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**Integrating Danube Region into Smart & Sustainable**

**Multi-modal & Intermodal Transport Chains**

# Prut Fairway Maintenance Plan

## Output T4.7 Integrated Port Development Plan [MD]

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# Table of contents

## Table of Figures

## Table of Tables

## Abbreviations

| Abbreviation | Explanation |
|---|---|
| **IWT** | Inland Water Transport |
| **DR** | Danube Region |
| **EU** | European Union |
| **RM** | Republic of Moldova |

**Purpose and objectives of the project**

**Output: T4.7: Integrated Port Development Plan [Republic of Moldova]**

An integrated Port Development Plan for Moldova will be developed by UTM which will summarize the findings of the infrastructure development plan for the hinterland connections of Giurgiulesti Port and the fairway maintenance plan for the Prut River.

The fairway maintenance plan will be developed for the navigable section of the River Prut (used by small vessels of 200-300 tonnes), with a dedicated focus on national needs and short-term measures in order to ensure efficient and effective realization of harmonized waterway infrastructure parameters.

A comprehensive plan will be elaborated for the development of hinterland infrastructure and intermodal connections (rail and road) from the Port of Giurgiulesti towards the hinterland.

The importance of considering the development of hinterland links and infrastructure in relation to enhanced corridor needs (be it a domestic trade corridor or a transit trade corridor) will be an essential element in the elaboration of this development plan.

**D.T4.5.2. Prut Fairway Maintenance Plan**

Economically viable transport services on the Danube River and its navigable tributaries (e.g. Prut River) are highly dependent on stable and sufficient fairway conditions. The Port of Giurgiulesti is located in the vicinity of the rivers Prut and Danube confluence, therefore good fairway & navigation conditions of the river Prut is an important prerequisite for the goods present at Giurgiulesti port to reach the hinterland represented by the east of Romania, the west of Moldova and even Ukraine. A fairway maintenance plan will be developed by the Technical University of Moldova for the navigable section of the River Prut (used by small vessels of 200-300 tonnes), with a dedicated focus on national needs and short-term measures in order to ensure the efficient and effective realization of harmonize.

## 1. The general characteristic of the Prut River

### 1.1. The Prut river basin

The hydrographic network of the Republic of Moldova is rich and varied (registering about 10 thousand hydrographic units, from rivers to ponds and springs), but at the same time it is unitary, because most rivers large and small are located geographically within a single general basin - the Black Sea.

The Prut river is the second as length hydrographic basin in Moldova. The surface of the Prut river basin occupies 27,540 km$^2$, river fall - 1,577 m, average slope - 1.63%, meandering coefficient 2.13.

It should be noted that, following modern modeling by GIS means, the surface of the river basin (in Romania and with the related areas on the territory of Ukraine and the Republic of Moldova) makes up a total area of 28,460.43 km$^2$.

The Prut originates on the eastern slope of Mount Hoverla, in the Carpathian Mountains in Ukraine (Ivano-Frankivsk Oblast) at 15 km to south-southeast of the village of Vorokhta, of the Chernogory massif of Forested Carpathian Mountains, and falls into the Danube River to the south of the village of Giurgiulesti, at a distance of about 164 km from the Danube mouth (Figure 1).

At first, the river flows to the north. Near Yaremche it turns to the northeast, and near Kolomyia to the south-east. Having reached the border between Moldova and Romania, it turns even more to the south-east, and then to the south. It eventually joins the Danube near Giurgiulesti, east of Galati and west of Reni.

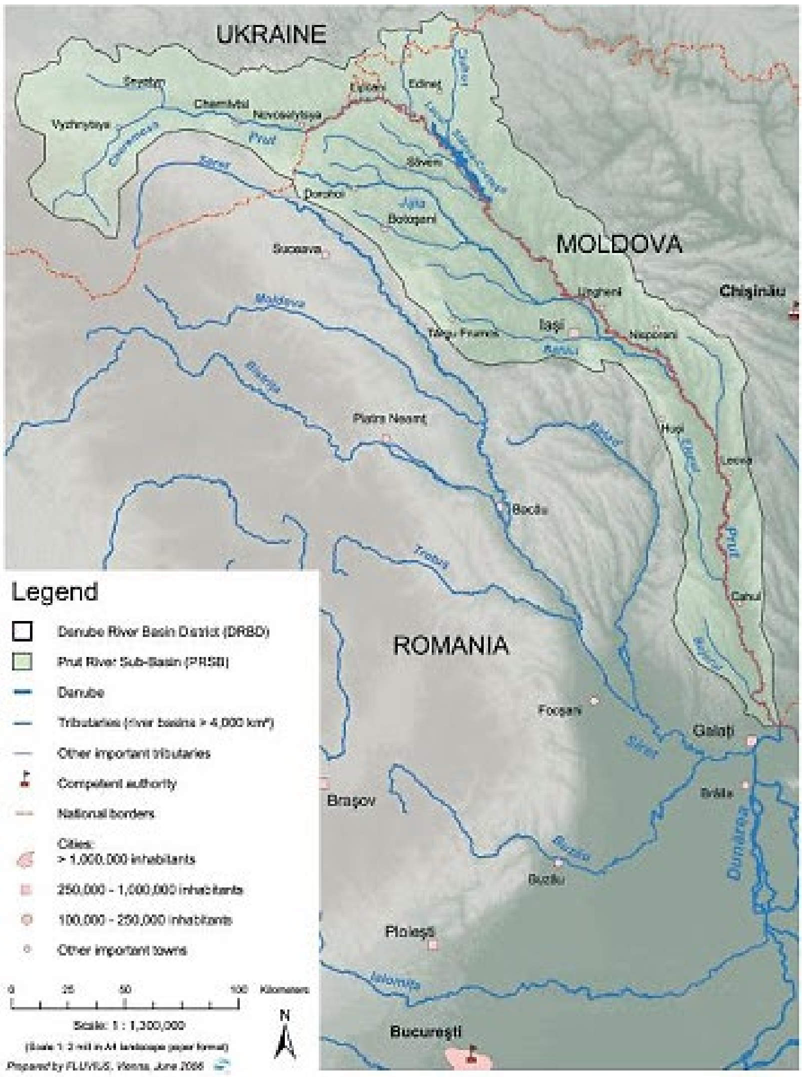
Between 1918 and 1939, the river was partly in Poland and partly in Greater Romania (România Mare). Prior to World War I, it served as a border between Romania and the Russian Empire. After World War II, the river once again demarcated a border, this time between Romania and the Soviet Union. Nowadays, for a length of 31 km, it forms the border between Romania and Ukraine, and for 711 km, it forms the border between Romania and Moldova. From its hydrographical basin 10,990 km$^2$ are in Romania and 7,790 km$^2$ in Moldova. The largest city along its banks is Chernivtsi, Ukraine.

The Costesti-Stinca Dam, operated jointly by Moldova and Romania, is built on the Prut. There is also a Hydro-Electric Station in Sniatyn, (Ukraine). Ships travel from the river's mouth to the port city of Leova (southern Moldova).

The lowermost part of the basin is strongly marshy. The average discharge at its mouth is 110 m$^3$/s (3,900 cu ft/s). The average discharge at the city of Leova is 69.2 m$^3$/s. The slope of the river varies from 100 m/km (near the source) to 0.05 m/km (near the mouth). In the upper reaches (to Delyatyn) it has a mountainous character, with a steep right bank, sometimes the cross-sectional profile of the channel has the form of a ridge. Near the city of Yaremche is the waterfall of Probiy.

The basin of the Prut River, being a transboundary basin, is located in the territory of three countries: 28% in Moldova; 33% in Ukraine; and 39% in Romania. Within Moldova the length of the river is 695 km, i.e., 71.9% of its total length. The Prut basin comprises 41 small river basins; these rivers are longer than 15 km; of them 13 are first-order tributaries. The maximum altitude of the basin is 429.5 m; the minimum one is 2.6 m.

8




Source: http://www.apelemoldovei.gov.md/pageview.php?l=ro&idc=139

Figure 1: Prut River Basin overview map

## 1.2. Hydrological and meteorological factors

### 1.2.1. Water level regime

The Prut River Basin is characterized by a dense hydrographical network. The density of the river network is 0.94 km/km$^2$. The density of the network due primarily to two factors: a large dissection of relief and at the same time a significant amount of rainfall. Prut starts in the north-eastern slopes of the Carpathians at an altitude of 1750 m. On the surface of the Prut river basin on the territory of the Republic of Moldova there are about 1,100 reservoirs and accumulation lakes (the lakes are mainly in the lower course of the river). Throughout the basin, from the Carpathians to the Danube, the Prut collects the waters of over 800 rivers, streams and brooks, including 580 of them on the territory of the Republic of Moldova.

On the territory of our country, the Prut River has only left tributaries, among which are Racovat, Larga, Vilia, Lopatnic, Draghiste, Ciuhur, Camenca, Nirnova, Lapusna, Sirma, Sarata, Tigheci, Larga.

Thus, within the Prut river basin, 83 surface water bodies were delimited, with a total length of 2152 km. The average length of river-water bodies is 26 km and only one body of water has a length exceeding 100 km, the average surface of river-basin basins is 99 $km^2$, 55 they have an area of less than 100 $km^2$.

Within the Prut river basin from the territorial limits of the Republic of Moldova are located 7 bodies of water-lakes. One of them (the ponds of the Cahul fish farm) has been identified as artificial water body.

Table 1: Parameters of water bodies lakes

| Lake | Position | Origin | Type | Surface, $m^2$ | Depth, m |
|---|---|---|---|---|---|
| Costesti-Stinca | Riverbed | WBL | Water storage | 42,56 | >15 |
| Badelnic | River meadow | Natural | Natural lake | 1,443 | 3-15 |
| Dracele | River meadow | Natural | Natural lake | 2,774 | 3-15 |
| Rotunda | River meadow | Natural | Natural lake | 2,329 | 3-15 |
| Beleu | River meadow | Natural | Natural lake | 8,538 | 3-15 |
| Antonesti | River meadow | Natural | Natural lake | 0,986 | 3-15 |
| Cahul | River meadow | Artificial | Water storage | 12,597 | 3-15 |

Source:
https://ieg.asm.md/sites/default/files/RO_MoldPlan_Prut_MD_final_Red_13.05.2016%20%28vb.17.05.2016%29.pdf

The maximum depth of the river Prut varies between 6-8 meters in the river meadow or near lakes and at the mount to Danube and 3 meters on average.

In the lower part of the river, after the embankment of the riverbed, the levels increased, reaching higher values. Thus, until the dam, the high flood levels were 490-500 cm per hour. Ungheni, 410-430 cm at or. Leova, and after damming 500-530 cm and 400-520 cm respectively.

High levels are also observed during the high spring waters. The increase of levels takes place very intensively (up to 4 m/day in 1901 in Yeremcea). As a rule, the level increases of high spring waters on the sector in the Republic of Moldova fall within the limits of 0.5-2.5 m above the average.

### 1.2.2. Water flow

The average annual volume of drainage of the Prut River is equal to 2.7 $km^3$ and varies from 1.2 $km^3$ in years with insufficient humidity up to 5 $km^3$, values obtained in the years with the high provision of water resources. The average annual flow is equal to 78 - 94 $m^3/s$, the fluctuations vary between 40 and 162 $m^3/s$.

The surface water resources in the Danube-Black Sea basin are quite modest. The region accounts for only about 1% of the country's total available surface water resources. The increase of water levels usually starts in mid-late March due to snow melting in the mountains, or fallout rain and sets the beginning of river floods in the Carpathians. Flood takes place in several waves, particularly during warming and often complicated or aggravated by rain. The highest spring flood are observed on small rivers usually in the second or third week of March. Maximum spring flood not always has the highest annual level, most of all the highest level is a level of rain floods. The intensity of spring flood level rise depends mainly on the water content in snow.

On the territory of the Republic of Moldova, the river has an average multiannual flow of 83.2 $m^3/s$ (at Ungheni). The annual flow of the Prut from the source to the discharge is 2.9 $km^3$ of water. The volume of the leakage (annual leakage norm) and its variability are: at the village of Corpaci - 82.0 $m^3/s$ and 234 mm, the coefficient of variation - 0.33; at the mouth - 92.0 $m^3/s$ and 108 mm, the coefficient of variation - 0.37.

The duration of floods is much shorter than that of large spring waters. On the Prut River their general duration is 13-25 days, with an increase period of 4-8 days and a decrease of 9-17 days. The duration of spring flood is 1.5 -2 months (table 2).

Table 2: Typical water flow on the network of hydro-meteorological service

| Prut river | Pre-flood flow, $m^3/s$ | Maximum flood rate, $m^3/s$ | Growth duration, days | Duration of the decrease, days | Total duration, days |
|---|---|---|---|---|---|
| Corpaci | 86 | 994 | 4 | 0 | 13 |
| Ungheni | 100 | 450 | 6 | 13 | 18 |
| Leova | 118 | 297 | 8 | 17 | 25 |

Source: https://plural.upsc.md/wp-content/uploads/2016/03/04-Vlad-Mischevca.pdf

During the period of run  off between June and August, which is the lowest, the waters of the Prut cannot be used for water supply (partly due to water consumption and retention in ponds), which is why they have been recorded for the last 50 years. years of hydrometric activities the characteristic values of the minimum average flows with the values for the characteristic insurances. Thus, according to the latest summaries, the minimum insured flow, after the commissioning of all accumulations, is at least 35 $m^3/s$ on the Prut at Ungheni.

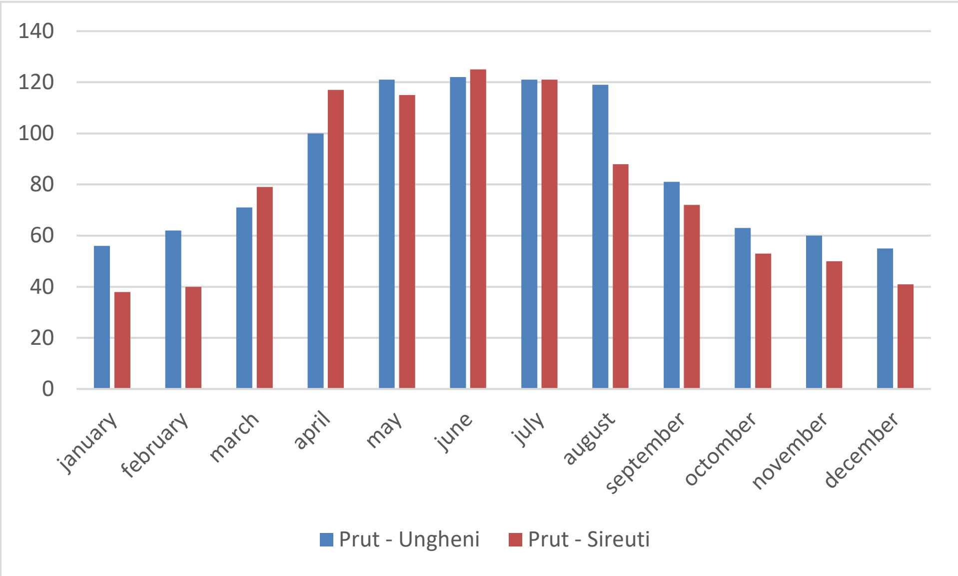
In the Prut basin, during the winter, the minimum runoff is influenced by strong frost phenomena (frosts or snow). The great spring waters begin in the first days of March and end in the middle of the third decade of April. The intensity of the level increase is on average 20-24 cm/day.

