30 | 547 | 55 |
| Annual maintenance | 1.0 | 0.83 | 30 | 322 | 32 |

On this basis we estimate a typical average dumping rate during Phase 1 and 2 in the order of 500 kg/s.

For the plume formation we assume that all material < 5 µm is lost to the environment. It is practically not possible to verify this assumption by comparing the dump site bathymetry before and after dumping. In the first place, such an assessment is probably not accurate enough to detect losses in the order of 10%. In the second place, the volume of the spoil after dumping changes; initially the volume increases due to entrainment of water during the dumping, and afterwards the volume decreases due to consolidation.

Regarding the marine currents, we estimate that southbound currents occur regularly (more than 50% of time), that a typical surface current speed is 0.25 m/s, that the depth average current velocity is 80% of this value, and that the water depth is 20m. Furthermore, we estimate the distance from the dump site to the Romanian border as 16 km. We assume that the sediment fraction <5 µm settles slowly, with a settling velocity of 0.1 mm/s.

By a Gaussian plume dispersion model applied to the horizontal plane, we can assess the concentration increase of suspended matter relative to the background concentration at the state border. We have assumed that the lateral dispersion coefficient is 3 $m^2/s$.

The result of the analysis is that the concentration increase at the state border is 5 mg/l. The accuracy of this assessment is of course limited, so the uncertainty in this estimate is significant. If we estimate the uncertainty at one order of magnitude, the estimated concentration at the state border would be in the range 2-20 mg/l.

The current velocity has a minor impact on this result. If it is reduced by a factor of 2 (0.10 m/s), the resulting concentration at the state border is still 5 mg/l. At a lower current speed, there is more time for settling, but at the same time mixing processes are less effective.

This impact is likely significant, because it is of the same order as the background levels of inorganic suspended matter, as presented in Section 2.1.5.

### 3.2.3 Coastal morphology

The coastal morphology of the Kiliya Delta is determined by three factors:

- The input of sediments carried from the north by the southward longshore drift in the littoral zone.

- The input of sediments carried by the Danube River.
- The large jetties at the Sulina mouth, which effectively prevent any sediment transport to the Romanian coast.

Under these determining factors, the Kiliya Delta shoreline shows a progressing trend, which is witnessed by the process of spit formation, e.g. directly south of the Bystry mouth (Ptichiya spit) and directly south of the Starostambulskiy mouth (Nova Zemlia spit).

Because the distribution of the sediment transport over the Danube branches is considered more or less similar to the discharge distribution, the construction of the shipping canal will result in a slightly larger sediment load towards the Kiliya delta (see Section 3.1 for the impact of the project on the discharge distribution). Also, the distribution of this load over the Kiliya Delta branches will be significantly different than before: the share of the Bystry branch will be larger and the share of the Ochakov and Starostambulskiy branches smaller.

Further relevant changes however are:

- The retaining dam will locally modify the coastal sediment transport:
  - The sediment influx from the north will probably be reduced; and
  - The northbound transport of sediments carried by Bystry and Starostambulskiy during southern wind conditions will also be reduced;
- The continuous maintenance dredging of the Bystry mouth sandbar section and the subsequent dumping of the dredged material off-shore will remove an amount of sediment from the littoral system.

The first factor can not be estimated, since we have no quantitative data on the sediment influx from the north. The second factor has been estimated at about 0.3 $Mm^3/y$ (or about 0.25 $10^6$ t/y). This we can relate to the total load of sandy material carried by the Starostambulskiy/Bystry system. We estimate that load at about 38% of a total of 5 x $10^6$ t/y carried by the Danube River, which is about 2 x $10^6$ t/y.

This implies that the delta section between the Bystry and Sulina branches will probably receive a smaller sand input after the implementation of the project than it does today. This will cause a reduction of sedimentation and processes like spit formation, and maybe even a shift to erosion. The reduced sand availability could have different effects on the Ptichiya spit. On the one hand, the life time of the spit could be extended due to the slowing down of the delta formation process. On the other hand, local erosion phenomena could shorten its life time.
Annex 45 to the UA report presents a modelling study of the sediment transports in the Bystry mouth zone, before the project and during different stages of the project implementation. The study takes into account current and wave-driven sediment transport, and includes a numerical modelling validation based on physical modelling results. The study claims that the completion of the sea retaining dam after Phase 2 of the project "will promote the stabilization of the Ptichiya Spit as a separate ecosystem". Since we had only access to an English language summary of the modelling study (the full report is in Ukrainian), we can not fully evaluate the assumptions made, the modelling approach and the uncertainty of results. What we can observe is that the modelled area is too small to assess the direct transboundary morphological effects to the Romanian coast section. Furthermore,

the removal of sediment from the littoral zone by maintenance dredging has been neglected in the calculations (Dr. Mark Zheleznyak, pers. comm.). Therefore, we can not support the abovementioned conclusion from the modelling study.

Anyhow, the transboundary nature of the morphological impacts is restricted to the Romanian coast section between the Kiliya and Sulina branches (in the order of 10 km long). South of the Sulina branch, significant impacts are effectively impossible due to the presence of the 8 km long Sulina jetties.

Mitigation of the morphological impacts could be achieved in two ways. Firstly, keeping the retaining sea dam relatively short (i.e. covering the surf zone only) would help to maintain a certain influx of sediments from the north. It is recommended that “lessons learned” from the Sulina example, where eventually 8 km long jetties have been constructed, could help optimise the design. Secondly, dumping the dredged material elsewhere inside the littoral zone would keep this material available for littoral processes.

