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Duljine tekućica u Hrvatskoj određene na temelju topografske karte mjerila 1 : 25 000

River lengths in Croatia determined from a topographic map at a scale of 1:25,000

U ovome je radu prikazano metodološki konzistentno mjerenje duljina tekućica ukupne duljine 40 ili više kilometara na prostoru Republike Hrvatske. Mjerenje je obavljeno vektorizacijom toka na temelju topografske karte u mjerilu 1 : 25 000. Suvremene ortofoto-karte korištene su kao dodatni kartografski izvor za provjeru. U radu su objašnjeni pristupi određivanja početne i završne točke tekućica, odnosno izvora i ušća, te su navedene njihove prostorne koordinate. U slučaju ukupne duljine toka rezultati su pokazali da se 21 duljina izmjerena u radu razlikuje do 5 % od dostupnih službenih podataka. Značajne razlike zabilježene su na rijekama na kojima su provedeni opsežniji hidrotehnički zahvati kanaliziranja i promjene pružanja toka, na rijekama jadranskoga slijeva na kojima postoje metodološke razlike u određivanju točke ušća te na velikim nizinskim rijekama na kojima su česte promjene u tlocrtu korita zbog prirodne dinamike i hidrotehničkih zahvata. Ovim je istraživanjem također utvrđeno da je najdulja hrvatska tekućica, s izvorom, ušćem i objema obalama na prostoru Hrvatske, rijeka Karašica, s ukupnom duljinom od 148 km.

Ključne riječi: duljine tekućica, topografske karte, izvor, ušće, Hrvatska

This study presents methodologically consistent length measurements of rivers with a total length of 40 kilometres or more in the Republic of Croatia. These measurements were performed by vectorising river channels from a topographic map at a scale of 1:25,000. Contemporary orthophoto maps were used as additional cartographic sources for verification. The approaches used to determine the starting and ending points of rivers, i.e. sources and mouths or confluences, have been explained and their spatial coordinates were listed. The results showed that in terms of total river length, the 21 rivers in this study differed from the available official data by less than 5%. Considerable differences were found for rivers where significant river engineering works had been carried out to channelize and divert flow, as well as for rivers in the Adriatic Basin where there have been methodological differences in determining the river mouth, and for large lowland rivers where changes in channel planform are common due to natural dynamics and engineering interventions. Moreover, this research revealed that the longest Croatian river, with its source, confluence, and both river banks situated entirely within the territory of Croatia, is the Karašica River, with a total length of 148 km.

Key words: river lengths, topographic maps, source, mouth, Croatia

Uvod

Poticaj za objavljivanje rada o duljini tekućica u Republici Hrvatskoj jest činjenica da do sada nije objavljen članak koji bi se tim pitanjem sustavno pozabavio. U hidrološkim radovima o određenim tekućicama katkad su autori izmjerili duljine tekućica, ali češće su podatci preuzimani iz različitih drugih izvora. Često nije poznato na koji je način duljina neke tekućice izmjerena, s koje podloge, kojega mjerila ili koje godine. Takvi podatci mogu se skupiti, ali ne za sve tekućice, te nisu posve usporediv skup podataka.

Hrvatske vode u Strategiji upravljanja vodama objavile su tablicu *2.2. Hidrološke značajke većih vodotoka* (Hrvatske vode, 2009, 11), s njihovom ukupnom duljinom i duljinom u RH te ukupnom površinom porječja i površinom porječja u RH. Za te podatke nisu navedena metodološka objašnjenja, a ukupno je navedeno 30 tekućica po sljevovima i porječjima. Nisu navedene sve tekućice od neke minimalne duljine.

Šira javnost i mediji nalaze podatke o duljini tekućica u Statističkom ljetopisu Republike Hrvatske, koji u poglavlju *Geografski i meteorološki podatci* donosi tablicu *1-8 Rijeke* (DZS, 2018, 47) u kojoj je poredano 28 tekućica koje dijelom ili u potpunosti protječu Hrvatskom prema njihovoj ukupnoj duljini. Uz to su dani podatci o duljini njihova toka u RH, ukupnoj površini porječja i površini porječja u RH. Kao izvor podataka naveden je PMF, Geografski odsjek. Međutim, iz metodoloških objašnjenja za geografske podatke jasno je da su podatci skupljeni iz različitih izvora[1] te nisu rezultat sustavnoga mjerenja.[2]

1 U metodološkim objašnjenjima Statističkoga ljetopisa za geografske podatke navodi se da su oni koji se odnose na „površine i dužine" preuzeti „iz Statističkih ljetopisa Republike Hrvatske, geografskih znanstvenih časopisa, Atlasa Republike Hrvatske i ostalih dokumentacijskih izvora" te da je „dio podataka dobiven vektorizacijom s topografskih karata mjerila 1 : 100 000 (dužina toka i površina porječja pojedinih rijeka u Republici Hrvatskoj) zbog nedostatka odgovarajućih izvora podataka."

