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HYDROTECHNICAL AND HYDROLOGICAL CONDITIONS FOR NAVIGATION IN THE CHANNELS OF THE DANUBE-TISA-DANUBE HYDROSYSTEM

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Abstract: *the Danube-Tisa-Danube Hydrosystem (Hs DTD) canals and experiences gained during navigation and research will be described. channels Hs DTD in the period from 2010 to 2021 with ships of the River Flotilla . And all in order to verify the accuracy of the data of JVP "VODE VOJVODINA" related to the hydrological characteristics of waterways and hydrotechnical characteristics of buildings on Hs DTD.*

Before these voyages, there was no information and data about the voyages of the ships of the River Flotilla in the Hs DTD channels. A survey was conducted before each voyage of the Hs DTD canal and hydrotechnical structures on the canals from the land with the use of motor vehicles and boats in order to measure the height of the free passage on the bridges and measure the depth of the canal due to the draft of the ship. The obtained data can be used for commercial purposes, and as is known, there are no ,,pilots" on the Hs DTD channels that can safely guide the ships to the desired location..

Key words: *Danube-Tisa-Danube hydrosystem (Hs DTD), navigation, height of free passage on bridges, depth, ship's draft*

1. INTRODUCTION

The Danube-Tisa-Danube hydrosystem is a unique canal network that connects the flows of the Danube and Tisa rivers through Vojvodina and represents a hydrotechnical system for drainage of internal waters, irrigation , flood defense, water supply, removal of used water, navigation, tourism , fishing and forestry. The DTD hydrosystem with natural and partially reconstructed watercourses has 960 km, of which 600.6 km is navigable: 355.5 km in Backa, and 245.1 km in Banat.

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Its network connects 80 settlements in Vojvodina, and within the system there are 23 bridges, five security bridges, 15 ship locks and five more that are no longer in operation, five large pumping stations and 86 bridges (64 road, 21 railway and one pedestrian).

At Hs DTD, cargo ships with a carrying capacity of up to 1,000 t can currently sail at 345.3 km, vessels with a carrying capacity of 500 t at 558.3 km and vessels with a carrying capacity of 200 t can sail at 600.6 km. On the Hs DTD channels there are about 30 transshipment places - wharves, specialized wharves and wharves with landfill. The possible annual traffic on Hs DTD waterways is about 7,000,000 t. In the past few years, the turnover is about 1,000,000 t, and the highest achieved turnover was in 1979 and was 4,213,000 t. Types of goods: gravel and sand - 80%, stone - 5%, agricultural products 1 - 2%, wood 3 - 5%, coal, metals, oil and oil derivatives - up to 10%.

2. HYDROTECHNICAL AND HYDROLOGICAL CONDITIONS FOR NAVIGATION ON THE CHANNELS OF THE DANUBE-TISA-DANUBE HYDROSYSTEM

1) Current situation on the Canals of the "Danube-Tisa-Danube" Hydrosystem

The canals of the "Danube-Tisa-Danube" Hydrosystem are of immeasurable importance for the sustainable development of this part of Serbia in terms of regulating the water regime. At the same time, in all phases of its construction, this canal network was designed as a unique waterway integrated into the waterways of the Danube and Tisa rivers in the area of Vojvodina. The total length of the navigable canal network is about 600 km, of which, according to the categorization of state waterways carried out in 2013, 13.1 km is in the Va category, and 289.8 km in the III category. Of the 17 ship locks built in total, 12 are 85 x 12 x 3 in dimensions (including the Brana na Tisza lock) and all are in operation. On the canals of the "Danube-Tisa-Danube" Hydrosystem, the revitalization of endangered sections polluted by silt (Vrbas, Zrenjanin) is needed, as well as the rehabilitation of the Bezdan lock, as the entry point from the Danube to the canal system near the town of Bezdan, which has not been in operation for more than 30 years. .

The authority for technical maintenance of the waterway on the HS DTD canals is JVP "Vode Vojvodina", which is also the manager of this water management facility.

Figure 1. Hydrosystem Danube-Tisa-Danube
Source: http:// www.vodevojvodine /

Characteristics of the channel of the "Danube-Tisa-Danube" Hydrosystem

The total length of the navigable canals of the "Danube-Tisa-Danube" hydrosystem with the course of the Tamis is 664.1 km, which is 47% of the total length of the waterways of Vojvodina, or 41% of the total length of the waterways of Serbia. On them, it is possible to navigate 1,000-ton vessels on 376.9 km, five-hundred-ton vessels on another 258.8 km, and two-ton vessels on the remaining 28.4 km of the canal waterway.