The summer rain floods usually begin after the spring flood. Their maxima usually exceed the spring flood level at 0.5 - 1.5 m. Incessant autumn rains cause considerable level rise, sometimes reaching 2-3 m (table 3, figure 2). Reducing the level lasts until August - September and reaches the lowest value at the end of September - October. Floods can be from 5-8 times to 10-12 times and more in some years. Is observed increase in autumn, which lasts for winter. In autumn can be very high and even catastrophic floods. Winter regime of levels is characterized by instability due to frequent thaws. The water level rises to 1.0 - 1.5 m, and sometimes by 2.0 - 3.5 m compared with the period before the flood.

Table 3: Typical values of water flow at the hydrological stations located in Prut river basin

| Discharge characteristics ($m^3/s$) | | | Gauging station | Period of time |
|---|---|---|---|---|
| $Q_{av}$ | $Q_{max}$ | $Q_{min}$ | | |
| 81-105 | 658-755 | 1,8-22,2 | Sireuti, Ungheni | 1950-2010 |

Source: http://www.meteo.md/images/uploads/Hydro/anuar_2019.pdf




Source: http://www.meteo.md/images/uploads/Hydro/anuar_2019.pdf

Figure 2: Monthly distribution of average flows

The typical maximum annual runoff modules for the Carpathian rivers are 20 - 30 l/s $km^2$. The modern exogenous geodynamic processes in river valleys of Prut basin are: water erosion from heavy rain and lateral erosion of slopes, on slopes - natural denudation and erosion, complicated in some treeless areas, landslides, avalanches, screes and quick sand. As a result of these processes in rivers and streams many diverse-grained materials are transported by waterways. The solid of suspended sediment can be dominant. The largest part of the solid runoff of mountain rivers is associated with mud flow.

### 1.2.3. Deformation of the riverbed

The Prut river basin located in the eastern part of Romania (Romanian sector), is a contact basin between the Moldavian Plateau, in Romania, in the west and the Podolic Plateau, on the territory of the Republic of Moldova, in the east. The evolution and geographical aspects are related to those of the Moldavian Plateau, some authors considering this unit a subdivision of this plateau.

In this aspect, the Prut basin overlaps on three structural units: The Moldavian Platform (up to the Falciu-Plopana fault); the Barlad Platform (between the Falciu-Plopana and Adjud-Oancea faults); the Covurluiului Platform. Each one of them presenting a base with corrugated formations covered by a quilt, with monoclinal arranged formations.

The relief is presented as a set of extensive interfluves with the appearance of bridges, hills and hills separated by wide valleys, carved in the monoclinal sedimentary cover. The general inclination of the relief, to the south – southeast, in the same sense as the orientation of the more important valleys, reflects an obvious adaptation to the structure. The monoclinal structure favored the appearance of positive forms and subsequent valleys.

The main steps required in morphology have values of 300-500 m in the northwest, 300-400 m in the central part, 150-200 m in the northeast and south and have a relatively balanced distribution. Altitudes above 500 m are low and isolated. The lowest elevations are found along the Prut corridor (130 m at Oroftina, 32 m near Ungheni and less than 15 m towards the confluence).

Mountain rivers are characterized by not deep valleys with steep slopes. River valleys are located across mountain ranges. The river valleys are mostly narrow, often with steep slopes and bluff. River valleys are expanding only in areas of soft outputs Oligocene rocks, forming a round or oblong canyon. These mountain rivers differ from lowland rivers in which landscape and geo-botanical terms are throughout more or less the same (azonal). The depth of the valleys in the foothills is 150 - 250 m and in the mountains it is 600 - 800 m. The slope is usually 60 - 70 m/km in the upper and 5 - 10 m/km in the lower parts of stream. The beds of the rivers are not deep. The width of the bed is mostly 3 - 5 m, in the upper part of the river it is 10 - 12 m and in the mouth part 80 - 100 m. The river beds have usually one river horn and covered of pebbles. The downstream parts of rivers usually have many river horns.

The upper part of Prut River is a typical mountain river, relatively small, with steep slopes, with boulders and pebbles as sediments. In this upstream section, the river flows through a deep valley, which resembles in canyons at times. The section is largely forested. Trees are often observed as debris in the water stream, especially at bridges. The river course is primarily flowing from south-west to north-east. At the town of Yaremche, the river forms the cascading waterfall of Probiy. The position and geographical configuration of the river on the territory of Moldova determine a remarkable diversity of geological structure, geomorphological characteristics and climatic conditions. The specificity of these environmental components significantly determines the characteristics of the biota, soils, hydrological and hydro chemical characteristics of groundwater and surface water (figure 3). The average value of the absolute altitude of the rayon landscape is 142 m, a typical value for the low regions.

On the territory of Moldova, the course of the Prut River can be conventionally divided into several sectors, described below.

**I.** Lipcani-Costesti

The river valley is winding, up to the village of Dumeni in the shape of a Latin V, downstream - in the shape of a crate; the width varies from 0.8 km (Sirauti village) to 9 km (Costesti town), predominates 2-4 km. The slopes are concave, steep, sometimes vertical, with meadow vegetation, often with hints of mother rock, sometimes convex, slow and moderately steep, capitalized (arable land). In the villages of Sirauti, Pereryta, Bogdanesti, they are covered with alder sub-trees and forest blackberries.

The meadow is observed only at the meanders of the river, with lengths of 0.5-2.0 km and Width from 120 m to 2.7 km. It is intersected by numerous streams, covered with shrubs, made of sandy clays.

The riverbed is very winding, branched. The islands, which are present sandy islands with lengths of 150-250 m, width of 30-80 m and which rise above the water by 0.5-2.5 m, being covered by shrubs. Sandbanks are frequent, every 2-3 km there are ridges with a length of 100-150 m, depth of 0.5-0.7 m, water flow speed - 0.8-1.3 m / s. In the places of confluence with other courses, injection cones are formed.

The predominant width of the river is 69-90 m, maximum - 140 m. Average depth 1-2 m, maximum - 5.3 m, minimum - in fords - 0.3 m. Water speed varies from 0.2 to 1.3 m / s. Remains of drowned trees are often found in the riverbed.

The riverbed is irregular, with sand and pebbles, at the edges - pebbles and rocky gravel.

The banks predominantly merge with the slopes of the valley and only on some small sectors they reach the height from 1.5 to 6.0-8.0 m, they are steep, eroded, covered with shrubs, made of clayey sands.

On this sector is located the Costesti-Stinca accumulation lake, the hydro technical node being put into operation in 1978. The dam is built at 576 km from the mouth of the Prut river.

The total volume of the accumulation lake is 1285 million. $m^2$, active volume - 450 mln. $m^3$.

The reservoir is used for irrigation, flood mitigation, hydropower, water supply for various uses, fish farming and less recreation.

**II.** Costesti - the confluence with Jijia district

The valley is weakly winding, box-shaped, with an average width of 6-9 km, maximum - 11 km (Costuleni village), minimum - 5.5 km (Chetris village). As the downstream distance decreases, the height of the slopes increases from 70-100 m to 120-160 m. The slopes are dismembered, concave (downstream of Sculeni village the left slope is convex), steep and very steep, covered with steppe vegetation, capitalized in agriculture. Landslides, particularly intense downstream of Macaresti village, are frequent throughout the sector. On some sectors there are terraces with a width of 0.5-2.0 km, with steep steps, even vertical, with a height of 8-12 km.

The meadow is bilateral, consistent on both banks, with a width of 3-6 km, at the junction with the Jijia river meadow it widens up to 8 km. The surface is irregular, the sector afferent to the riverbed is a little high, forested or covered with shrubs, the central part and from the foot of the slopes of the valley - lowered. The meadow is predominantly pointed, interspersed with numerous stables up to 30 m wide and up to 2 m deep. Some depressions are swampy, covered with reeds and shrubs. It consists of sandy clays and clayey sands.

The riverbed is very winding, unstable, often breaking the banks at the meanders. In 1955 the narrow isthmus from Taxobeni village was blown up and as a result the length of the river was shortened by 5 km. Frequent islands with a length of 50-150 m, width of 10-15 m, height of 1.5-2.5 m, are of alluvial origin, covered with shrubs. The largest island is located 2.7 km upstream of Bisericani village and has a length of 800 m, a width of 150 m. There are often sandbanks, many islets; the branches of the river, which bypass the islands, are 10-40 m wide. The dominant width of the river is 50-80 m, maximum - 140 m (at the beginning of the sector), minimum - 28 m (Braniste village). The depths are of the order of 0.8-2.5 m, maximum - 7.1; the velocities of the watercourse vary within the limits of 0.4-0.7 m / s.

In 1970, 0.5 km upstream of Barboieni village, a landslide created a natural ridge with a length of 150 m, the water speed here is 2.5 m / s. The bed of the riverbed is irregular, sandy, rarely with pebbles.

The banks are steep, with a height of 3-5 m, eroded, consisting of clayey and sandy-clayey rocks, in the softer places - sand and pebbles. The coastal sector is forested.

**III.** Confluence with Jijia district - Stoianovca village

The river valley is a little winding, in the shape of a crate, with a width of 7.0-8.5 km, in the village of Tochile-Raducani it widens up to 11 km, in the village of Leuseni it narrows up to 5.2 km. The slopes are steep and very steep, concave (the left ones in many convex places), with a height of 100-140 m, at Toceni village - 180 m. Between the villages Poganesti and Sarata-Razesi on the left side there is strong erosive activity of the ravens. Landslides are observed every 3-4 km. The slopes are plowed or covered with steppe vegetation.

The riverbed is bilateral, up to the village of Poganesti, more expressed on the left bank, dammed, it shows, downstream more pronounced on the right bank, with some dammed sectors. Downstream of Sarata-Razesi village, in the meadow there are small lakes and swampy lands, on the coastal strip the forest is replaced by shrubs. The meadow consists of sandy clays and clayey sands.

The riverbed is very winding, without branches; at low water levels, muddy sandbanks appear every 2-5 km. The predominant width of the river is 50-70 m, 2 km downstream of the Sarata river outlet - 120 m. The depths vary from 0.7 to 7.3 m; 3-5 m predominates. The speed of the watercourse does not exceed 0, 6 m / s.

The banks are steep, with a height of 3-4 m, the mother rocks rarely appear in daylight, they are forested.

The bed of the riverbed is irregular, sandy and sandy-muddy.

**IV.** Stoianovca - confluence with the Danube river

The valley is a little winding, box-shaped, with a width of 5.0-8.5 km, towards the mouth of the river it widens up to 12 km. The slopes are concave, with a height of 80-120 m, steep and very steep, practically everywhere very dismembered by ravines and ravines, in the village of Brinza the left slope is almost vertical. The predominant right slope is plowed, the left one covered with steppe vegetation. Between Falciu and Rinzesti, on the right side, at Zirnesti village and town. Cahul on the left side, the terraces with a width of 1.0-1.5 km, with steep steps and a width of 6-12 m are well expressed. The slopes and terraces are predominantly made of clay rocks.

The meadow is bilateral, consecutive on both banks, with a width of 5-7 km. Downstream of Valeni village, it widens up to 8.2 km. In the sector between the villages of Stoianovca and Crihana Veche, Vadul-lui-Isac and Brinza on the left bank and Oancea and Sivita on the right bank, it is drained by drainage channels, dammed, it shows. In the rest of the sectors the meadow is swampy, with many lakes with a length of 1.0-2.5 km and a width of 0.5-1.0 km. The largest is Lake Brates located in the sector related to the mouth, on the territory of Romania; its length is 12 km, width - 7 km, maximum depth - 5.1 km, surface - 72 ha. The meadow consists of sandy clays and clayey sands.

The riverbed is winding, especially in the sector of Cucoara village - Slobozia-Prut village. Branch branches are not observed. It has a width of 60-80 m, maximum - 104 m, near the village of Crihana. The depths are 2-4 m, maximum 15 m (2 km upstream of Zirnesti village). The speed of the watercourse varies between 0.4-0.6 m / s, maximum - 1.0 m / s (s. Crihana).

The bed of the riverbed is sandy-muddy, irregular.

The banks of the river are very steep, even vertical, with a height of 1-2 m, in many places they merge with the slopes, they are forested.


Source: https://media.springernature.com/lw685/springer-static/

Figure 3: Evaluation and terrain of the Prut River Basin

### 1.2.4. Seasonal factors

The territory of the Prut River Basin is characterized by a temperate continental climate. In some years there are dry periods, which have a significant effect on the flow and hydrological regime of rivers of the Prut River Basin. The basic regularity of annual precipitation is their decrease with distance from the mountains.

There is an irregularity of rainfall in time. It so happens that one-month annual norm falls half, and on some day monthly rainfall. This defines the flood regime of the river and the formation of floods. In the Prut RB there are observations during 1990-2013 that showed a change in average monthly and average annual air temperature in comparison with the standard climatic norm. Over the past 24 years the average annual temperature has increased by 0,2-1,9 °C. The largest increase in air temperature was observed during the winter months (January, February). In the summer months (July, August) temperature has increased by an average of 0,7-1,9 °C.

In the long cycle for the years 1990-2019 the average long-term rainfall in the PRB compared to the standard, increased from 9 to 93 mm, except for the meteorological station Sireuti, where long-term average rainfall has decreased by 23 mm. The highest rainfall was recorded in 1998, 2001, 2007, 2008, 2010 (exceeding the norm ranged within 280-450 mm). It was formed the catastrophic floods during these years. Rainfall that exceeds the norm in most cases falls on the month of March, June, August and November. The "wet" years have also months of precipitation significantly lower than normal. This is usually for months April, May and August.

Ice phenomena – another seasonal factor- usually begin with ice on the shore, the fall of autumn ice lasting 3-6 days, often ice generally does not form. At ridges and rapids, for a period of 1-1.5 weeks, ice caps are kept, which contribute to the formation of bottom ice. The ice bridge is formed by increasing the ice surface on the shores, merging it, most often in late December - early January. The river often does not freeze, with only ice on the shore (winters from 1947-1948, 1654-1955, etc.). In the case of long-lasting monks, the succession of the ice bridge with the thawing of the river and the drainage of the rivers are observed, and in some years even the complete release of the ice river.