2 Geografski odsjek PMF-a opremljen je za digitalna mjerenja geografskim informacijskim sustavom 1992. godine. Od tada do 2016. nije provedeno sustavno mjerenje svih tekućica u RH. Od 2016. godine provode se sustavna hidromorfološka istraživanja u sklopu projekata za potrebe Hrvatskih voda (Zaharia i dr., 2018), ali podatci tih istraživanja nisu bili izvor za odnosnu tablicu Statističkoga ljetopisa RH.

Introduction

The reason for publishing an article on the length of rivers in the Republic of Croatia is that no such article has been published that systematically deals with this topic. In hydrological studies of certain rivers, river lengths are sometimes measured by the authors themselves, but more often the data are taken from various other sources. The way that a river was measured is often unknown, i.e. from which base map, at which scale, or from which year. Such data can be collected, but not for all rivers, and they do not represent a fully comparable dataset.

In their Water Management Strategy, Croatian Waters published the following: *Table 2.2. Hydrological Characteristics of Major Watercourses* (Croatian Waters, 2009, 11), which provides data on total river lengths and length within the Republic of Croatia, as well as total catchment areas and catchment areas within the Republic of Croatia for major watercourses. No methodological explanations are provided for these data. A total of 30 rivers are listed by catchments and basins. The listed rivers do not meet a particular minimum length criteria.

The general public and media can find data on the length of rivers in the Statistical Yearbook of the Republic of Croatia, which contains *Table 1-8 Rivers* in the Geographical and Meteorological Data chapter (CBS, 2018, 47). In this table, 28 rivers that flow partially or entirely through Croatia are listed according to their total length. In addition, data on their length within the Republic of Croatia, total catchment area, and catchment area within the Republic of Croatia are given. The source of the data is the Faculty of Science, Department of Geography (of the University of Zagreb). However, it is clear from the methodological explanations of the geographical data that the data were collected from various sources[1] and that they were not the result of systematic measurement[2].

1 The methodological explanations of the Statistical Yearbook for geographical data state that those related to 'areas and lengths' are taken 'from the Statistical Yearbooks of the Republic of Croatia, geographical scientific journals, Atlas of the Republic of Croatia, and other documentation sources' and that 'part of the data is obtained by vectorisation from topographic maps at a scale of 1:100,000 (length of flow and catchment area of individual rivers in the Republic of Croatia) due to the lack of appropriate data sources.'

2 The Geography Department of the Faculty of Science was equipped with a Geographic Information System for digital measurements in 1992. From then until 2016, no systematic survey of all streams in the Republic of Croatia was carried out. Since 2016, systematic hydromorphological surveys have been carried out as a part of various

Podatci s novijih, odnosno ažuriranih kartografskih podloga potrebni su i zbog toga što su tekućice dinamični sustavi te se njihova obilježja mijenjaju. U tom smislu svaki podatak o duljini (kao i drugim morfološkim veličinama) tekućice odraz je stanja u trenutku mjerenja, promjenljiv je i treba ga redovito osvježavati. Duljina rijeka neprestano se prirodno mijenja. Rijeke koje slobodno otječu mijenjaju svoj glavni tok, krivudajući i mjestimično se granajući u rukavce. Ljudske aktivnosti na regulaciji tekućica također ih mijenjaju. Posebno je izrazit utjecaj izravnavanja toka tekućica čime se može znatno skratiti njihova duljina. Primjerice, duljina Krapine regulacijskim je radovima skraćena sa 106 km sredinom 19. st. (mjereno prema povijesnom katastru, listovi u mjerilu 1 : 2880 iz 1860. i 1861.) na današnjih 68 km duljine, što znači za 35,9 % (Martinić i Orešić, 2020).

Postojala je, dakle, potreba za objavljivanjem podataka o duljini najduljih tekućica u Hrvatskoj prema suvremenom stanju i na temelju metodološki konzistentna mjerenja. Prilikom istraživanja izmjerene su duljine tekućica na teritoriju Republike Hrvatske vektorizacijom topografskih karata Državne geodetske uprave, koje čine najsveobuhvatniji dostupni izvor podataka. U ovome su radu zbog ograničena opsega navedene samo tekućice ukupne duljine 40 ili više kilometara.

Izvori podataka i metodologija mjerenja

Izvori podataka

Detaljna vektorizacija tekućica na teritoriju Republike Hrvatske provedena je u programu ArcMap 10.3.1. na temelju topografske karte u mjerilu 1 : 25 000 (TK25), koja je korištena preko Web Mapping Servicea (WMS) Geoportala Državne geodetske uprave (DGU). Navedena topografska karta (TK25) izrađena je u razdoblju od 1996. do 2010., a ažurira se od 2011. godine u kartografskoj projekciji HTRS96/TM na elipsoidu GRS80 sa središnjim meridijanom 16° 30‘ E. Dodatni izvor

Moreover, data from more recently updated base maps are required, as rivers are dynamic systems with constantly changing characteristics. In this sense, all length data (as well as all other morphological parameters) only reflect the state at the time of measurement. Therefore, they are variable and should be updated regularly. The length of any given river constantly changes due to natural processes. Free-flowing rivers change their main course, meander and anabranch in some places. River regulation activities also have an impact on river change. The effect of channel straightening is particularly pronounced, as it often significantly shortens a river's length. For example, the length of the Krapina River was shortened from 106 km in the mid-19th century (measured according to the historical cadastre, 1:2,880 scale sheets from 1860 and 1861) to 68 km today by regulation works, which corresponds to a decrease of 35.9% (Martinić and Orešić, 2020).