Naziv kanala	Dužina kanala	Deonica (km)		B (m)	B_{vo} (m)		T (m)	Klasa kanala
		od	do		min	max		
Bečej-Bogojevo	90,2	0,0 39,0 47,5	39,0 47,5 90,2	27,0 14,4 21,5	33 37 40	200 41 50	1,95 1,95 1,95	III III III
Novi Sad-Savino Selo	39,1	0,0 4,4	4,4 39,1	35,0 27,7[1)]	46 48	130 54	3,00 1,95	Va III
Vrbas-Bezdan	80,9	0,0 6,3	6,3 80,9	25,0 15,2	36 22	 150	1,95[2)] 1,80	-[2)] II
Odžaci-Sombor	27,8	0,0	27,8	21,0	33	40	1,95	III
Bački Petrovac-Karavukovo	52,0	0,0 20,0 40,0	20,0 40,0 52,0	18,0 9,6 7,8	35 25 25	37 32 27	1,95 1,80 1,15	I[3)] I[3)] I
Prigrevica-Bezdan	31,7[4)]	0,0	31,7	18,0	40	52	1,80	II
Kosančić-Mali Stapar	21,1[5)]	0,0 4,5	3,5 21,1	13,5 11,5	38 20		1,95 1,30	II I
Bezdan-Baja	12,7	0,0	12,7	7,0	20	30	1,30	I
Banatska Palanka-Novi Bečej	147,3	0,0 8,7 26,0 27,5 45,0 57,0 85,0	8,7 26,0 27,5 45,0 57,0 85,0 147,3	54,0 44,0 12,0 44,0 33,0 21,0 24,0	90 90 35 60 50 40 46	160 100 40 80 60 60 66	3,00 1,95 1,95 1,95 1,95 1,95 1,95	Va III II III III III III
Begej	34,6	0,0 9,2	9,2 34,6	32,0 25,0	33 33	176 60	3,00 1,95	III III
Plovni Begej	31,2	0,0	31,2	17,0	30	40	1,80	II
Kikindski kanal	32,0	0,0	32,0	16,0	35	40	1,80	II

B – širina plovnog puta
B_{vo} – širina vodnog ogledala
T – preporučeni gaz merodavnog plovila

1) – na km 23,55 nalaze se ostaci pontonskog mosta čime je sužena širina plovnog puta na 17,2 m
2) – na deonici kanala od km 1 do km 6,3 je onemogućena plovidba zbog velikog zamuljenja od otpadnih voda koje se na toj deonici ulivaju u kanal i zbog novo-postavljenog mosta na km 2,6 koji ne omogućuje dovoljnu plovnu visinu od nivoa vode do donje ivice konstrukcije mosta (DIK)
3) – kanal je zarastao travom i trskom pri čemu je plovna širina nedovoljna za III odnosno II klasu
4) – na km 31,7 nalazi se vodozahvatna ustava Bezdan koja onemogućava plovidbu
5) – na km 3,75 i km 4,50 kanal je pregrađen kaskadnim prelivom i ustavom Ruski Krstur koji onemogućavaju plovidbu

Figure 2. Classification of waterways Hs DTD
Source: https://www. vodevojvodine .rs

The channel BECEJ - BOGOJEVO (90.0 km) represents the main waterway of Backa. The entrance from the Tisa (km 72.70) is near Becej and goes through the new Becej lock (the old lock has been put out of service), and from the Danube (km 1363.43) through the Bogojevo lock. The translation time depends on the water level of the Tisza and the Danube. The entrances to both locks are perpendicular to the course of the river, which makes it difficult to navigate. In addition to the two external ones, the canal has only one internal lock in Kucura (km 47.3), with a translation duration of about half an hour. The canal connects 15 inhabited places, of which Becej, Srbobran, Vrbas, Backo Gradiste and Ruski Krstur are important as docks and transshipment places.

The forks are at km 8.5 (dead end for Backo Gradiste), km 39.1 (connection with the Vrbas - Bezdan canal), km 53.59 (Fork with the Novi Sad - Savino Selo canal), km 61.86 (fork with

along the Kosancic - Mali Stapar canal), km 78.57 (fork with the Odzaci - Sombor canal) and km 84.05 (fork with the Backi Petrovac - Karavukovo canal).

On this channel, the Odzaci safety pier is located, with two navigable openings of 16 meters each, to ensure two-way navigation. It was built as part of the second defensive line along the line of the average high terrain of the Danube and Tisza watershed. Simultaneous two-way navigation of thousand-ton vessels is possible through the canal, except for the section from km 39.3 to 47.3 (from the fork with the Vrbas-Bezdan canal to the Kucura lock), where only one-way navigation is possible for this category of vessels, or simultaneously two-way for five hundred ton vessels. The channel passes through the bed of Crna Bara (km 9 - km 30), which has a large navigable width. In this section, the ship should be steered carefully due to the large number of dings and large drifts in strong winds.