Duration of ice phenomena in the Ungheni and Leova are on average 40 days, maximum - 132 days (in winter 1908-1909); minimum - no ice.

The surface of the ice is predominantly smooth, due to frequent thaws - with an average thickness of 10-25 cm, maximum, reached at the end of February, 50-60 cm (winters from 1964-1965, 1953-1954). The clearing of the ice river takes place at the beginning of March and begins with the melting of the ice on the banks. Drainage of ice floes takes 1-3 days.

The average turbidity of the water – also a seasonal factor – increases in the direction of the river: in Yaremcea it is 180 g / m3, in Chernivtsi - 420 g / m3, in Ungheni - 750 g / m3. In 1969 with the highest leakage of suspended alluvium, the average annual turbidity in Chernivtsi was 3100 g / m3, in Corpaci - 1000 g / m3. Very high turbidity is observed during the passage of intensive rain floods. An example is the flood of June 1965, when the degree of saturation with suspended alluvium at Ungheni was 12,000 g / m3.

The river carries a maximum amount of suspended alluvium during high spring waters (45-50%) and summer floods (35-45%). In some years, the flow of alluvium in the summer can exceed that in the spring. Thus, at Yaremcea, in 1969, only in June the alluvial runoff constituted 94% of the annual amount. In dry years up to 70-80% of the annual alluvial runoff is formed in the spring-winter period. The number of days in the year with increased turbidity, as well as the concentration of suspended alluvium, increases from the source to the mouth of the river. In 1965 a turbidity higher than 500 g / m3 in the city of Yaremcea was maintained for 4 days, in Chernivtsi - 57 days, in Ungheni - 105 days, in Leova - 121 days.

### 1.3. Hydro construction

Within the Prut River Basin in the Republic of Moldova, there is only one Hydroelectric Power Station (HPS) located near the city of Costesti, 576 km away from the source of the Prut River. It was built on the Prut River in collaboration with Romania in 1978 and put into operation in 1979. Costesti-Stinca HPS was built to regulate the flow of floods and produce electricity, as well as to provide agriculture and industry with water resources. Electricity production is evenly distributed between the Republic of Moldova and Romania.

# 2. Navigation on the Prut River on the Giurgiulești-Ungheni segment

## 2.1. The history of river navigation

During the reign of Alexandru Ypsilanti in Moldova (1786-1788) there was talk of "the construction of a navigable canal that will pass through Iasi", with the intention that Siret be connected to the Prut for navigability. The idea was officially resumed in the Organic Regulations (1832). The chapter on the Roads provided for the navigability of some rivers in the Principality of Moldova, including the Prut and the Siret, including their union through the Bahlui River: “The Siret and the Prut ... needs to be cleaned and made more skillful for floating or making communication channels through the Bahlui river, which would also be very useful for the capital's trade”.

The set of hydro technical works of strategic importance in water management began to take shape in the second half of the 17$^{th}$ century. Political and economic problems have delayed their realization. Only in 1785 was a large-scale scheme designed to solve the problem of navigation between the Baltic Sea and the Black Sea by connecting the Vistula with the Dniester, through the Breast and an artificial canal with a length of about 6.4 km. Further through a set of works, the Dniester would be connected with the Prut.

In the Middle Ages, the Prut was permanently navigable, and after 1856 the activity of the Moldavian fleet intensified, but only from 1870 can we speak of an organized navigation. The Convention concluded in Bucharest, on 3 (15) December 1866, between the Governments of Austria, Romania and Russia, entitled "Stipulations on Navigation on the Prut", was the founding act of the Joint Commission of the Prut.

The Convention provided for the freedom of navigation on the Prut for ships under all flags and the obligation for them and their crews to comply with the rules of navigation established by the "stipulations". Article 7 provided for the establishment of a Standing Joint Commission, composed of delegates from Russia, Austria and the United Principalities.

In 1859, in the act of the Union, there was an article stipulating that in order to give up the position of the capital in Iasi “the navigable Prut will be made and it will be connected with Iasi, which will acquire the status of city porto-franco”.

In 1933, Professor Andreescu Cale presented a well-founded scheme - with solid technical and economic arguments - which, in addition to solving the navigability of the Prut, Bahlui and Bahluiet, proposed solutions for flood protection, water resources and capitalization of hydropower potential.

The first attempt to remove impediments for the river navigation took place only in 1968. It is important to mention that the initiative belonged to the Russians, who, after obtaining Romania's consent, began to clean the Prut riverbed over an appreciable distance, in two stages, first from the Danube to Ungheni, then upstream, to the Hydrotechnical Node from Costesti-Stinca. Also during that period, the Russians began research on the navigable potential of this river.

Everything was interrupted in 1973, when there was a large landslide on the left bank, more precisely at kilometer 337. The Bucharest authorities have been involved, since 1970, in their own hydro technical studies, concluding that the ships, even those with a capacity of 1,000 tons, could rise to almost the northeast of the country, until the accumulation from Costesti-Stinca.

If downstream only the maintenance of the riverbed was needed, by dredging, upstream locks should have been built, so that the vessels could cope with the difference in level between the various areas crossed by the river.

In 1977, the Romanians and the Russians agreed on the idea of restoring navigation on the Prut, and a Hydrotechnical Convention was signed between the two states. All sorts of studies and discussions followed, but by 1989 nothing concrete had been done.

Following the geopolitical changes that characterized the area, through a 1995 agreement, Bucharest was given the task of drafting a Convention between Romania and the Republic of Moldova. A project is also being made related to the organization of the future Prut Navigation Administration. Two research expeditions took place, in 1992 and 1993, to see the state of the riverbed. Two studies are recorded, the first in connection with "the possibility of reactivating Romanian naval transports on the Prut River", and the next on "the pre-feasibility of resuming navigation on the Prut". The latest study was approved by the Technical-Economic Council of the Ministry of Transport.

### 2.2. Legal aspects of cross-border cooperation

In general, aspects of cross-border cooperation are governed by Moldovan-European legislation, namely:

- REGULATION (EU) 2021/1060 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 24 June 2021 laying down common provisions on the European Regional Development Fund, the European Social Fund Plus, the Cohesion Fund, the Fair Transition Fund and the European Maritime Fund, Fisheries and aquaculture and the establishment of financial rules applicable to these funds, as well as the Asylum, Migration and Integration Fund, the Internal Security Fund and the Financial Support Instrument for Border Management and Visa Policy;
- REGULATION (EU) 2021/1058 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 24 June 2021 on the European Regional Development Fund and the Cohesion Fund;
- REGULATION (EU) 2021/1059 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 24 June 2021 on specific provisions for the European Territorial Cooperation (Interreg) objective supported by the European Regional Development Fund and the external financing instruments;
- REGULATION (EU) 2021/947 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 9 June 2021 establishing the Instrument for Neighborhood, Development Cooperation and International Cooperation - "Global Europe", amending and repealing Decision No 466/2014 / EU of the European Parliament and of the Council and repealing Regulation (EU) 2017/1601 of the European Parliament and of the Council and Regulation (EC, Euratom) No 1605/2002 480/2009 of the Council.

These also include aspects of cooperation for the development of the Prut river basin region. In a narrow sense, we refer to the EU's neighborhood policies, more specifically to the application of these policies by the Romanian side.

In terms of cross-border cooperation on the Prut River, it is interesting to discuss the possibilities for euro development in the regions including the Prut River. Here we should mention the collaborations with the Romanian side that cover quite large areas; in Romania - Botosani, Iasi, Vaslui, Galati counties, also the upstream Prut counties, and in the Republic of Moldova - the entire Prut river basin. The objective of cross-border cooperation in this regard is the following: Improving accessibility in regions, developing transport and common transport networks and systems with the main priority: Development of cross-border transport infrastructure and ICT infrastructure. This objective led to the formation of three Euro regions - "Lower Danube", "Upper Prut", as well as the Romanian Euro region "Siret-Prut-Nistru". Thus, over 70% of the territory and 60% of the population of the Republic of Moldova are part of the Euro regional framework of Moldovan-Romanian cooperation. For this reason, in the context of achieving the goal of integration into the European Union, for the Republic of Moldova the intensification of cross-border cooperation with Romania is beneficial and necessary.

Although the benefits of cross-border cooperation are well known, cross-border cooperation initiatives between the Republic of Moldova and Romania are still sporadic and are limited to individual and local initiatives rather than consistent policies. After almost 25 years of activity of the Moldovan-Romanian Euro regions (the Lower Danube Euro region was created on August 14, 1998) we can see that the evolutions of cross-border cooperation on this segment of the European border remain modest. Effective cooperation has been and remains permanently blocked by a lack of political will on the part of the central authorities on both sides of the Prut and a host of other objective and subjective factors.

The Upper Prut Euro region is an administrative structure for cross-border cooperation between Romania, the Republic of Moldova and Ukraine, materialized in the form of a Euro region. The current constituents of the "Upper Prut" Euro region are the Chernivtsi and Ivano-Frankivsk region of Ukraine, Botosani and Suceava counties in Romania, Balti municipality and Briceni, Edinet, Riscani, Glodeni, Falesti, Singerei, Donduseni, Ocnita districts of the Republic of Moldova.

The motive for its creation is both the interest of the European Union to get involved in its own border area, located in the vicinity of areas of instability, and that of the participating states. Thus, if the Romanian state is interested in institutionalizing support for a significant minority outside its own borders, the Ukrainian state is interested in recognizing the borders inherited from the Soviet Union and establishing gates for European integration, and the Moldovan one is interested in improving its security prospects, development and anchoring in an international cooperation mechanism. The Upper Prut Euro region, which has a role to play in promoting economic stability and preventing possible ethnic conflicts, differs from the Western European Euro regions. These differences are due to the emphasis on education, science and culture and in particular on the protection of national minorities across borders, as well as the creation of opportunities to help address ethnic issues in the area.

Following the agreement which laid the foundations of the Euro region on 22 September 2000, its development has led to the initiation of cultural and social exchanges as well as the implementation of cooperation projects on economic development, infrastructure and environmental protection. However, this development has not been without difficulties, controversy and syncope.

The difficulties were related to the sometimes ambiguous framework of the basic treaty between Romania and Ukraine, the economic situation of the component countries, the differences between the various national systems, the excessive administrative centralism, and the territorial architecture that included additional regions in order to avoid the predominance of a certain national specificity. In addition, the change in the character of the Romanian border into the eastern border of the European Union has increased the difficulty of creating an integrated system of cross-border space. Added to this were the controversies over the distribution of European money between states, as well as the different capacities to carry out cross-border cooperation projects or the lack of development of major projects.

For the time being, this Euro region is not a self-sustaining structure.

The aim of the "Siret-Prut-Dniester" Euro region Association is to expand and improve relations between communities and local authorities in the economic, educational, cultural, scientific and sports fields and to ensure a sustainable development of the region in the context of alignment with European standards.

The association also aims to respect, defend and guarantee the rights and interests of the territorial administrative unit members of the Siret - Prut - Dniester Euro region, being a non-governmental organization, with full structural, organizational and functional autonomy from any political and apolitical, governmental or non-governmental in the country or abroad.

The "Siret-Prut-Dniester" Euro Region Association has the following objectives:

- transforming borders from dividing lines instead of communicating between neighbors;
- overcoming mutual prejudices and divergences between people in the Euro region;
- overcoming psychological barriers through permanent information exchanges as premises of understanding and trust;
- consolidating democracy and developing territorial administrative units;
- overcoming the national peripheral position and isolation;
- stimulating economic growth and development and improving the standard of living;
- rapid assimilation and, respectively, an approach to the ideal of European integration;
- consulting, assistance and coordination of cross-border cooperation;
- the continuous improvement of the transport and communications infrastructure in and between the border regions, which lays the foundations for long-term cross-border cooperation and for new economic activities;
- diversification of activities in rural areas to prevent population migration and increase the number of commuters across the border;
- qualitative improvement of human resources;
- development of strategic cross-border agricultural marketing concepts, waste recycling, tourism and regional development;
- adopting cross-border urban and rural development policies;
- preservation of cultural heritage;
- solving everyday border problems and creating new crossing points.

Members of the Siret-Prut-Dniester Euro Region Association: Iasi, Prahova and Vaslui counties in Romania, Anenii Noi, Basarabeasca, Calarasi, Causeni, Cimislia, Criuleni, Drochia, Dubasari, Falesti, Floresti, Glodeni, Hincesti, Orhei, Rezina, Riscani, Soroca, Straseni, Soldanesti, Stefan Voda, Telenesti, Ungheni and Balti, Moldova.

The Lower Danube Euro Region Cross-Border Cooperation Association has as founding members Galati County Council, Tulcea Council and Braila County Council in Romania, Cahul District Council and Cantemir District Council in Moldova, Odessa Regional Council, Odessa Regional State Administration and Reni District Council from Ukraine.

The Lower Danube Euro Region operates under the Convention signed on August 14, 1998. It represents a partnership between Romania, through Tulcea, Braila and Galati counties, the Republic of Moldova, through the districts of Cahul and Cantemir and Ukraine, through the Odessa Regional Council.

Conceptual notes on the financing of projects within the Romania-Ukraine and Romania-Moldova Cross-Border Cooperation Program were submitted within this Cooperation Association. The members of this Euro region will also work together to implement projects funded under the Black Sea Cross-Border Cooperation Program.

In the past in terms of cross-border cooperation, the Moldovan authorities have included the Prut River in the following agreements and programs:

- AGREEMENT between the Government of the Republic of Moldova and the Government of Romania on cooperation for the protection and sustainable use of Prut and Danube waters;
- PROTOCOL of the 3rd meeting of the group of experts from the Republic of Moldova and Ukraine on the issues of protection and use of living aquatic resources in border watersheds;
- JOINT OPERATIONAL PROGRAM of the Black Sea 2007-2013;
- JOINT ROMANIA-UKRAINE-MOLDOVA OPERATIONAL PROGRAM. The Romania-Ukraine-Moldova Joint Operational Program was one of the European Union's ENPI financing instruments, which was to be implemented at the external borders of the enlarged Europe in the period 2007-2013.

### 2.3. Current navigation situation

Republic of Moldova has two free flow inland waterways (rivers Nistru and Prut) which are in accordance with the European Agreement on main domestic shipping routes of international importance, done at Geneva on 19 January 1996 (Decision Parliament nr.1431/24.12.97 ratifying the European Agreement on main domestic shipping routes of international importance, Official Gazette 5/17, 01.22.1998), classified as routes of international importance.