## 3.3 Summary of findings

| **Operations** | **Possible impact** | • **Transboundary impact?**<br>• **Likely significant?**<br>• **Impact duration**<br>• **Impact spatial extent** |
|---|---|---|
| Widening and deepening shipping channel (phase 1 and phase 2 of construction) | Modification of discharge distribution over main Danube branches (Kiliya – Sulina) | • Transboundary impact<br>• Phases 1 and 2: unlikely to be significant in view of natural variability<br>• Permanent impact<br>• Affects whole delta |
| | Modification of water level dynamics in main Danube branches (Kiliya) | • Transboundary impact<br>• Phases 1 and 2: unlikely to be significant in view of natural variability<br>• Permanent impact<br>• Affects whole delta |
| | Modification of sediment transport distribution over main Danube branches (Kiliya) | • Transboundary impact<br>• Phases 1 and 2: unlikely to be significant in view of natural variability<br>• Permanent impact<br>• Affects whole delta |
| | Modification of discharge distribution over Kiliya Delta branches (Bystry, Starostambulskiy) | • Transboundary impact<br>• Phases 1 and 2: likely significant in view of natural variability<br>• Permanent impact<br>• Affects Ukrainian Kiliya delta |
| | Modification of water level dynamics in Kiliya Delta branches | • Transboundary impact<br>• Phases 1 and 2: likely significant in view of natural variability<br>• Permanent impact<br>• Affects Ukrainian Kiliya delta |
| | Modification of sediment transport distribution over Kiliya Delta branches (Bystry, Starostambulskiy) | • Transboundary impact<br>• Phases 1 and 2: likely significant in view of natural variability<br>• Permanent impact<br>• Affects Ukrainian Kiliya delta |

| **Operations** | **Possible impact** | • **Transboundary impact?**<br>• **Likely significant?**<br>• **Impact duration**<br>• **Impact spatial extent** |
|---|---|---|
| Dredging operations during construction or channel maintenance | Strong increase of water turbidity near dredging works due to sediment losses during dredging | • Transboundary impact<br>• Significance can not be assessed<br>• Temporary (during dredging)<br>• Local (vicinity of dredging sites, area can not be quantified) |
| | Overall increase of turbidity in riverine and marine waters due to sediment losses during dredging | • Transboundary impact<br>• Unlikely to be significant in view of natural variability<br>• Permanent (due to channel maintenance)<br>• Affects Kiliya branch, Kiliya Delta and adjacent marine waters |
| Offshore dumping of dredging spoil | Increased turbidity in marine waters due to sediment losses during dumping | • Transboundary impact if marine currents are southbound<br>• Likely significant in view of natural variability<br>• Temporary (during dumping)<br>• Affects marine waters over larger distances |
| Maintenance dredging of sandbar section in Bystry mouth, and subsequent off-shore dumping of spoil | Transboundary changes to coastal morphology due to removal of river sediment from littoral system | • Transboundary impact<br>• Significance can not be determined<br>• Permanent<br>• Restricted to the appr. 10 km long Romanian coast section between the Kiliya and Sulina branches long Sulina jetties |
| | Local changes to coastal morphology due to removal of river sediment from littoral system | • Not directly of a transboundary nature[8]<br>• Significance can not be determined.<br>• Permanent<br>• Affects Kiliya Delta coast (Ukrainian coastal section) |

[8] *Indirect transboundary impacts could be the result via an impact on birds and/or fish.*

| Operations | Possible impact | • Transboundary impact?<br>• Likely significant?<br>• Impact duration<br>• Impact spatial extent |
|---|---|---|
| Construction of seaward retention dam | Transboundary changes to coastal morphology due to change of littoral sediment transport fluxes | • Transboundary impact<br>• Significance can not be determined<br>• Permanent<br>• Restricted to the appr. 10 km long Romanian coast section between the Kiliya and Sulina branches long Sulina jetties |
| | Local changes to coastal morphology due to change of littoral sediment transport fluxes | • Not directly of a transboundary nature[9]<br>• Significance can not be determined.<br>• Permanent<br>• Affects Kiliya Delta coast (Ukrainian coastal section) |

## 3.4 Mitigation of impacts

The potential project impacts discussed in this report may in some cases be mitigated by specific measures. Occasionally, such measures have been mentioned above. The identification of such measures in general is beyond our current scope and will not be discussed further.

## 3.5 Recommendations for further research

On the basis of the information available to us, we can make the following recommendations.

1. A sound Environmental Impact Assessment document in a transboundary framework is lacking and needs to be provided, including a characterisation of the baseline situation, an assessment of the expected impacts of the project construction and operation, the identification and assessment of measures mitigating any expected adverse impacts and a monitoring plan to assess the actual impacts in the years to come[10].

2. There exists a significant database and knowledge base on both sides of the border regarding the subjects discussed in this report (river hydrology, hydraulics, sedimentology and coastal morphology). In order to provide a sound and mutually accepted basis for the abovementioned EIA document, it is recommended to carry out a joint bilateral research effort to characterise the baseline situation and assess the project impacts. This effort should include modelling studies by bilateral research teams and could make use of international experts in a supportive role.

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[9] *Indirect transboundary impacts could be the result via an impact on birds and/or fish.*
[10] *It is acknowledged that many building blocks for such an assessment already exist.*

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