The NOVI SAD - SAVINO SELO canal (39.11 km) is part of the Small Canal, better known as the Crown Prince Alexander Canal. In terms of importance, the Backa channel is second. It connects the Becej - Bogojevo canal (km 53.59) near Savino Selo with the Danube near Novi Sad (km 1253.4). At km 4.38 is the Novi Sad external lock, which is the only one on the canal. The transfer of the ships lasts from 30 to 40 minutes, depending on the water level of the Danube. Downstream from the Novi Sad lock (km 4.30) a turnpike for ships was built, which is also used as a winter shelter in the winter.

Navigation without translation is possible further from Savino Selo all the way to Bogojevo and Srpski Miletic via the Becej - Bogojevo channel, or Backi Petrovac - Karavukovo, and Odzaci - Sombor channel, then to Kucura and Rusko Krstur via the Becej - Bogojevo and Kosancic - Mali Stapar channels. Along the entire length of the canal, simultaneous two-way navigation of thousand-ton vessels is possible.

The forks of the canal are at km 21.21 (connection with the Backi Petrovac - Karavukovo canal), km 39.10 (connection with the Becej - Bogojevo canal) and km 35.33 (fork with the non-navigable Jegricka canal).

The canal connects seven populated places, the most important of which is Novi Sad, as the largest industrial and agricultural center of Vojvodina.

The VRBAS - BEZDAN canal is known as the Great Canal or the Franz Joseph and King Peter Canal. It is a section of the former Becej-Bezdan canal. Between the fork with the Becej - Bogojevo canal (km 39) as the beginning, and the entrance to the Danube (km 1425.60), as the end, stretches a waterway 80.9 km long.

The forks are located at km 35.40 with the Kosancic–Mali Stapar canal, and km 51.65 with the Odzaci–Sombor canal and km 77.46 with the Bajski canal.

Simultaneous two-way navigation of one-thousand-ton vessels is possible only downstream of the Vrbas lock, while between the Vrbas and Bezdan locks, simultaneous two-way navigation of five-hundred-ton vessels is possible. The Mali Stapar lock is the smallest lock on the network of navigable canals of the "Danube-Tisa-Danube" hydrosystem. Translation at Bezdanska Prevodina takes between 50 and 70 minutes, and 40 minutes each at Mali Stapar and Vrbas.

At km 71.7, a safety bridge Ceská Ĕuprija was built, with a 12 m wide navigable opening and the basic task of closing the channel to protect it from Danube floodwaters and further flow into Backa.

The canal connects Vrbas, Kula, Crvenka, Backi Monostor and Bezdan.

The ODZACI-SOMBOR canal (27.9 km) connects the Vrbas-Bezdan (km 51.65) and Becej-Bogojevo (km 78.57) canals. It is connected to the Prigrevica-Bezdan canal via a fork at km 21.41. Interpreters are in Srpski Miletic (km 6.06) and Sombor (km 27.4). The canal enables simultaneous two-way navigation of thousand-ton vessels and is a transit route for ships from Novi Sad and Bogojevo that sail to Sombor. There are no docks built on it.

The BACKI PETROVAC - KARAVUKO canal (52.0 km) connects the Becej - Bogojevo canal (km 84.05) near Karavukovo with the Novi Sad - Savino Selo canal (km 21.21) near Backi Petrovac. The Bac safety road at km 33.35 has a width of 16 m and is basically the same as the roads in Kupusina and Odzaci.

The canal enables one-way navigation of thousand-ton vessels on the section from km 0.00 to km 20.0, one-way navigation of five-hundred-ton vessels from km 20.0 to km 40.0, and on the remaining part of the canal, one-way navigation of two-ton vessels.

Canal KOSANCIC – MALI STAPAR (21.1 km). Constitution in Russki Krstur divides this channel into two blind branches. The first leg from Kosancic to Ruski Krstur begins at the fork with the Becej–Bogojevo canal (km 61.86), and ends at the Ruski Krstur junction (km 3.7). One-way navigation of five-hundred-ton structures to the Ruski Krstur pier is possible through this section. There are no turnstiles on it, so vessels must return by sailing astern. The second leg Ruski Krstur–Mali Stapar (16.66 km) allows for one-way navigation of five-hundred-ton vessels and turns in the turnpike near Kruscic. Because of the above, this channel is not of major importance for navigation.

The BAJSKI canal (12.7 km), once Alimentacioni or Sugovicki, is essentially a branch of the Vrbas-Bezdan canal. It starts at the fork of the Vrbas - Bezdan canal at km 77.46. At km 0.16 is the Sebes-fok lock, which has been converted into a safety lock. One-way navigation of five-hundred-ton buildings is possible through the canal. Navigation through this channel has no major economic importance.

The BANAT PALANKA - NOVI BECEJ canal (147.3 km) is the main highway of Banat. The entrance from the Danube (left bank) is at km 1075, and from the Tisa at km 65 through the Novi Becej lock. Two outer locks (Kajtasovo and Novi Becej) and one inner lock (Botos) were built on it. It enables simultaneous two-way navigation for thousand-ton vessels along the entire length, except for the section from km 73.1 to km 87.3, where only one-way navigation is possible for this category of vessels and two-way for other vessels. The forks of the canal are at km 87.8 with Tamis, km 109.1 with Begeja and at km 134.3 with the Kikinda canal. Apart from the forks, turnings are also possible at the mouth of the Brzava (km 75).