I. E 80-07 - River Prut, the estuary up to Ungheni (407.0 km);

**II.** E 90-03 - Dniester River from Belgorod-Dnestrovsk port (Ukraine) to the port of Bender (228 km).

In 2005, in the agreement was concluded between Moldova and Romania on navigation on inland waterways of the Republic of Moldova and Romania. In 2006 bilateral agreement was concluded between the Government and the Cabinet of Ministers of Ukraine on navigation on inland waterways of Moldova and Ukraine, which allows Moldovan economic agents operating ships, to exploit the inland waterways of Ukraine and Romania.

Inland waterways of the Republic of Moldova is possible to transport goods through gaskets made of pusher craft and barges to load capacity to 600 tons on the river Prut.

Giurgiulesti Port Complex development creates prerequisites for the development of his part of the Prut river, which is a tributary of the Danube, for the transportation of goods transshipped from ships into the river, and goods transported directly through the inland waterway transport.

Given available to the Government for rehabilitation works of inland waterways of the Republic of Moldova and Moldova's internal needs (making construction and rehabilitation of national roads) was necessary use the Prut for transportation via inland waterway transport, directly in Romania in the first stage of dragging until Cahul. Prut use for direct transportation via inland waterway transport is due to the fact that domestic shipping is the most economical advantageous and environmentally gentle.

In order to restore navigation on the river Prut (the first stage up to Cahul) no major investments are needed. At the moment Giurgiulesti - Cahul are five thresholds that need to be removed. The estimated cost of these works is - 5.00 million lei. Material extracted from specified thresholds can be used in construction; mines FAP will cost to maintain the navigable channel. Also use Prut for transporting goods from port Giurgiulesti will wear demine roads and will save some funds for repairing and maintaining roads considerable. Fairway maintenance will flood risk to communities and agricultural land adjacent rivers, diminishing damage compensation costs incurred by the state budget (about 500 million USD for 2008 and 2010).

Noted that in areas adjacent Prut existing infrastructure works allows loading / unloading without making any investment. Given the above, low cost investment in inland waterways restoration, fairway maintenance, repair current low cost means for performing floating and transporting cargo and expenditure compared to investments in infrastructure and other transport equipment show attractiveness and the need to develop inland waterway transport.

Navigation on the Prut River was resumed in June 2012 on the Cahul Giurgiulesti section, when a barge with 600 tons of gravel reached Cahul from the port of Constanta. In 2012, the Ungheni river port invested about 800 thousand lei to clean the Prut riverbed on the Cahul - Cantemir segment over a distance of 70 km. The port of Giurgiulesti has the capacity to receive ships with a length of up to 120 meters. The area has, among others, an oil terminal, another for cereals, but also spaces for passenger ships.

## 2.4. Infrastructure for river navigation

### 2.4.1. Ports

The navigational system of the Republic of Moldova includes 2 ports of international importance:

I. P 80-62 - Giurgiulesti port (133 km) as the port complex under construction on the Danube;

II. P 90 - 03 - 02 - port Bender (228.0 km) on the river Nistru.

Another port on the Prut river, but still of local importance is Ungheni River Port, and is specialized in freight/goods transportation in vessels up to 600 tones capacity.

In the last 15 years, there has been a significant increase in economic and naval infrastructure in the Giurgiulesti Port Complex, located in the extreme south of the Republic of Moldova. The Giurgiulesti port complex is the only port in Moldova that offers direct access to international waterways and the Black Sea, which serves as a favorable point for entry and exit of goods into/from Moldova. Located less than a kilometer from the border with Romania/EU and the border with Ukraine, the port of Giurgiulesti is located at the crossroads of several international trade routes between EU countries and Eastern European states, states in the Baltic Sea and Black Sea region. The distance from Giurgiulesti to Chisinau is 223 km, to Galati - 10 km, Bucharest - 247 km, Lviv - 776 km, Kiev - 686 km, Minsk - 1,238 and Moscow - 1,532 km. At the regional level, the Port of Giurgiulesti is positioned as a logistics center on the border with the European Union, with access to car, rail, river and maritime communication routes.

### 2.4.2. Mooring

On the Prut River, with the exception of the ports indicated above, there are undeveloped quays located upstream of the Giurgiulesti port complex and at Leova. These quays are without capital engineering constructions. The Naval Agency of the Republic of Moldova actually calls them temporary quays. The quays on Prut can serve as moorings for cargo ships.

### 2.4.3. Bridges

Today, on Prut there are nine bridges, of which six are roads: Lipcani-Radauti Prut; Costesti-Stinca; Sculeni-Sculeni; Leuseni-Albita; Cahul-Oancea; Giurgiulesti-Galati; and three railways: Ungheni-Iasi; Stoianovca-Falciu and Giurgiulesti-Galati. However, no train has been running at Stoianovca-Falciu for more than four years.

### 2.4.4. Problematic places

Inland waterway transport is often hampered by the presence of problematic places. These problematic places can be formed by: bridges; fairway; locks; missing links on the river. Bridges and fairway may cause impediments for navigation on the Prut River. Thus, the bridges built downstream of Ungheni which falls into this category of impediments are at: Leuseni-Albita; Cahul-Oancea; Giurgiulesti-Galati; Stoianovca-Falciu and Giurgiulesti-Galati. The ones from Giurgiulesti are not problematic, because they are already sailing there. The others can be problematic if the navigable channel after digging and cleaning will allow the access of ships with a tonnage of over 600 tons or with bigger dimensions. So bridges at the moment are not a major problem for river navigation on the Prut. But the Prut's waterway is a problem, because the depth, the width of the river in places where the Prut has narrow bends or river meanders do not allow the navigation of heavy or big sized barges. Such places where the meanders constitute potential problems for navigation we can see near Ungheni, Macaresti, Barboieni, Balauresti, Leuseni, Poganesti, Sarata Razesi, Leova. In the listed places another problem other than small angle meanders are the small width of the river. These problematic places limit the dimensions and loading capacities of ships, so it is required a careful selection of the ships that will be allowed to navigate.

## 2.5. Prospects for the development of navigation on the Prut River

Speaking about the prospects for the development of navigation on the Prut, we mention the complex process of cooperation between the Republic of Moldova and Romania regarding the sustainable use of aquatic resources on the Prut and the Danube.

The Republic of Moldova and Romania continue to cooperate on the sustainable use of water resources in the Prut and Danube. Thus, the Governments of both parties are continuously updating the policies and instruments regarding the implementation of the Moldovan-Romanian Agreement on cooperation for the protection and sustainable use of the Prut and Danube waters. The document was signed in Chisinau in 2010.

The purpose of updating the policies in the field is determined by the need for the protection and sustainable use of water resources, the operation of the Costesti-Stinca Hydro Technical Node on the Prut River, as well as the application of other provisions of the Agreement.

The new sessions of the Intergovernmental Hydro Technical Commission on the territory of the Republic of Moldova will also be initiated.

Another Moldovan-Romanian agreement that would affect the use of the Prut River is the Agreement between the Government of the Republic of Moldova and the Government of Romania on technical, financial, legal and organizational issues regarding the consolidation of the border road bridge between the two states, over the Prut River between Giurgiulesti (Republic of Moldova) and Galati (Romania), signed in Chisinau on February 11, 2022. A new round of negotiations and discussions that took place in December 2021, contributed to the final form of this agreement.

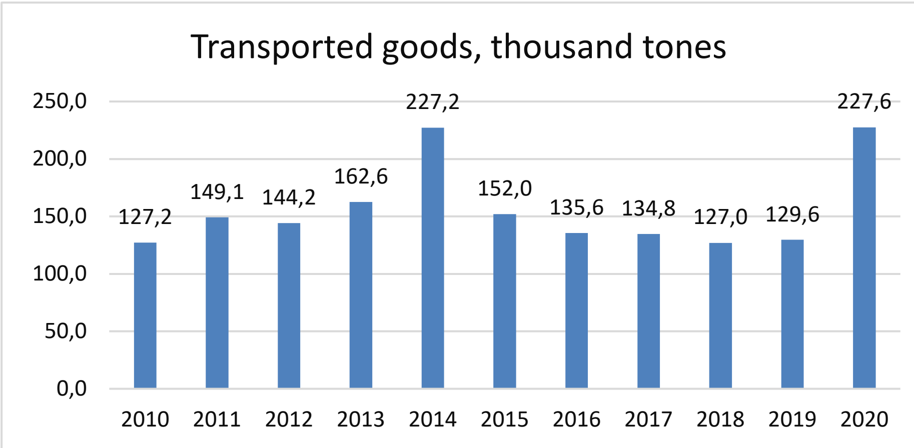
The purpose of the Agreement is to ensure the consolidation of the border road bridge, which will interconnect the road infrastructure between the two states on the alignment of the following roads: on the territory of the Republic of Moldova the national road M3 Chisinau - Comrat - Giurgiulesti - Romanian border and on Romania, DN2B. The draft Agreement includes regulations on the signatory parts of the Agreement, definitions, type of consolidation works, traffic flow measures, environmental protection, the establishment of a Joint Commission to coordinate all activities related to the consolidation of the objective, its entry into force, its amendment and its termination. The level of the Agreement is intergovernmental.

### 2.5.1. Evaluation of transport structure and volumes

The structure of inland waterway transport is characterized by low descriptive parameters. Bulk construction materials such as gravel, pebbles, sand are most often transported on inland waterways. Another category of transported goods are cereals that are grown in the country and intended for export through the port of Giurgiulesti or for storage in other places than where they are grown.

The volume of goods transported by inland waterways is represented in the figure below (figure 4).

The information presented contains data on domestic shipping throughout the country. From the analyzed data we see an increase in 2020 of the volume of transported goods, which proves that the internal naval transport acquires a certain popularity among the economic agents.

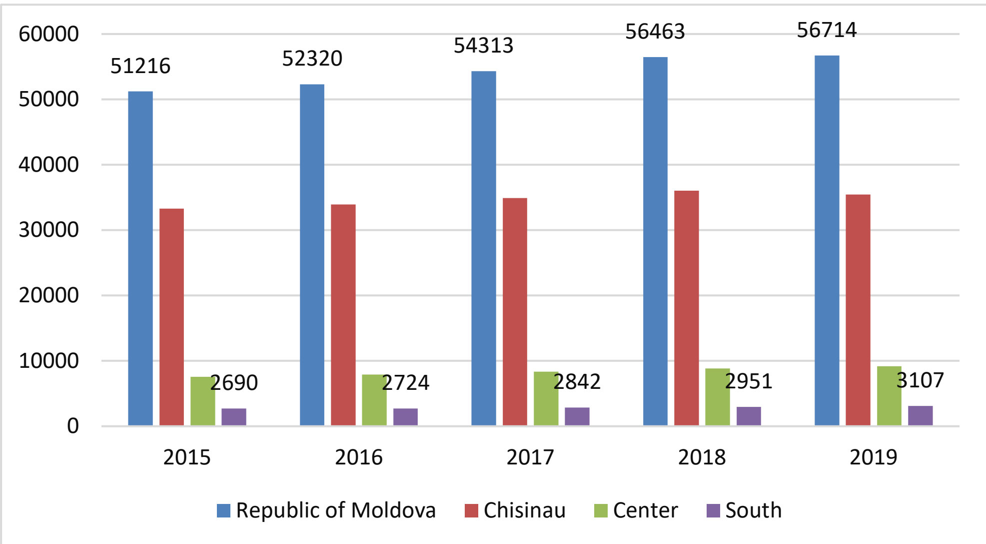



Source: adopted data from https://statbank.statistica.md/

Figure 4: The evolution of freight transport by inland waterways

### 2.5.2. Evaluation of shippers and consignees

Currently, the shippers and consignees of goods transported on the Prut River include a small number of local and foreign economic agents, so it is advisable to study potential customers of river transport services on the Prut.

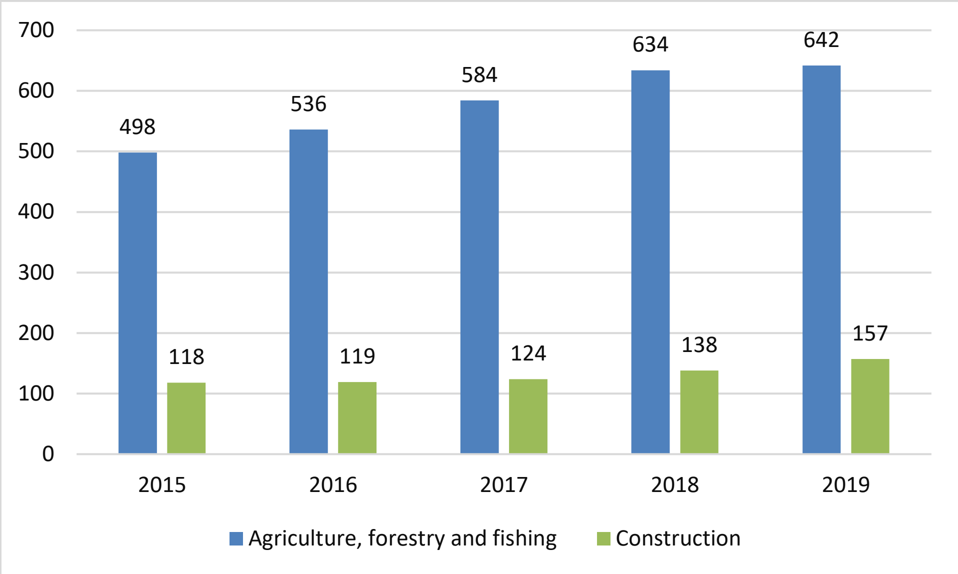



Source: adopted data from https://statbank.statistica.md/

Figure 5: Comparison of the total number of enterprises by regions of interest (2015-2019)

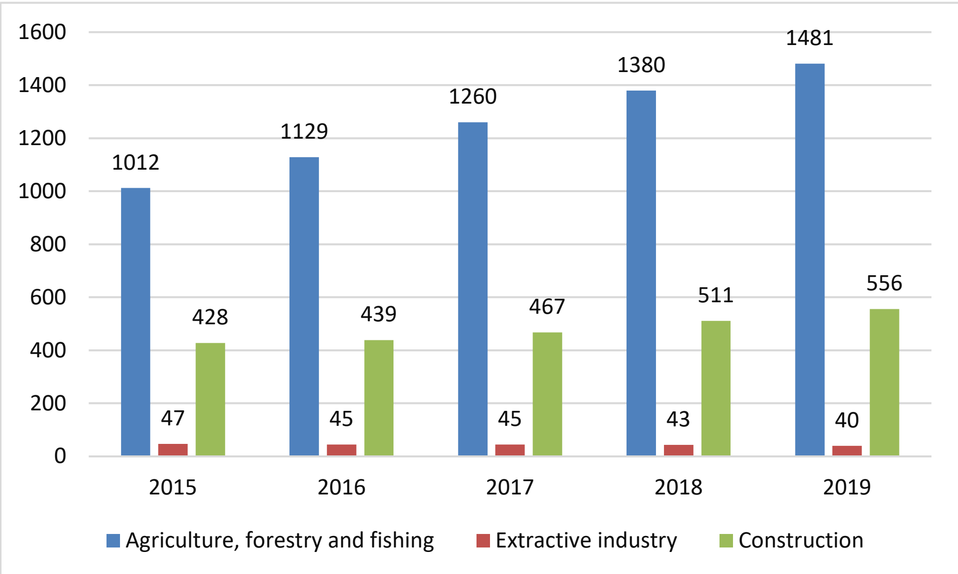
Thus, the comparative study by country and by region of the total number of economic agents becomes interesting (figure 5), after which we will indicate the data regarding the number of enterprises on economic activities related to Prut navigation activities and carrying out their activity either in the southern region, or in the center of the country (figure 6, figure 7).