BEGEJ Canal (Tisa - Klek) (67 km). The reconstructed Begej canal is from the junction with the Tisza near Titel to Klek (km 34.8). From Tisa to Klek, simultaneous two-way navigation is possible for thousand-ton objects. It is characteristic that this channel has the water level of Tisa up to Stajicevo. When sailing, you should take into account the water level values, which are extremely high in certain periods, which is why passing under bridges can be a problem. The canal connects Perlez and Zrenjanin, which is the industrial and agricultural center of Banat, with the Begej shipyard.

Navigable BEGEJ (Klek - state border) (29 km). From Klek to Itebej, it passes along the old route of Begeja. Simultaneous two-way navigation for five-hundred-ton objects is possible on this channel. The canal connects Itebej, Begejce and Zitiste.

The KIKIND channel begins at the fork with the Banatska Palanka–Novi Becej channel at km 134.3, and ends at the junction with Zlatica. With its length of 50.3 km, it enables one-way navigation for one-thousand-ton objects and simultaneous two-way navigation for five-

hundred-ton objects. There are no locks on the canal. It is connected to the Tisa waterway by the Banatska Palanka–Novi Becej canal, through the lock in Novi Becej, and by the Begej canal through the Stajicevo lock.

The river TAMIS , from the aspect of navigation, has two parts. One part of the stream is channeled, namely on the stretch from Tomasevac to Jasa Tomic, and enables the one-way navigation of one-thousand-ton objects and the simultaneous two-way navigation of five-hundred-ton objects. The second part of the Tamis stream, which is not navigably connected to the first, goes from the confluence with the Danube near Pancevo, in a length of another 3 km, on which part is the Pancevo lock.

3. HYDROTECHNICAL BUILDINGS ON THE DANUBE-TISA-DANUBE HYDROSYSTEM CHANNELS

(1) Dam

The dam on the Tisza near Novi Becej was completed in 1977 and is the largest facility on the DTD Hydrosystem. The dam has seven spillways and a lock for ships up to 1000 tons. With its construction and raising the level of the Tisa upstream, gravity catchment was enabled, that is, the supply of the Banat area with water from the DTD Hydrosystem. The 520 m long Tisa river bed is blocked by a dam for high water. A road bridge was designed on the pillars of the dam, as a traffic connection between Banat and Backa.

Figure 3. Dam on the Tisza
Source: Photographed on a voyage in 2012

(2) Ship Locks

10 new locks were built on the DTD canal, while five old locks were connected to the Hydrosystem. Some old locks today serve as prisons. There is also a lock in the structure of the Tisza dam. The role of the lock is to translate ships from one level of water to another.

Old locks: Backi Monostor (not in operation); Backo Gradiste (not in operation); Vrbas (today Vrbas Constitution); Little Stapar; Serb; Bezdan (reconstructed on September 25, 2020);Becej - old (today a cultural monument); Serbian Itebej; Klek.

New locks: Sombor; Serbian Miletic;Bogojevo; Novi Sad; A bitch; Bechej; Vrbas; Novi Becej; Stajic's; Botos; Kajtasovo.

Kanal	km kanala	Naziv prevodnice	Karakteristike komore prevodnice			Br. telefona
			Dužina (m)	Širina (m)	Dubina[1] (m)	
Bečej - Bogojevo	0,16	**Bečej**	85,0	12,0	3,0	066/8642-225
	47,30	**Kucura**	85,0	12,0	3,0	066/8642-226
	89,45	**Bogojevo**	85,0	12,0	3,0	066/385-643
Novi Sad - Savino Selo	4,30	**Novi Sad**	85,0	12,0	3,0	066/8642-341
Vrbas - Bezdan	6,20	**Vrbas**[2]	85,0	12,0	3,0	
	34,40	**Mali Stapar**[3]	62,4	8,1	2,5	
	80,80	**Bezdan**[4]	68,0	9,1	2,5	
	70,3	**Pontonski most**				063/888-6312
Odžaci - Sombor	6,00	**Srpski Miletić**	85,0	12,0	3,0	066/8642-381 066/8642-383
	27,40	**Sombor**	85,0	12,0	3,0	066/8642-259
Bajski kanal	0,16	**Šebešfok**[5]	69,0	9,4	2,5	
Banatska Palanka – Novi Bečej	8,70	**Kajtasovo**	85,0	12,0	3,0	066/8091-087
	85,60	**Botoš**	85,0	12,0	3,0	066/8642-181
	147,20	**Novi Bečej**	85,0	12,0	3,0	066/8643-052
Kanal Begej	9,20	**Stajićevo**	85,0	12,0	3,0	066/8642-182
Kanal Plovni Begej	0,70	**Klek, donja**[6]	64,0	9,7	2,4	
	0,80	**Klek, gornja**	72,1	9,7	2,4	
	29,0	**Srpski Itebej**[6]	72,1	9,7	2,4	
Reka Tisa	63,0	**Brana na Tisi**	85,0	12,0	3,0	066/8643-051

1) – Dubina vode pri minimalnom vodostaju
2) – Prevodnica Vrbas nije u funkciji
3) – Prevodnica Bezdan nije u funkciji čime je prekinuta veza sa Dunavom u pogledu plovidbe
4) – Prevodnica Mali Stapar radi na ručni pogon i u jako je lošem stanju te se ne preporučuje prevođenje
5) – Prevodnica Šebešfok radi kao ustava i omogućuje prolaz manjih plovila (jahti i čamaca) koji su na ekološki pogon, samo pri određenim hidrološkim i vodnorežimskim uslovima
6) – Prevodnice Klek i Srpski Itebej nisu u funkciji

Figure 4. Characteristics of locks on Hs DTD channels
Source: https://www. vodevojvodine .rs

(3) Constitution

On the basic canal network of the Hidrosystem DTD, there are 23 constitutions, 18 new ones and five constitutions that existed even before Nikola Mirkov started building the Hidrosystem. Constitutions were built as independent facilities or together with locks as part of the hydro node. The task of the constitution is to regulate the water level in the canal. Constitutions bear the names of the places where (or next to) they were erected, and are located in the following places:

- Abyss
- Serbian Miletic
- Novi Sad
- A bitch
- Russian Krstur
- Vrbas
- Despot's
- Dragon
- Frog
- Little Stapar
- Novi Becej
- Fall down
- Sajan - (constitution in Zlatica)
- Itebej and Klek
- Stajic's
- Botos
- Tomasevac
- Centa
- Again
- Pancevo
- Kajtasovo

(4) Security constitutions

Safety structures are located on the channels of the Hidrosystem in Backa. There are five of them and they form a system that prevents the intrusion of flood waters from the Danube into the central and southern parts of Backa. They are constructed in such a way that navigation is possible through them, and they can also let in adequate amounts of water for irrigation. The security constitutions are:

- Shebeshfok
- Czech bridge
- Cabbage
- Chimneys
- Bach

(5) Pumping stations

On the basic canal network of Hs DTD, there are six large pumping stations that serve to supply the canal with water, when this is not possible to a sufficient extent by gravity. They also serve to remove excess water from the canal network and to regulate the water level.

- Bezdan I
- Abyss II
- Bogojevo
- Bechej
- Frog
- Pancevo

(6) Bridges

During the construction of the Hydrosystem DTD, many roads were cut, so 86 new bridges were built. Of these, 64 are road bridges, 21 are railway bridges, and one is a pedestrian bridge. The length of the bridge depended on the width of the canal, and the width of the bridge was determined by the road category. The lower edge of the structure is determined to allow navigation, or they are designed so that they can be moved such as electric, movable, steel bridges or wooden pontoon bridges.

4. HYDRO-NAVIGATION MEASUREMENTS ON THE DANUBE-TISA-DANUBE HYDROSYSTEM CHANNELS WITH RIVER FLEET VESSELS IN THE PERIOD FROM 2010 TO 2021

Navigation on the Banatska Palanka - Novi Becej canal

Navigation through this channel is possible along its entire length from PKM 0 to 147.3. There are three locks on this channel: "Kajtasovo" at PKM 8.7, "Botos" at PKM 85 and "Novi Becej" at PKM 147.

The "Kajtasovo" translation center was completed in 1979. It connects the main canal Banatska Palanka - Novi Becej with the Danube. It is part of the Kajtasovo hydronode together with the constitution of the same name. It has one double-winged and one segmental gate. Transports ships with a carrying capacity of up to 1000 t.

"Botos" prison was built in 1971. in the composition of the Botos hydronode, together with the constitution of the same name. It is located on the Banatska Palanka - Novi Becej channel. It provides navigation between the Central Banat and South Banat parts of Hs DTD. It has one sliding and one double-leaf gate. Transports ships up to 1000 t capacity.

"Novi Becej" translation facility was built in 1972. The task of this lock is to ensure navigation between the Tisza and the main canal Banatska Palanka - Novi Becej. It has two sliding gates. Transports ships up to 1000 t.

The dimensions of the locks are: length 85m, width 12m and depth 3m. The smallest measured depth of the channel is 1.7 meters. There are 19 bridges on this canal, and the smallest measured height of the free passage is 6.5 meters, under the gas pipeline bridge on PKM 55.