The fields of activity of interest in the present study are: agriculture, constructions and extractive industry.




Source: adopted data from https://statbank.statistica.md/

Figure 6: Comparison of the total number of enterprises by fields of activity in southern region of the Republic of Moldova (2015-2019)




Source: adopted data from https://statbank.statistica.md/

Figure 7: Comparison of the total number of enterprises by fields of activity in center region of the Republic of Moldova (2015-2019)

As we can see from the information presented, the southern region has a small number of economic agents compared to the central region. So measures will be needed to attract not only businesses in the south, but also to work with those in the center. Also in Figure 6 we did not indicate the enterprises in the extractive industry, as their number varies from 1 to 3, which is irrelevant. We must also note that the local economic agents in the region have a modest purchasing power, which should also lead us to foreign economic agents that have trade relations with the southern or central region of the country.

### 2.5.3. Characteristic of river transport service operators

The main carrier (and the only one nowadays) on the Prut River is the State Enterprise PORTUL FLUVIAL UNGHENI, which was founded in 1993. The founder of the company is the PUBLIC PROPERTY AGENCY. The company operates activities related to Ungheni River Port and Giurgiulesti Port. This undertaking provides freight transport services between the shippers and the consignees of the goods. The clients of the enterprise are the construction enterprises from the region, the enterprises dealing with the trade of construction materials, enterprises dealing with the cultivation and marketing of cereals from the southern part of the Republic of Moldova.

The company registers from 2018 losses in the balance sheets, in 2017 registering a profit of about 45 thousand lei (Financial Statements of the enterprise published on the website of the Public Property Agency http://www.app.gov.md/intreprinderi-de- stat-3-378). That is why it is necessary to implement strategies to attract and create a group of stable customers that would bring income to the company. The target group of customers to focus marketing policies could be those identified in the previous chapter.

If another river transport service operator appears on the Prut River, they have all the chances to occupy or attract a larger number of customers given the same marketing policy focused on creating a loyal customer base.

### 2.5.4. Projects for the development of navigation on the Prut River

Inland river transport is a ubiquitous component of economic development and environmental protection strategies developed and implemented by the ministries of resort of the Republic of Moldova. It is also present in strategies for integrating national policies into the European spectrum of environmental or socio-economic policies.

In the Second National Communication of the Republic of Moldova prepared by the Ministry of Ecology and Natural Resources under the United Nations Convention on Climate Change from 2009 one of the objectives is to identify and implement measures to attenuate greenhouse gas emissions. In this sense, inland river transport comes as a solution in the country's transport sector. Thus, this document proposes the rearrangement of internal waterways and the improvement of their operating parameters. One of the results of this communication was the elaboration of the Prut River Basin Management Plan which refers to the permanent monitoring works of the Prut River Basin, with emphasis on the water quality of the Prut River, the possibilities of navigation and their ecological impact.

We must mention that most of the European projects involving the Prut River and its basin, aimed at knowing the ecological impact of economic activities on the river water and less the development of navigation on the Prut. It did not become a special priority until after 2008.

Previously, the efforts of the country's leading authorities regarding the renewal of navigation on the Prut were outlined in Decision no. 453 of 24.03.2008 regarding the approval of the Concept of the development of naval transport in the Republic of Moldova. This concept aims to develop river transport on the Prut from the south of the country to Ungheni.

## 2.6. Technical characteristics of the Prut River

Based on the performed study on the Prut River, can be formulated the following characteristics regarding the technical aspect in the table below.

Table 4: Prut River characteristics

| Characteristics | Upper course | Middle course | Lower course |
|---|---|---|---|
| River channel | The river starts in the Carpathians mountains and has a narrow channel and a small depth. | It has a broad valley, which is between the upper and the middle course's shape. | The river has wide channel at the mouth of the Danube, which is also deep about 6-8 m. |
| Force/strength and speed of the water | The water is slow, as there is low force is it. | The current is fast, but the land is not as steep so it is slower and has less force downwards, but more horizontal. | The current goes slowly as the amount of water is greater and the force in it is greater too. |
| Amount of water | There is little water as it only comes from the source of the river. | There is more water than in the upper course as there tributaries which give water to the river. | There is a lot of water as more tributaries have joined, but some of the water might have been used for irrigation. |
| Amount of sediment in the water | There is little sediment as the river has not picked up much sediment in this area. | The river starts to get sediment from the banks, which makes erosion and deposition by and of these happen. | There is a certain amount of sediment, which is left behind forming dams, they were cleaned after drainage works. |
| Shape of the river | The shape of the river is approximately linear with some meanders near the middle course. | The river changes its course a lot because of the meanders on its way. | The river has many meanders as it has little force to erode its way downwards. |

Characteristics of the Prut river would help us to choose technical parameters for the inland water transportation. Here we decide the dimension of the vessels and the structure of the fleet.

Before determining the dimensions of pushed and towed river trains we must delimit the possible cases of the realization of the internal water transport. There are two basic possibilities in the case of the Prut River - intermodal transport when the cargo unit is transshipped from one means of transport to another and multimodal or single transport with the actual transshipment of goods from one means of transport to another, or moving gods from quays to the ship.

The first way is most often done with the use of containers as loading units.

The second way is efficient in the case of transporting construction materials, grain, goods that are currently transported on the Prut, or generalized palletized or packaged goods.

In inland transport there are several different loading units whose dimensions and other typical characteristics differ in dependence to the kind of loading units for which they are constructed. This is why an integration of IWT is not a simple decision of just changing a mode within a transport chain. There have to be some prerequisites of changing a single transport into an intermodal transport.

Intermodal transport with IWT, which is the first way indicated below, competes with single road transport. Suitable loading units therefore have to be harmonized with road trailers, they should have the same dimensions to get the maximum of pallets in it, as this is the efficiency criterion in here. But they also must be stackable and need metal fittings for top lifting. According to experts, the 45 feet pallet-wide containers that are also used in short sea shipping are adequate to fulfil these prerequisites.

To involve IWT in logistic chains there are also concepts to carry trailers and swap bodies on barges. In some cases, for example in combination with container transport, this may be an added value to shippers if vessels do not have maximum load. But normally a carriage of those boxes would be far from cost-covering as trailers and swap bodies are neither stackable nor do they have the right dimensions with regard to the optimal use of vessel capacity. Also some questions arise of standardization and the implementation of a new generation of trailers and swap bodies in inland transport; such questions strongly depend on broad acceptance by shippers, forwarders and logistic providers.

To conclude, intermodal transport with IWT first of all needs intermodal loading units that are suitable to this mode. That means a choice of intermodal transport must precede a decision upon the relevant transport mode(s) on the part of the shipper or the forwarder.

Another question is how regular would be the transportation in future, whether or not it will have a transportation schedule. There are several examples of scheduled services in IWT which show that this could be an efficient market sector if certain conditions are respected on the quantity of goods transported. Different load factors in upstream and downstream operations must not always be a precondition, as transport on the Rhine clearly demonstrates: Two thirds of tonnage moves upstream whereas only one third moves downstream.

## 2.7. Maximum dimensions and structures of pushed and towed river trains

The technical and organizational parameters of the ships in operation are decisive factors concerning the competitiveness of inland water transportation. They refer to both intermodal and single transport competition. Above all, competitiveness is determined by the costs, which are influenced by various parameters like those listed in the following:

- size and ship's capacity utilization ratio;
- draught or draught restrictions, respectively;
- ship technology, equipment, age and condition of the ship;
- flag, i.e. registration of the ship;
- operator structure (independent ship owner or shipping line);
- operation modus, e.g. operation time of 14-, 18- or 24 hours;
- crew structure (number, qualification and nationality of the crewmembers).

There exist a variety of classification methods for floating objects used in inland navigation.

Among others the most distinctive are:

1. According to the area of navigation:

- River (canal) ships;
- River-sea vessels (sea-going vessels properly equipped also for the operation in inland waterways);
- Lakers (vessels designed and built to cope with specific conditions on the lake where they operate).

2. According to the dedicated purpose:

- Commercial vessels including:
- ✓ Cargo ships;
- ✓ Passenger ships for daily excursions or for cruising (equipped with cabins);
- Technical floating objects (push boats, tugs, dredgers, floating cranes, floating docks, workboats etc.);
- Pleasure crafts (motor or sailing yachts and boats, water bikes, wind surfing-boards etc.);
- Special ships (police, customs, survey, fire-fighting ships, icebreakers, military vessels, supply ships etc.).

3. According to the installed machinery (self-propelled and non-self-propelled vessels);

4. According to the kind of propulsion;

5. According to the floating regime when running;

6. According to the hull configuration (conventional monohulls, twin-hulls, trimarans).

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However, there exist plenty of other classifications based as for example on: material of the hull, structural and hydrodynamic particulars, type of the prime mover (engine), kind of commodity to be transported or type of service to be provided.

The classification used here is adopted on the base of the purposes assigned to the vessels, and thereby the most attention was paid to river cargo vessels and barges.

Self-propelled river ships

The majority of inland navigation ship types are standardized in their main dimensions (however within certain tolerances). The lists and basic considerations on most typical sizes for self-propelled cargo ships and pushed barges including approximate tonnage capacities are given beneath. These vessel types/sizes have had peculiar developments within the politically and on many spots also physically divided network. Since the end of the cold war and especially after the opening of the Main-Danube Canal and the Danube confluence (South-East Corridor) joining the integrated European waterway network a number of these vessels have free access to other corridors too.

The variety of vessel sizes is caused by both the market requirements and the area of navigation. Larger shipment sizes, stable markets and favorable nautical conditions along the route – in inland navigation that practically means wide and deep rivers and canals with high bridges – set up general prerequisites for the operation of larger ships. But on the other side, larger ships cannot operate on smaller waterways if draught, width or air draft restrictions are excelled. That leaves an opportunity and need for a reasonable share of also smaller vessels in the fleet (Source: Prospects of Inland Navigation within the Enlarged Europe).

In Europe, there are around 10,000 inland vessels in Rhine countries, and more than 3,000 vessels in Danube countries. In Rhine countries, 72% of all vessels are dry cargo vessels (self-propelled units or dumb barges). Tanker vessels account for 15% and push & tug boats for 13%. 75.4% of all 3,214 vessels in the Danube fleet are dry cargo vessels (self- & no propelled). 18.3% are push or tug boats and 6.3% are liquid cargo vessels (self- & non-propelled). The total loading capacity of the Danube fleet amounts to 3.4 million tons, of which 93% is dry cargo tonnage and only 7% liquid cargo tonnage.

Table 5: Standard sizes of self-propelled river ships in Europe

| Vessel type | Dimensions (LxB) | Tonnage capacity at a draught of | | | | |
|---|---|---|---|---|---|---|
| | | 1,50m | 2,00m | 2,50m | 2,80m | 3,50m |
| Large river motor ship | 110,00m x 11,40m | 600 t | 1200 t | 1800 t | 2100 t | 3000 t |
| Europe ship | 85,00m x 9,50m | 570 t | 930 t | 1350 t | | |
| Johann Welker | 80,00m x 8,20m | 600 t | 940 t | 1280 t | | |
| Gustav Koenig's (extended) | 80,00m x 8,20m | 500 t | 800 t | 1100 t | | |
| Gustav Koenig's | 67,00m x 8,20m | 420 t | 670 t | 1000 t | | |
| Kempner | 50,00m x 6,60m | 400 t | 600 t | 650 t | | |

| Vessel type | Dimensions (LxB) | Tonnage capacity at a draught of | | | | |
|---|---|---|---|---|---|---|
| | | 1,50m | 2,00m | 2,50m | 2,80m | 3,50m |
| Peniche | 38,50m x 5,00m | 250 t | 300 t | 400 t | | |
| BM-500 | 56,50m x 7,60m | 415 t | 475 t | | | |

Source: Prospects of Inland Navigation within the Enlarged Europe

There is another crucial aspect: the utilization of carrying capacity of the fleet. The shipment size might not always be equal to the maximal carrying capacity of the ship at her draught allowed on the given circumstances, for example under actual nautical conditions along the route.

**Pushed barges**

The different barge size standards were developed in particular navigation areas matching the usual nautical conditions. The most common European barge measures 251 by 37 feet (76.5 m × 11.4 m) and can carry up to about 2,450 tons (2,700 short tons). The most frequently used barge is the "Europe-barge-class type IIa". There are other longer and shorter barges available that have been adjusted in their dimensions, according to their designated navigation area and waterway requirements. An overview is provided in the following table:

Table 6: Standard sizes of pushed barges in Europe

| Barge type | Dimensions (LxB), m | Tonnage capacity at a draught of | | | | Area of use |
|---|---|---|---|---|---|---|
| | | 2,00 m | 2,50 m | 2,80 m | 4,00 m | River or corridor |
| Europe Type I | 70,00x9,50 | 940 t | 1240 t | | | Rhine, MLK |
| Europe Type II | 76,50x11,40 | 1250 t | 1660 t | 1850 t | | Rhine, MLK, Danube |
| Europe Type IIa | 76,50x11,40 | 1140 t | 1530 t | 1800 t | 2800 t | Rhine |
| Europe Type IIb | 76,50x11,00 | 1100 t | 1500 t | | | Danube |
| GSP-54 | 54,00x11,00 | 900 t | | | | Elbe, Oder |
| SP-65 | 65,00x8,20 | 900 t | | | | Elbe, Oder |
| SP-35 | 32,50x8,20 | 415 t | | | | Elbe, Oder |
| LASH | 18,70x9,50 | 250 t | 335 t | 385 t | | Weser, Rhine |
| See-Bee | 29,75x10,70 | 490 t | 640 t | 730 t | | Weser, Rhine |
| Interlocutor | 38,25x11,40 | 585 t | 775 t | 900 t | | Danube |
| OBP-500 | 45,50x9,60 | 480 t | | | | Oder |

Source: Prospects of Inland Navigation within the Enlarged Europe

**Pushed tow systems**

The possibility to transport big capacities by interlinking barges is also used in combination with self propelled motor vessels of same or similar size. In this case the merits of the self-propelled motor vessel are combined with those of the pushed tow system.