Navigation on the Begay Canal

Navigation through this channel is possible along its entire length from PKM 0 to 34.6. On this channel there is the "Stajicevo" lock at PKM 9.7. The "Stajicevo" prison was built in 1971 in Begej. It is part of the Stajicevo hydronode together with the Stajicevo watershed. It has two

sliding gates. It enables the connection between Tisa and the Banat part of Hs DTD. It can handle ships with a carrying capacity of up to 1000 tons.

Dimensions of the lock: length 85m, width 12m and depth 3m. The smallest measured depth of the channel is 3.2 meters. There are 10 bridges on this canal, and the smallest measured height of the free passage is 6.5 meters, under the railway bridge in Zrenjanin on PKM 26.

The largest populated place for basing ships is the town of Zrenjanin. In Zrenjanin, there is no organized place for mooring ships (there are no cleats, no connection to the city's water and electricity network), but the coast is walled along the entire length of the canal and is suitable for docking ships. Boats can be moored under the pedestrian bridge at PKM 27.8, where there is also a small pier for the boats of the nearby rowing club, where, with the approval of the VK managers, it is possible to get a connection to the water supply network.

Navigation on the channel Becej - Bogojevo

Navigation through this channel is possible along its entire length from PKM 0 to 90. There are three locks on this channel: "Becej" at PKM 0.2, Kucura at PKM 47.4 and "Bogojevo" at PKM 89.5 and one safety lock "Odzaci". The "Bechey" translation house, which is thought to have been designed in Eiffel's office, was completed in 1896. It is located at the junction of the DTD canal with the Tisza. It is designed as a two-level gate with two sliding gates and one double-leaf gate (according to Tisza). It is the first lock in Europe that was powered by its own produced direct current. It has been out of use since 1975 and is protected as a cultural monument. The translation "Kucura" was completed in 1962. It enables navigation on the part of the Becej - Bogojevo main canal. It is located within the Kucura hydronode together with the Kucura constitution. It has two double gates. Transports ships up to 1000 t. The "Bogojevo" translation center was built in 1963. It is located at the junction of the Becej - Bogojevo canal with the Danube. Enables navigable connection between the Danube and navigable canals in Backa. It has two sliding "sunroof" gates. Transports ships up to 1000 t.

Odzaci Security Constitution was built in 1962. Its main task is to establish a second defensive line on the high ground of the Danube and Tisza watershed. It has two openings with a width of 16 meters each. The structure is closed with steel beam fasteners.

The smallest measured depth of the channel is 2.1 meters. There are 21 bridges on this canal, and the lowest measured height is 6.5 meters, under the railway bridge in Backi Gradiste on PKM 9.

Basing is possible in Srbobran, by bow connection on the left bank of the canal on PKM 27, the bank is low and dirt. There is no landscaped embankment for ships, trees nearby can be used.

Table 1. Overview of canal bridges and structures Becej – Bogojevo *(Source: Authors)*

1	Канал	ПКМ	Врста моста/устава	Путни правац	ВИСИНА МОСТА (цм)	ДУБИНА (м)
1	Канал Бечеј Богојево	1	друмски	Бечеј	610	2,3
2	Канал Бечеј Богојево	8,5	друмски	Бачко Градиште	630	2,5
3	Канал Бечеј Богојево	9	железнички	Бачко Градиште	605	2,1
4	Канал Бечеј Богојево	19,5	железнички	Надаљ	605	2,2
5	Канал Бечеј Богојево	25	друмски	Турија	720	2,9
6	Канал Бечеј Богојево	29	друмски	Србобран	670	2
7	Канал Бечеј Богојево	36	друмски	Ауто пут	660	1,7
8	Канал Бечеј Богојево	39,5	железнички	Врбас	650	2,2
9	Канал Бечеј Богојево	40	друмски	Врбас	620	2,3
10	Канал Бечеј Богојево	43,5	железнички	Магистрала	670	1,7
11	Канал Бечеј Богојево	47,4	друмски	Преводница Куцура	-	-
12	Канал Бечеј Богојево	52	друмски	Војни мост	670	2,9
13	Канал Бечеј Богојево	54	друмски	Савино Село-Деспотово	595	2,9
14	Канал Бечеј Богојево	55	железнички	Савино Село-Деспотово	612	3
15	Канал Бечеј Богојево	59	друмски	Косанчић	637	3,1
16	Канал Бечеј Богојево	67	друмски	Лалић-Руски Крстур	730	2,9
17	Канал Бечеј Богојево	72	друмски	Оџаци-Бачки Грачац	720	2,9
18	Канал Бечеј Богојево	73	железнички	Оџаци-Крушчић	760	3
19	Канал Бечеј Богојево	75	железнички	Оџаци-Бачки Брестовац	740	3
20	Канал Бечеј Богојево	77	друмски	Оџаци-Српски Милетић	690	3
21	Канал Бечеј Богојево	78	устава	Оџаци	690	2,9
22	Канал Бечеј Богојево	83	железнички	Каравуково-Богојево	700	3
23	Канал Бечеј Богојево	84	друмски	Каравуково-Богојево	700	3

Navigation on the Novi Sad - Savino Selo canal

Navigation through this channel is possible along its entire length from PKM 0 to 39.1. On this channel there is the "Novi Sad" lock at PKM 4.3. The "Novi Sad" translation center was completed in 1963. It is located 4.4 km from the junction of the Novi Sad - Savino Selo canal and the Danube. It is a part of the Novi Sad hydro node together with the constitution of the same name. It has one double-winged and one plunging gate. At this lock, the maximum unevenness between the Danube and the canal occurs (up to 9.1 m). Transports ships up to 1000 t. Dimensions of the lock: length 85m, width 12m and depth 3m. The smallest measured depth of the channel is 2.2 meters. There are 9 bridges on this channel, and the smallest measured height of the free passage is 6.1 meters, under the railway bridge in Novi Sad at PKM 7. At PKM 23.5, at the place of the old bridge, there is a narrowing of the waterway with a width of 17 meters.

Navigation on the Odzaci-Sombor canal

Navigation through this channel is possible along its entire length from PKM 0 to 27.8. There are two locks on this channel: "Srpski Miletic" on PKM 6 and "Sombor" on PKM 27. The "Srpski Miletic" lock was built in 1961. on the route of the Odzaci-Sombor navigable canal. Together with the constitution of the same name, it forms the Srpski Miletic hydronode. It has two double gates. Transports ships up to 1000 t. The "Sombor" prison was built in 1965. It connects different levels, i.e. it enables navigation between the Vrbas - Bezdan and Odzaci - Sombor canals. It has one plunging and one double-leaf gate. Designed to translate ships up to 1000 t. It can also work as a constitution. Dimensions of the lock: length 85m, width 12m and depth 3m. It is possible to base the ships near the village of Srpski Miletic on PKM 4. The smallest measured depth of the channel is 2.7 meters. There are 3 bridges on this canal, and the smallest measured height of the free passage is 7.21 meters, under the road bridge in Srpski Miletic on PKM 4.

Table 2. Overview of canal bridges Odzaci-Sombor *(Source: Authors)*

1	Канал	ПКМ	Врста моста	Путни правац	ВИСИНА МОСТА (цм)	ДУБИНА (м)
1	Канал Оџаци-Сомбор	3	друмски	С.Милетић-Богојево	720	2,9
2	Канал Оџаци-Сомбор	10	друмски	Дорослово-Сонта	735	2,9
3	Канал Оџаци-Сомбор	20	друмски	Пригревица-Стапар	700	3

Navigation on the Prigrevica-Bezdan channel

Navigation through this canal is possible up to the main water catchment "Bezdan" at PKM 31.7 with the prior notice of the PUC "Vode vojvodina" in order to open the passage on the pontoon bridge at PKM 23. On this channel there is a safety dam "Kupisina" at PKM 12 and the main water catchment "Bezdan" on PKM 31.7. The "Kupusina" security structure was built in 1963 on the Prigrevica-Bezdan canal. The basic task of this constitution is the establishment of a second defensive line cut by the Prigrevica-Bezdan canal. In the event of a flood upstream of it, it takes over the role of the Bezdan water catchment system, in terms of the gravitational supply of water to Backa. It has two openings with a width of 16 meters each. The closing of the constitution is done with two sets of metal beam fasteners deposited in the houses on both sides of the constitution. The main catchment basin of Bezdan is the basin of the Bac part of HS DTD. It is located at the most upstream part of the Hydrosystem, at the junction of the Danube and the Prigrevica-Bezdan canal. According to the Constitution, water from the Danube is admitted to HS DTD with a flow rate of up to 60 m3/sec. Construction began in 1958 and was completed in 1960. The Constitution has three equal openings of 5 meters each, with segmental shutters measuring 5x4.2 meters. The smallest measured depth of the channel is 2.9 meters. There are 7 bridges on this channel, and the smallest measured height of the free passage is 7.3 meters, under the road bridge in Kupusina on PKM 9.

Table 3. Overview of canal bridges Prigrevica-Bezdan *(Source: Authors)*

1	Канал	ПКМ	Врста моста/устава	Путни правац	ВИСИНА МОСТА (цм)	ДУБИНА (м)
1	Канал Пригревица-Бездан	1	железнички	Сомбор-Пригревица	730	3,2
2	Канал Пригревица-Бездан	7	гасовод		-	3
3	Канал Пригревица-Бездан	9	друмски	Купусина-Апатин	730	3,1
4	Канал Пригревица-Бездан	10	железнички	Купусина-Апатин	740	2,9
5	Канал Пригревица-Бездан	13	друмски (устава)	Купусина-Апатин	740	3
6	Канал Пригревица-Бездан	23	понтонски	Б.Моношгор	-	3
7	Канал Пригревица-Бездан	31	друмски	Батина-Бездан	740	3,2