The engine power of modern motor vessels (up to 1.99 kW) and their navigational and technical equipment allows for up to three additional Europe barges, which increases the loading capacity to as far as 10,000 t.

Here too the advantage lies in the possibility to individually control the capacity, depending on demand and relation, which would not be possible in that manner with single, self-propelled motor vessels:

- Mostly vessel and barge types for waterways of class IV and V are used in pushed tow systems;
- Self-propelled motor vessels used in pushed two systems usually have higher engine power and a specific bow form for the coupling of the barges;
- An interlinked coupling in a linear manner is just as possible, as parallel coupling (interconnected through simple rope connections). It is only subject to fairway conditions;
- It was mentioned repeatedly as a disadvantage of the pushed tow system that it is not possible to handle cargo of the self-propelled unit and the barge parallel, although desired due to the lack of time;
- Maintenance work can only be organized acceptably efficient.

Based on the information collected, it is possible to select those types of river vessels that fit the parameters of the Prut River.

## 3. Maintenance of the Prut fairway on the Giurgiulesti-Ungheni segment.

### 3.1. Requirements for navigation and handling

Waterways have always provided an avenue for transportation, communication, agricultural development and trade. This is the reason for what navigation of rivers to transport people and goods precedes historical record. However, within the last few centuries, navigation structures have significantly augmented the ability of industry to transport goods to and from inland ports. In many cases, improvements in river navigation have provided an economical method of transporting large quantities of grain, petroleum, coal, metals and ores, fertilizers and chemicals, forest products, and other cargo, but the improvements have not come without a cost. Or, this is the main purpose of our project – to increase and to assure the intensification of the navigation on Prut river up to Ungheni. For a continuous and efficient navigation on Prut river up to Ungheni it is necessary to increase river depths, eliminate meandering, and reduce water velocities in river bedside and on river problematic places. These structures are often expensive in monetary, societal and environmental costs, as we will describe in the 5$^{th}$ module of this paper.

In some cases, the necessary navigation structures require navigation dams or multipurpose dams. Navigation dams form a deep, low velocity reservoir in locations where passage was once impractical because the river was too shallow or currents were too swift or we have problematic places. Multipurpose dams are often used to provide a steady supply of water in times when flows would normally be low, what is happening on Prut river as well. The steady supply allows navigation downstream of the dam that would otherwise be impossible during low flow periods. If a multipurpose dam can be circumnavigated by barge tows, the reservoir behind the dam aids navigation in the same way as the reservoir behind a navigation dam. Although both types of dams assist inland navigation, the dams may be associated with a variety of problems. Sediment laden rivers may deposit large quantities of sand in reservoirs, and severe erosion may occur downstream of the dam. Reservoirs formed behind the dam offer recreational opportunities, this means we can use them for navigation when the river water level do not permit the normal navigation, or when there are some works for cleaning sediments from riverbed. Larger reservoirs sometimes inundate vast areas of agricultural land and populated areas. Finally, the dams may cause habitat loss, or restrict passage of migratory fish.

While dams often help reduce the risk of flooding, other structures may increase flood risks. In some locations, dikes are installed to increase river depths. During floods, the dikes continue to restrict flow in the river, causing higher river stages. Navigation structures also influence where sediment is eroded and deposited. Sedimentation always occurs in areas of low water velocities and low turbulence such as in reservoirs, backwater areas, and behind dikes. Erosion occurs where water velocities are high such as in channel cut-offs, or where natural sediment loads have been altered such as downstream of dams.

There is almost always an environmental cost when the natural flow of a river is changed; the cost may come in the form of erosion, sedimentation, introduction and propagation of exotic species, or loss of habitat. With careful planning and wise decisions, environmental costs can often be reduced. Dam releases can simulate natural flows in times when excess water is available, the size and location of dams can be chosen to limit habitat loss, and measures can be taken to prevent the introduction and spread of exotic species. Furthermore, placement of navigation structures and vessel operation procedures can be modified to reduce unwanted sedimentation and erosion.

These structure can help to ensure a continuous navigation on Prut river up to Ungheni but we propose that they should be built only in the problematic places on the river, the ones indicated above in 2nd section, and in the places where the water level drops more often below the navigation level, so we will reduce the negative impact on the environment.

Also in order to minimize not only the impact on environment but financial costs too, using right capacity and dimension vessels on Prut river it would be an effective decision. This in turn requires the optimal selection of the fleet for navigation, so domestic shipping operators should also know the requirements for the fleet used before they begin the transportation process, also customers and freight forwarders could form optimal consignments of goods to be transported a well-established work plan.

### 3.2. The concept of organizing river transport on the Prut River

Before setting down on paper an efficient plan for increasing and improving the existent intern navigation of goods on Prut river, we must summarize the main issues to be taken into account:

- The share of cargo currently is very small as compared to whole Danube river trade.
- There are serious navigable constraints owing to sedimentation and river courses, namely where we have meanders.
- There are not enough vessels and operators for such routes from Republic of Moldova.
- There is serious lack of storage facility around the waterways.
- Environmental and social protections are the key factors that need to be addressed in the waterways.
- There are serious concerns of institutional set up along the waterways.
- Private sector participation in the developmental plans is still not forthcoming.
- Cargo operator transit arrangement has not yet been standardized.
- Investment loans are not forthcoming.
- Integrated development is not a visionary thrust area for private economical sector.

In order for the project to work, certain requirements and procedures need to be specified in detail. First of all, after setting down the scenario for the works that need to be done, it is necessary to inspect physically all problematic places and to reset the parameters of the work plan according to reality. We propose below a work plan to ensure continuous navigability on the Prut River from Giurgiulesti to Ungheni.

Table 7: Work steps for maintaining navigation on the Prut River

| Activity | Responsible part | Terms |
|---|---|---|
| Inspection of all problematic places on the river, namely: | | |
| Measuring the water level, the depth, thickness of the bedrock, the width of the river in problem areas; | | |
| Periodic monitoring of the water level in the river before carrying out the excavation works; | | |
| Identification of the narrowest meanders on the river for starting the construction of dams, barrages, doing excavations works in the riverbed. | | |
| Contracting of economic agents to deal with excavation and dredging works; | | |
| Identification and preparation of the land necessary for the storage of sediments excavated from the river; | | |
| Dredging works | | |
| Periodic inspection of the river, especially after torrential rains and floods in the area to detect problems, remove them, thus ensuring better navigation on the river. | | |

Source: designed by the author

Before starting the project with the works submitted above, we must identify the persons who will perform the observations, measurements, identify and establish contracts with economic agents. It is recommended that individuals have access to a common database during observations and measurements to facilitate the selection and processing of data. Excel tables can be used indicating the days on which the measurements were made, the persons responsible and the place where the appropriate measurements were taken. After the accumulation of data, it would be good to initially contract a structure, an economic agent in the field of geodesy to deal with the elaboration of the excavation project, later the construction of dams, or canals.

The arguments proving the necessity of increasing and improving the navigation on Prut river are as follows:

- It can be a supporting role for road and rail transport.
- It is far more cost effective per kilometer of travel.
- It is highly efficient in energy consumption per ton load carried.
- Load capacity can be doubled by small increase in depths by dredging.

- Considerable flexibility in ageing transportation and cost elasticity.
- Inherently low human cost.
- Reduce sediment problem along the Prut river.
- The deposition of material from dredging can be viewed simply as a relocation of material rather than an input of new pollutants.
- Sediment can be useful for soil amendment and landscaping.
- Managing pollution in the Aquatic system through the prevention of pollution and remediation techniques.

However, the remediation could be achieved in any of the following: Speciation/ separation, destroying the organisms by incineration, soil washing, solidification, Phytoremediation, Bioremediation.

Considering the above, it becomes quiet apparent that ensuring a green and consistent waterway would be most meaningful for the national level, not only for the Republic of Moldova, but for Romania too, as they are in the river aquifer.

### 3.3. Dredging plan

Dredging is an excavation activity or operation usually carried out at least partly underwater, in shallow seas or fresh water areas with the purpose of gathering up bottom sediments and disposing them at a different location. In actual sense, dredge is a device for scraping or sucking the riverbed / seabed, used for dredging and dredger is a ship or boat equipped with a dredge. In technical usage, any floating vessel equipped with dredging equipment is called a dredger. (*Source: DREDGING OF THE INLAND WATERS AND SUSTAINABLE MANAGEMENT OF THE WATERWAYS FOR NATIONAL DEVELOPMENT, Adejare, Q. A.1 (quadriadejare@yahoo.com), Opaluwa, Y. D.1 (geopaldy_xy@yahoo.com) and Prof. Nwilo, P. C.2 (pcnwilo@yahoo.com)).*

There are several types of dredging which are carried out in waterways to ensure that the waterways are kept clear and navigable. The common types of dredgers are:

- Clearing and snagging dredgers which are used to track log jams, clear debris, sunken vessel, etc.
- Mechanical and hydraulic dredgers which are principally used to clear riverbeds, ponds, estuaries, interlinks between rivers.

Most waterways have soft ground, except for parts where there is a rock bed. There are other types of dredgers, namely: Dust dredger. Dear side costs that are used to remove loose, compacted granular material at a fast pace. Dragons can also be amphibians and are usually portable.

Without regular dredging operations, as is the case in most parts of the world, world trade would have been affected, as most of the goods travel by ship and have to access ports or seas via canals. In addition, the pleasure boat was also restricted to smaller vessels. Most marine dredging operations (and disposal of dredged material) will require appropriate licensing from relevant regulators, and dredging is usually performed by port companies or appropriate government agencies.

Main reasons for dredging include:

- Increasing / maintaining the depth of water in a navigation channel.
- Spot excavations preparatory to major waterfront construction like, bridges, piers, or dock foundations.
- Harvesting sand for usage in concrete production or for beach restoration.
- Waterways management and maintenance for flood and erosion control.

The dredging process creates debris that is transported to locations other than the dredged area; dredging can disrupt aquatic ecosystems, often with negative effects. On the other hand, dredging can produce land reclamation materials or other purposes (usually related to construction). Dredging has also historically played a significant role in socio-economic development and growth.

An assessment of the physical, chemical and biological characteristics of the sediment is required to determine: possible dredging methods; options for use, disposal or treatment; potential impacts; the extent of biological and / or chemical tests; and monitoring needs.

Sediments are natural elements in any river basin, as well as in the seabed. Although dredging interferes with the natural cycle of sedimentation and resuspension, nowadays the environmental focus has shifted to a "river basin approach", ie taking all activities into account in a total perspective. The scope is changing from the management of dredged material to the complete management of sediments in the river basin. It integrates the economic need for dredging, the beneficial use of the material and the reduction of the effects of dredging and disposal, as well as the control of the source.

The dredged material is no longer seen as a "scrap" or "waste", but as a resource. Beneficial use of dredged material can be defined as the placement or use of dredged material for a specific productive purpose. Mineralogy and geotechnical properties qualify it for use in the manufacture of high value products for beneficial use. The dredged material can be used in a variety of beneficial applications. A list of these includes remedying the oceans, restoring mountain areas, filling degraded ponds and pits, creating and restoring wetlands for water quality and habitat treatment, and creating / restoring other habitats such as oyster reefs and bird habitat. Beneficial end products include topsoil, building cement, lightweight aggregate, bricks and architectural tile. Often, these beneficial uses can save the public costs. All dredged materials proposed for beneficial use will be evaluated in a framework that protects human health and the environment. Most dredged materials can be a valuable resource and should be considered for beneficial uses.

Most dredged materials are clean sediments. It should be recognized as a resource, as part of the ecological system. The options for beneficial use are numerous: ranging from coastal food, the creation of land or wetlands and soil improvement to the construction of dams and use as a building material. The dredged material should be used, whenever possible, to maximize the benefits for both the project and the beneficial user.

Anticipated derivable benefits from the dredging of the Prut river system would among others, include the following:

- Improved transportation system through increased navigational channel for the movement of bulk cargoes. This would lead to the realization of the National Transport Strategy and mass transit objectives of the country.

- Economic viability resulting from reduction in the cost of transportation.
- Availability and affordability of transportation services. Presently the volume of cargo is expected to double as a result of the dredging.
- Improved communication link between the Ungheni and Giurgiulesti.
- Job opportunities along the riverine and inland areas arising from the dredging project.
- The dredging will provide auxiliary benefits to the host communities in the area through the development of fish ponds at designated locations, as a mitigating measure to disruptions in fishing activities that may be suffered by fishermen.
- Dredge spoils will be used to fill up marshy areas if requested by communities. This would result in increase in habitable and agriculturally productive land mass available to the host communities.
- Improved quality of life from the numerous economic activities that would be generated along the riverbanks.
- It would minimize problems of environmental pollution arising from emission of greenhouse gases and noise from people and vehicle.
- Diversion of traffic to waterways would in turn provide relief to roads and consequently improved lifespan of roads.
- It will lead to bulk transportation of goods thereby reducing the cost of these goods. (Not for ocean vessels carrying large cargoes).

Strategies for Sustainable Management of Waterways for National Development

To ensure that the Prut river waterway get the proper thrust, certain measures need to be taken at the national level which would be in the following lines:

- Raise tax-free point and mobilize fees for infrastructure development.
- Encourage commercial/joint venture and provide for grants and subsidies.
- Encourage private sector participation.
- Introduce phased tax exemption.
- Enhance depreciation rate of vessels.
- Introduce vessel-building subsidy for Waterways.
- Minimize the custom duty.

Other strategies that could enhance sustainable management of the waterways therefore include:

### 3.3.1 Phased Development

To ensure that waterways are properly projected, development should be done in stages, and integrated waterway development should define human parameters for infrastructure requirements, dredging, navigation equipment, terminal, etc. and daily requirements, along with operational issues. Once this step is completed, then the next development step would be to define the Strategic Marketing Plan, project master plan, preliminary engineering for infrastructure, channels, navigation, terminals, storage, etc.

### 3.3.2 Organizational Management

This is cardinal to the realization of the goals of this scheme and the major components of this strategy are:

(a) Monitoring and advising on the Prut river corridors issues including both the man-made and natural aspects;

(b) Realizing the potential for understanding and enjoyment of all aspects of built and natural infrastructure along the waterways through education and promotion;

(c) The strong central control of all aspects of waterways management. In order to fulfil these functions adequate professional staff would be required in the following areas:

- Strategic planning;
- Navigation & Engineering;
- Planning & Development;
- Natural & Built Heritage;
- Education, Promotion, and Marketing.