Navigation on the Vrbas-Bezdan channel

Navigation through this canal is possible from PKM 51.65 (the fork with the Odzaci-Sombor canal) to PKM 80.9 Bezdan") with the prior notification of the PUK "Vode vojvodina" in order to open the passage on the pontoon bridge on PKM 71. On PKM 72 there is the old constitution is 12 meters wide. Navigation through the channel from PKM 0 to PKM 51.65 is not possible due to the low height of the free passage for the ships of the River Flotilla. The "Bezdan" translation center was completed in 1856 and is the first facility in Europe where underwater concreting was applied. A concrete factory is organized on the construction site itself. Concreting lasted continuously day and night for 90 days. The portico had two pairs of double-winged gates at either end of the chamber. The pair of gates that corresponded to the water level at the moment the vessel passed through the lock was used. It connects the Vrbas-Bezdan canal with the Danube. In the period from 1995 to 2020, the lock of the lock was not in operation but served only for defense purposes against the high waters of the Danube. The smallest measured depth of the channel is 2.7 meters. There are 7 bridges on this canal, and

the smallest measured height of the free passage is 6.2 meters, under the railway bridge Sombor-Apatinna PKM 57.5.

The translator was put into operation on September 25, 2020. allows passage for ships of 500 tons and ensures a minimum draft depth of 3 meters. It has retained its authentic appearance as when it was built in 1856. year, so the gates are opened manually because it is protected as an industrial heritage.

Figures 5 and 6. Bezdan translation center after reconstruction
Source: Photographed on a voyage in 2021

Table 5: Overview of canal bridges Vrbas-Bezdan *(Source: Authors)*

1	Канал	ПКМ	Врста моста/устава	Путни правац	ВИСИНА МОСТА (цм)	ДУБИНА (м)
1	Канал Врбас-Бездан	55	друмски	Сомбор-Апатин	750	2,7
2	Канал Врбас-Бездан	57	железнички	Сомбор-Апатин	630	3
3	Канал Врбас-Бездан	57,5	железнички	Сомбор-Апатин	620	2,8
4	Канал Врбас-Бездан	68	друмски	Б. Моноштор	700	3
5	Канал Врбас-Бездан	71	понтонски	Б. Моноштор	100	3,4
6	Канал Врбас-Бездан	72	пешачки/устава	Б. Моноштор	740	3
7	Канал Врбас-Бездан	79,7	друмски	Сомбор	740	3

Navigation on the channel Backi Petrovac - Karavukovo

Viewing through this channel was possible in a length of 1.5 km and a passage was made under the Backi Petrovac - Novi Sad bridge. The width of the channel in this section is 35 meters, and the depth is about 2.3 meters. The width of the channel is a limitation for turning ships.

Sailing on the river Thames

A view of the Tamis river is possible up to PKM 3, at PKM 0.5 there is a safety post "Pancevo". The PANCEVO CONSTITUTION was built in 1973. at the mouth of the Tamis near Pancevo and is an integral part of the Pancevo hydronode. Hydronode Pancevo protects the coast of Lower Tamis from the negative effect of the stagnation caused by the HPP "DJerdap" dam. Pancevo allows for the separation of the waters of the Tamis and the Danube and maintains a controlled lower water level in the Tamis upstream of Opovo, enabling the passage of large waters of the Tamis. Ustava has three flow fields, the middle one is 24.5 meters wide and the two outer ones are 12 meters wide. The shutters are segmental.

5. CONCLUSION

Hydrotechnical and hydrological conditions on the canals of HS Danube-Tisa-Danube enable safe and secure navigation for ships of the River Flotilla on all canals on which surveys were carried out in the period from 2010 to 2021.

The research carried out in this period found that the locks enable the transfer of two ships of the River Flotilla, in one transfer it is possible to transfer three ships at the same time.

The height of the free passage under the bridges, the width and the measured depths on all channels of HS DTD III, IV and V categories allow for unhindered navigation by the ships of the River Flotilla

The speed on the HS DTD canals is limited by regulation to 8 km/h, in practice it is not possible to achieve a higher speed than 11 km/h, due to the limited width and depth of the canal. At a higher number of revolutions of the main engines, the load on their work increases and the large draw of water and the creation of waves.

All measurements and researches have confirmed that it is possible to safely navigate Hs DTD channels for ships with a displacement of up to 100 tons, a height of up to 5.40 meters and a draft of 1.20 meters. This enables the development of river transport to the cities on the canals (Becej, Novi Becej, Zrenjanin, Sombor...) and the increase of economic activity in the entire region.

The navigation of River Flotilla ships is enabled through the Hs DTD canals from Banatska Palanka (Danube river PKM 1075) to Novi Sad (Danube river PKM 1255), to Bogojevo (Danube river PKM 1367) and Bezdan (Danube river PKM 1425).

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