### 3.3.3 Resource Management

The current situation of a multitude of government departments and other agencies involved in various aspects of waterway management has led to a lack of cohesion. Therefore, in order to improve the uniform coordination and efficient management of resources, the application and monitoring of water quality should continue to be carried out by local authorities and other agencies with a statutory obligation to do so.

### 3.3.4 Development Control and User Management

Where development, industrial or recreational projects could have a negative impact on waterway corridors, special control areas should be identified in consultation with local authorities and users included in their state development plans. The infrastructure of the inland waterway system needs to be improved in partnership with local authorities, local communities and the private sector.

Recognition of the wider socio-economic benefits of waterway projects must be taken into account in urban waterway development plans to ensure maximum benefit to the areas involved. Waterways can be used as a catalyst for development. All developments on waterway corridors, including tourism-related projects, should take into account potential negative effects on waterway heritage. Policies and guidelines are needed to ensure sustainable development on waterway corridors. The voluntary sector should be encouraged to continue its involvement in the development of waterways, and non-governmental organizations should be recognized as important.

The potential for inland waterway transport to encourage and support increased economic and social development in rural areas is enormous.

### 3.3.5 Balance Economy and Ecology

The overall goal of management should be to achieve a sustainable solution, subject to sound environmental, social and financial assessments, weighing and balancing all associated risks. Identifying and involving all potential stakeholders and stakeholders from the conceptual stage to the completion of the project is essential. Clear and competent communication on the physical, environmental, social and financial effects of a project should always be considered a key success factor. The dredging community is often able to repair contaminated sediments. Even when this is possible, high priority should always be given to source control. Successful implementation of prevention strategies will require collaboration between all actors from source to sinking.

### 3.3.6 The Need for Sustainable Relocation

Sea or river sediments normally contribute to the sustainability of natural ecosystems. Their role in the processes of the river, estuary and coastal areas should be respected whenever possible. Removing marginally contaminated sediment from an ecosystem can in fact, in specific cases, be more harmful than relocating it. Consequently, an environmental impact assessment is crucial, especially when considering the sustainable management of rivers and the coast. Environmental impact assessment is an important prerequisite for dredging initiatives. Such an assessment is used to establish and, where necessary, to explore options for mitigating the potential effects of dredging or disposal on the physical environment, wildlife, habitats, fisheries, archeology and many other interests.

### 3.3.7 Environmental Impacts

Dredging can disrupt aquatic ecosystems, often with negative effects. In addition, dredge residues may contain toxic chemicals that may adversely affect the disposal site; In addition, the dredging process often dislodges chemicals from benthic substrates and injects them into the water column. The dredging activity can create the following main effects on the environment: Release of toxic chemicals (including heavy metals and PCB) from bottom sediments into the water column;

- Short term increases in turbidity, which can affect aquatic species metabolism and interfere with spawning;
- Secondary effects from water column contamination of uptake of heavy metals, DDT and other persistent organic toxins, via food chain uptake and subsequent concentrations of these toxins in higher organisms including humans;
- Secondary impacts to marsh productivity from sedimentation;

- Tertiary impacts to avifauna which may prey upon contaminated aquatic organisms;
- Secondary impacts to aquatic and benthic organisms' metabolism and mortality; and
- Possible contamination of dredge spoils sites.

### 3.4. Technology and organization of dredging works

Definition: A dredger is a piece of equipment which can dig, transport and dump a certain amount of underwater laying soil in a certain time. The quantity of soil moved per unit of time is called Production. Dredgers can dig hydraulically or mechanically. Hydraulic digging make use of the erosive working of a water flow. For instance, a water flow generated by a dredge pump is lead via suction mouth over a sand bed. The flow will erode the sand bed and forms a sand-water mixture before it enters the suction pipe. Hydraulic digging is mostly done with special water jets. Hydraulic digging is mostly done in cohesion less soils such as silt, sand and gravel.

Mechanical digging by knives, teeth or cutting edges of dredging equipment is applying to cohesive soils. The transport of the dredged soil can be done hydraulically or mechanically too, ether continuously or discontinuously.

Table 8: Transport type used in different dredging technology

| | Hydraulically | Mechanically |
|---|---|---|
| Continuously | Transport via pipeline | Transport via conveyor belts |
| Discontinuously | | Transport via grab, ship, car |

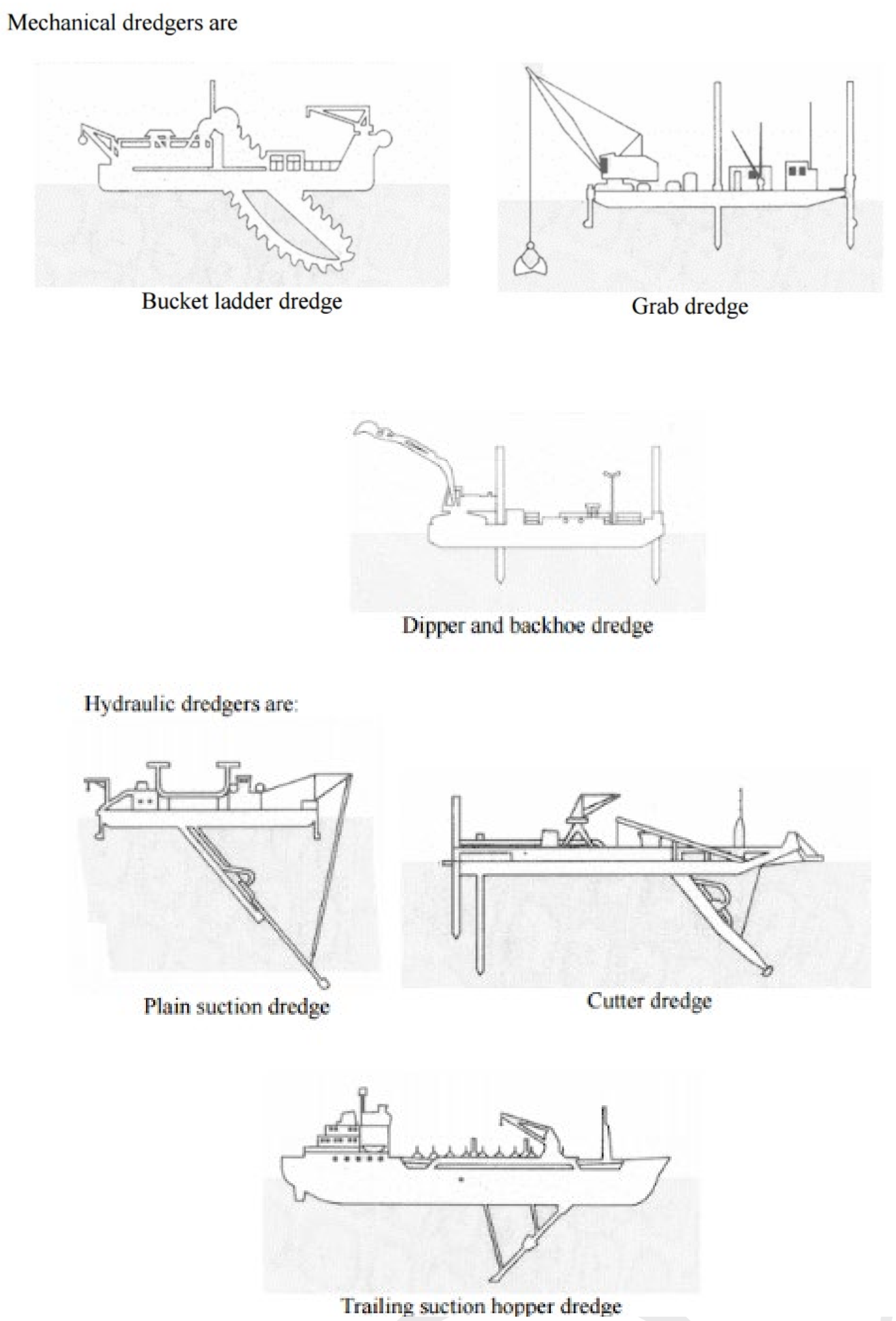
Source: Prof. Ir. W. J. Vlasblom, Designing Dredging Equipment

Deposition of soil can be done in simple ways fi by opening the grab, turning the bucket or opening the bottom doors in a ship. Hydraulic deposition happens when the mixture is flowing over the reclamation area. The sand will settle while the water flows back to sea or river.

Dredging equipment can have these three functions integrated or separated. The choice of the dredger for executing a dredging operation depends not only on the above mentioned functions but also from other conditions such as the accessibility to the site, weather and wave conditions, anchoring conditions, required accuracy and so on.

Types of dredging equipment

Dredging equipment can be divided in Mechanical Dredgers and Hydraulic Dredgers. The differences between these two types are the way that the soil is excavated; either mechanical or hydraulic.




Source: Prof. Ir. W. J. Vlasblom, Designing Dredging Equipment

Figure 8: Mechanical and Hydraulically Dredgers

For dredging works on the Prut river we can use mechanical dredgers, namely bucket ladder dredger. All dredgers except the trailing suction hopper dredgers are stationary dredgers, which means that they are anchored by wires or (spud) poles. Examples of bucket ladder dredgers we present below.


Source: http://sc04.alicdn.com/kf/HTB1eAUoX0jvK1RjSspiq6AEqXXaV.jpg

Figure 9: 2020 China Dredger Manufacturers 28inch 7000m3/h Sludge Pump Dredger/boat/sand and Gravel Dredges (ccs Certificate)


Source:
https://sc01.alicdn.com/kf/HTB1VCcRKeuSBuNjSsziq6zq8pXas/234459880/HTB1VCcRKeuSBuNjSsziq6zq8pXas.jpg

Figure 10: China HICL dredger shipyard 24inch 5500m3/h wheel bucket dredger/water master dredger sale (CCS certificate)

Of course the presented examples have a big excavation capacity and also a very high price. The Prut river and the required dredging works permits to look up at other equipment with a lower capacity and price. Also we can contract companies that own such equipment and pay for the work performed on problematic places.

As a more expensive method, more consistent in time, but not so invasive on the Prut river bio system, we can also review alternative dredging techniques for waste disposal. Alternative dredging follows a three-step process. First, the river's depth, bottom composition, and vegetation are evaluated. Second, a system of laminar-flow inversion and oxygenation is designed to create the aerobic conditions that are required for the rapid decomposition of organic sediment. Third, a bio augmentation program is designed to accelerate sediment digestion and re-establish a thriving food chain that begins to naturally process and remove the nutrients and organic matter that have accumulated over time.

If, however, we decide to use conventional methods of dredging and draining the riverbed, we must understand that dredging and desilting can have serious and long lasting negative impacts on the environment. For example, it can damage or destroy fish spawning grounds and make river banks unstable. Silt can become suspended in the water, lowering oxygen levels, potentially releasing harmful chemicals that may be present. This, in turn, impacts on wildlife, and water quality downstream. The silt that has been removed from rivers can be difficult to dispose of, particularly where it is contaminated due to the industrial activity along the river basin.

Before we undertake dredging and desilting activities we must be sure the work will not have any negative impacts on the environment, water quality or flood risk elsewhere in the riverbed. We also should take into account companies that design and undertake the work in a way that improves the river habitat or if that is not possible, minimize any impact as far as we can.

Taking action across entire river basin and riverbed is a much more effective and efficient way to protect communities and increase their resilience to flooding and the river navigability.

The most visible measures include flood walls, embankments, and demountable and temporary barriers, which help to contain water within river channels and tributaries.

Working with partners, we also must carry out activity alongside Prut river basin, restoring peatlands, planting trees, and building leaky dams, all of which contribute to slowing the flow of water into communities further downstream. In urban or rural areas, we must work with local authorities and other partners to promote sustainable drainage systems, which can include the creation of ponds and green spaces to help soak up rainwater, rather than it flowing quickly into drains and river.

Across the country we should work closely with Environmental Authorities to manage ecological risks related to increasing the level of navigability of the river and first related to dredging works.

## 4. Maintenance of the Prut fairway in the Giurgiulesti port area

### 4.1. General operating requirements for the port of Giurgiulesti located on the Prut River. General development scenario

Future constructions on the territory of Giurgiulesti port require to analyze the present constructions on the territory of the port, the current structure of the port and the services provided and the relief of the adjacent territory, which includes the possibilities of widening the port, possible dimensions of future hydro port constructions.

Port construction techniques and procedures are influenced by the topological and technical characteristics of the site, such as its situation and geology and the intended use of the plot. It occurs under greenfield or brownfield conditions.

Port development on a brownfield site involves reconverting an existing (mostly industrial) site for terminal use.

Brownfield port construction usually involves large-scale clean-up operations of contaminated soil and the renovation and deepening of the quay walls. It results in the rehabilitation and reuse of existing port real estate, thereby avoiding lengthy and difficult port extension procedures. Redevelopment of port brownfields produces numerous environmental, social, and economic benefits. By cleaning up and returning these lands to use, communities can remove dangerous structures and stop or stabilize contamination near waterways. Port redevelopment presents valuable opportunities for waterfront redevelopment, and it may catalyze revitalization in the broader community. Brownfield redevelopment frees space for various uses and creates a more available property for sale or lease, providing ports with additional sources of revenue. Besides, redevelopment of previously used sites can help alleviate pressure on undeveloped wetland and coastal areas, thus protecting important coastal habitats.

Construction of a port on a greenfield site mostly involves extending a port on a vacant site along a river, estuary, or coastline.

Historically, the majority of port development projects were labeled greenfield, which often goes hand in hand with port migration. The vacant site might be located in a green zone, wetland, or agricultural area. Getting permission for a greenfield development usually takes a long time given existing spatial planning and environmental rules and regulations, and the required extensive project evaluation. For example, the Bird and Habitat Directive and the Water Directive of the European Commission impose a complex regulatory condition on greenfield development for ports. Such developments can imply small or large-scale land reclamation works along the riverside or the digging of a dock on dry land connected to a river or existing dock system.

Land reclamation is based on hydraulic fill, a process whereby sediment or rock excavated by dredgers from the seabed or other borrow areas is transported and placed into the designated reclamation area.

Well-graded quartz sands are the preferred material for landfills. Before the hydraulic fill can commence, extensive preparatory engineering studies are conducted to collect bathymetrical (a measurement of the depth of bodies of water), topographical (physical features of the area), geological (soil and rock), and geotechnical data on the reclamation site and the borrow areas. This step also includes an examination of the hydraulic, meteorological, and environmental conditions. Based on these studies, a method and the right equipment are chosen to obtain the desired mix of soil/sand and water to facilitate the dredging, transport, and placement of fill material, and to meet the load-bearing and stability requirements of the reclaimed site. The quality of the landfill will be determined by its stiffness, strength, density (liquefaction resistance), and drainage capacity. The nature of the fill will influence the type of equipment, the means of transport, the reclamation method, and the possible need for ground improvement. Much used ground improvement techniques include vertical drains and vibratory, dynamic, or explosive compaction with or without admixtures.

On the territory of Giurgiulesti port we have to set up the scenario for both brownfield and greenfield port construction. This is because on the spot are located next to the actual engineering constructions of the port and some improvised constructions by the locals, which requires the adoption of the plan for brownfield port construction. At the same time, it is desired to explore the territory adjacent to the engineering constructions near the port, which has not yet been explored or used, which requires the adoption of the plan for greenfield port construction.

### 4.2. Port hydro technical constructions: berths, quays, ensuring the required water depth

At the moment it is required to plan the works regarding:

- On the territory of the Giurgiulesti Free International Port - cleaning the quays to maintain the necessary water depth in the port;
- On the territory of the State Enterprise Ungheni River Port – capital waterside facilities, that mainly includes construction of engineering objects that will ensure the transport of general goods and cereals; modernization of passenger docks, also cleaning the river bedside to ensure the necessary water depth for the access of river ships.

Waterside facilities include berthing facilities, such as harbor basins, approaches, access channels, locks, harbor dams, and breakwaters; cargo handling and ferry facilities, including goods transfer quays and piers, shoreline protection; and landing bridges, shipbuilding berths, fitting quays/wharfs, and dry docks. Offshore construction activities specific to ports include preparing the waterside, including construction/capital dredging (and disposal of dredged material); excavation and blasting; and filling and other work related to the construction of quays, piers, harbor basins, access channels, dams, breakwaters, and dry docks.

To maintain the necessary water depth, it is indicated to construct berths and quays. A quay wall is a soil retaining structure that provides a mooring place for ships, bearing capacity for crane loads, goods and storage, and sometimes a water-retaining function.

The basic role of a berth structure is to accommodate a particular vessel or range of vessels as well as cargo handling operations. There is a wide variety of berth structures with different characteristics with a variety of engineering considerations. More specifically, the method and sequence of construction, the availability of construction materials, and the support of major construction plants such as cement making can determine the type of structure finally selected. This structure and the availability of construction equipment can significantly influence the construction schedule in view of factors such as weather downtime and the availability of contractors.

General parameters that are considered when choosing an appropriate quay wall type include:

- Dredging and filling in order to minimize the environmental impact of those operations.
- Access and safety during all the stages of the construction and operation of the structure.
- Berth orientation, berth geometry, and berth length.
- Required depth alongside the berth.
- Seabed conditions.
- Local construction materials, method of construction, and construction difficulties.
- General site considerations such as drainage and filters, wave pressures on walls, scour protection, the risk of earthquakes, paving and surface water drainage, the chance of ice formation.

The possible failure or malfunction of a quay wall can be caused by the failure of the sheet pile wall, too much groundwater flow, not enough soil stability, or failure of the supporting points.

Quay walls are typically equipped with quay wall fenders, ship mooring bollards, crane rails, cable gutters, and other technical features. Typical Cross-Sections of Quay Walls are presented in the figure below.

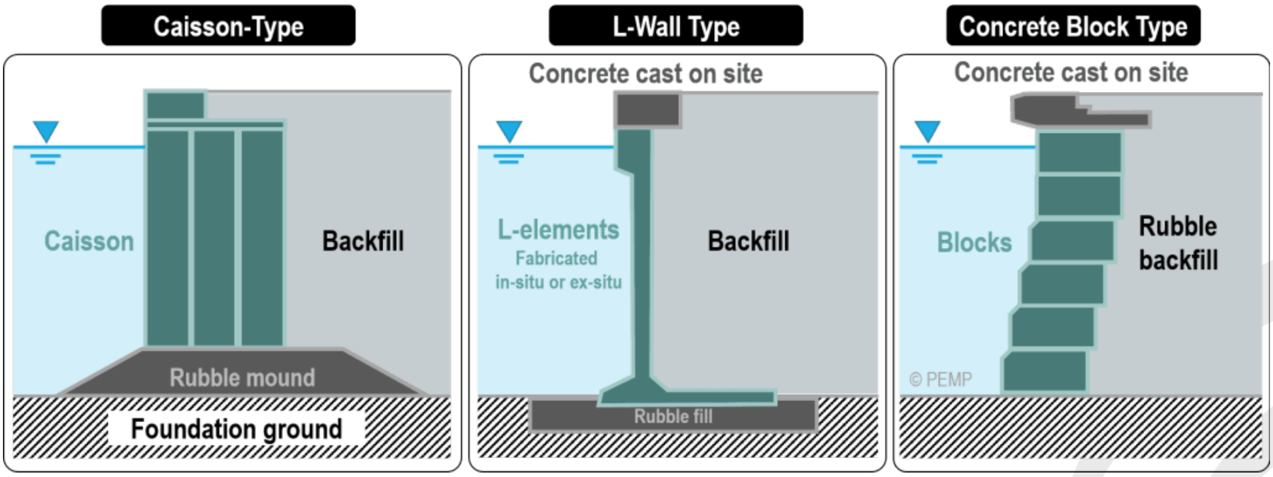



Figure 11: Typical Cross-Sections of Quay Walls

### 4.3. Navigation conditions: tonnage, access for ships, handling of ships in port

A harbor is a stretch of water where vessels can anchor or secure to buoys or alongside wharves to obtain protection (by natural or artificial features) from storms and rough water. A port is a commercial harbor or commercial part of a harbor with terminals, quays, wharves, enclosed docks, and facilities for transferring cargo from shore–to-vessel or vessel-to-shore. This includes onshore facilities and structures for receiving, handling, storing, consolidating, and loading or delivering waterborne shipments or passengers. Ports may include terminals, which generally serve a specific function, such as for containers, bulk shipments of cement, iron ore, grain, etc., and these terminals maybe be operated by a third party. Ports also may provide ship support facilities and services, including waste management and effluent discharge facilities, maintenance of vehicles and equipment, painting and other vessel maintenance.

The above definition requires us to provide all aspects related to commercial activity, transport and logistics to be held in the area of Giurgiulesti Port, both in the Free Economic Zone and in the Ungheni River Port. First of all, the spaces for the handling of inland waterway vessels selected in the previous chapters must be provided. Second, a water depth must be ensured as indicated. Both the first and the second point can be ensured by the periodic dredging of the Prut riverbed in the Giurgiulesti port area.

The access of the ships at this moment is possible in the Free Economic Zone Port Giurgiulesti, as well as it is possible to maneuver them, as well as the necessary depth is ensured. Capital works to ensure these conditions are needed in the Ungheni River Port.

Onshore construction typically includes site preparation and development, the removal of any existing vegetation, and the grading and excavation of soils for the installation of structural foundations and site utilities that are typical of industrial development projects. Port development may include construction of new infrastructure and/or rehabilitation of existing infrastructure, such as piers and buildings. Onshore facilities typically include:

- Cargo storage and handling facilities, including crane tracks and bridges for loading/unloading cargo; pipelines, roads, railway lines and other areas for cargo distribution, storage and stacking areas; above-ground and underground storage tanks; warehouses; and silos;
- Facilities for embarking/disembarking passengers, such as parking areas and administration buildings;
- Vessel support facilities, such as those used to store and supply water, power, food and oil/used oil;
- Drainage networks (e.g., for storm water);
- Waste management and effluent treatment and discharge systems, such as for wastewater/sewage, oil contaminated wastewater, and ballast water;
- Port administration buildings;
- Equipment maintenance and repair facilities, such as vehicle maintenance bays; and
- Flood defenses such as gates and dikes in ports exposed to high water and flood risks.

All these constructions are necessary to be designed and realized on the territory adjacent to the Giurgiulesti Port Free Economic Zone, in the context of the development of the Ungheni River Port.

#### 4.4. Dredging plan

Capital dredging for new ports includes the excavation of sediments to increase depth of berths and navigation channels for access by larger vessels. Sediments, even in new port developments, may contain contaminants. Much of this contamination originates from land-use practices in the adjacent watershed and is transported by rivers and surface runoff to lakes, bays, and the sea, where certain contaminants, such as polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), metals, and pesticides, tend to concentrate in the sediments. These must be taken into account when excavating and dredging works in the Port of Giurgiulesti.

In areas affected by sedimentation from rivers, estuaries, and land runoff, sediments are usually deposited over a period of time. Therefore, concentrations of contaminants can vary substantially over a vertical profile of the dredge cut. Typically, the upper layer is organic-rich and fine-grained, and is the most contaminated. The deeper materials are typically coarse-grained or hard-pan materials that are less contaminated. However, historical contamination, such as from previous shipyards and spills, can result in contamination even in these materials. Material dredged from channels or outer harbor areas tend to be relatively coarse-grained and uncontaminated, although the nature of the materials is a function of the historical activities within the region. Sediment quality can be assessed by sampling and testing.

The re-suspension of sediment during dredging or excavation processes may be reduced by selecting an appropriate dredging method:

- Grab or clamshell dredgers collect sediments in a crane-mounted bucket, helping to keep material consolidated (e.g., lower water content);
- Bucket dredgers pick up sediment by mechanical means, often with many buckets attached to a wheel or chain;
- Backhoe dredgers are shore-based or "pontoon mounted" diggers used in shallow waters and confined spaces;
- Trailing suction hopper dredgers are typically used for maintenance dredging in coastal areas. Sediments from the seabed are pumped through trailing drag-heads into a reception tank (hopper); and/or
- Water injection dredgers are used for maintenance dredging in coastal areas and rivers, particularly in muddy areas and in areas with sandy ripples on the bottom. Water injection dredgers inject water in a small jet under low pressure into the seabed to bring up sediment in suspension as a turbidity current that flows downslope before being moved by a second burst of water from the dredger, or carried away by sea currents.

Non-contaminated, dredged materials can usually be disposed of in open waters or used to counter shoreline erosion, for beach nourishment, or as fill materials, although a license from national authorities is typically required to discharge dredged material. Contaminated sediments are generally placed in confined disposal sites located either on land or in the water.

### 4.5. Technology and organization of dredging works

Installation of pier columns, piles and other underwater foundations, and construction of harbor basins and access channels, may require excavation of sediment and underlying material. Soft material can be excavated using conventional means, however, excavation of hard materials often involves blasting. Foundations can penetrate natural low-permeability layers and facilitate vertical migration of saline water and contaminants. As with dredging, these construction activities also cause turbidity and generate crushed material and other debris requiring disposal. The use of explosives usually releases nitrogen and blasted material into the water. Other contaminants, including metals and petroleum products, may also be released from sediments. Uncontaminated materials can be disposed of in open water, or used to construct breakwaters and other features, or for land reclamation. Contaminated material may need to be placed in a confined disposal facility.

Piers, wharves, and similar structures create the ship berths and provide the platforms for waterside cargo handling. These structures are typically constructed of concrete, steel, or lumber treated with chromated copper arsenate (CCA) or creosote as a preservative. Preservatives can leach from treated lumber, and the use of CCA-treated lumber is being phased out due to toxicity concerns. Filled structures, such as breakwaters, are crucial elements of port design and constitute sizable areas of artificial shoreline that are often projected into a bay, harbor, or estuary. Rubble mound breakwaters are commonly used and constructed by dumping rocks or debris of various size distributions from dump trucks, barges, or from fall pipes by barges.

Ships may enter and leave the port under their own power or assisted by tugboats. While berthed in the harbor, vessels need an ongoing source of power for cargo handling, climate control, communications, and other daily operations. Power can be supplied by the ships' engines or by shore-based utilities. Most vessels are powered by diesel internal combustion engines, although some vessels may be powered by boilers and steam engines/turbines. Air emissions from vessels consist primarily of particulate matter, carbon monoxide, sulfur dioxide, and nitrogen oxides from propulsion and auxiliary boilers and engines. Coal-fired boilers generate a large quantity of particulate matter. Heavy particulate matter emissions are also generated when carbon deposits are blown from coal- and oil-fired boilers.

Maintenance dredging involves the routine removal of siltation material and sediment in harbor basins and access channels. This activity is important to maintain depths and widths and ensure safe access for the ships as well as efficient navigation depth in the neighborhoods and dock gates to ensure access to basins and dry docks. Maintenance dredging may take place continuously or once every few years, depending on the port.

### 4.6. Freight and passenger berth maintenance plan

Land-based operations at ports include cargo handling; fuel and chemical storage and handling; passenger embarking and disembarking; ship support services; waste and wastewater management; vehicle and equipment maintenance; and buildings and grounds maintenance.

Cargo handling includes unloading, storage/stacking, and loading dry and liquid cargo. Cargo typically includes containers, dry bulk, liquid bulk, and general cargo. Cargo handling includes use of vehicular traffic such as harbor vessels, trucks, buses, and trains and on-dock cranes, terminal trucks, and track cranes. Bulk cargo may be transferred using cranes with grab buckets and front-end loaders, or pneumatic continuous ship loaders and unloaders, or belt conveyors.

Hazardous cargo, such as oil, liquefied gas, pesticides, and industrial chemicals, may require specific handling facilities or areas within the port, including separation from other cargo by cofferdam, void space, cargo pump room, or empty tanks. Pipe systems are required for handling bulk fuels and liquid chemicals.

Hazardous cargo may be released through leaks and spill during transfer and storage, contaminating soil, surface water, or groundwater. Volatile organic chemicals may also evaporate and be released to the air.

Passenger terminals may be required within the Ungheni port area for embarking and disembarking passengers, including provision of parking facilities and temporary holding areas.

A port may offer ship support services such as solid waste and wastewater collection, electricity supply, fuels, and fresh water. The port or a separate company located within the port area may offer ship fuels, and fuel may be supplied by bunker boats. Fresh water may also be offered and pumped onboard ships.

## 5. Ecological aspects of navigation on the Prut River

Human activities related to river navigation and navigation itself affect the ecological status and biochemical levels of a river in different ways. From an ecological point of view, navigation is not the only ecological pressure, but also the activities related to hydropower plants also cause damage to river ecosystems.

The works of digging the riverbed and transforming it to facilitate navigation have a dramatic effect on river ecosystems. All engineering work that takes place at this stage affects the hydro-morphological structure of rivers, as well as natural structures and ecological communities - such as barriers or dams that prevent fish from migrating to spawning grounds; another way to affect ecosystems is to raise the turbulence of water during excavation and riverbed cleaning works that affect the development of microorganisms.

Changing the speed of water flow as an effect of navigation on the river, the retention of water by locks or hydropower plants can lead to the loss of fish species that cannot adapt to these changes.

Degradation or alteration of the riverbed can lead to environmental damage. The canals built to help navigation change the flora and fauna of the river.

Pollution of water with waste from ships also leads to ecological damage. The waves produced by the movement of ships disturb the habitat of some species of fish, invertebrates or other organisms. The reduced light due to navigation also affects the growth of algae and plants that serve as food for other species and have the role of cleaning the river water.