Therefore, there was a need to publish data on the lengths of the longest rivers in Croatia, based on methodologically consistent measurements. Within the scope of the research, the lengths of rivers in the territory of the Republic of Croatia were measured by vectorising the topographic maps of the Croatian Geodetic Administration, which represent the most comprehensive data available. Due to the limited scope, only rivers with a total length of 40 kilometres or more are included in this paper.

Data sources and measurement methodology

Data sources

Detailed vectorisation of rivers on the territory of the Republic of Croatia was carried out using the ArcMap 10.3.1. program on the basis of a topographic map at a scale of 1:25,000 (TK25), used via the Web Mapping Service (WMS) of the Geoportal of the Croatian Geodetic Administration (CGA). The cited topographic map (TK25) was created over the period of 1996 to 2010 and has

projects for Croatian Waters (Zaharia et al., 2018), but the data from these surveys were not the source for the corresponding table of the Statistical Yearbook of the Republic of Croatia.

podataka za vektorizaciju tekućica bile su digitalne ortofoto-karte iz 2019. i 2020. godine te Hrvatska osnovna karta u mjerilu 1 : 5000 (HOK5), koje su također korištene preko WMS-a Geoportala DGU. Iako su ortofoto-karte najnoviji izvor podataka, one se ne mogu rabiti u slučaju malih tekućica s gustom riparijskom vegetacijom gdje korito nije jasno vidljivo. Prema tome, topografska karta odabrana je kao najsveobuhvatniji i najpouzdaniji izvor podataka za ovo istraživanje. Međutim, u slučaju velikih nizinskih rijeka Save, Drave i Mure te rijeke Orljave, na kojima su česte promjene korita, točnost vektorizacije provjerena je na najnovijim ortofotokartama.

Male tekućice s koritom užim od 10 m koje su na topografskim kartama prikazane linijom vektorizirane su prema toj liniji. Tekućice sa širinom korita većom od 10 m vektorizirane su prateći crtu sredine korita prema topografskoj karti. U određenim slučajevima bilo je potrebno provjeriti lokacije izvora, odnosno početaka ili dijelova toka pojedinih tekućica izlaskom na teren ili su korišteni rezultati terenskih istraživanja na kojima su autori sudjelovali u sklopu projekata hidromorfoloških istraživanja tekućica u RH (Vučković i dr., 2018; 2019; 2021).

Za dijelove tokova tekućica koji se nalaze izvan granica Hrvatske korišteni su besplatno dostupni podatci: Open Street Map (OSM) (Geofabrik, n.d.) i EU-Hydro (Copernicus, 2020).

Prostorni podatci OSM-a preuzeti su sa servisa *geofabrik.de*. OSM je jedan od najistaknutijih dobrovoljnih i tzv. *crowdsourced* sustava geografskih informacija (VGI – Volunteered Geographic Information). Njegov je cilj stvaranje besplatne, vektorske prostorne baze podataka koristeći priloge više od sedam milijuna registriranih korisnika (Open Street Map, 2020). Korisnici prikupljaju prostorne podatke koristeći se ručnim istraživanjem, GPS uređajima, zračnim snimkama i drugim besplatnim izvorima, koje zatim specijalizirani urednici uvode u središnju bazu podataka.

Paneuropski hidrografski skup podataka EU-Hydro i digitalni model reljefa EU-DEM izrađeni su u sklopu programa *Copernicus* u razdoblju od 2009. do 2012. godine. EU-Hydro (Hy-

been updated since 2011 in the HTRS96 / TM cartographic projection on the GRS80 ellipsoid with the central meridian 16 ° 30 ‘ E. Digital orthophoto maps from 2019 and 2020 and the Croatian base map at a scale of 1:5,000 (HOK5) were used as auxiliary data for vectorisation via the CGA WMS Geoportal. Although orthophoto maps represent the most recent data, they cannot be used in the case of small streams with dense riparian vegetation where the channel is not clearly visible. Therefore, topographic maps were chosen as the most comprehensive and reliable data source for this study. However, in the case of major lowland rivers, e.g. Sava, Drava, Mura, and Orljava, where channel changes are frequent, the accuracy of vectorisation was visually checked against the latest available orthophoto maps.

Small rivers with channel width less than 10 m, represented by lines on topographic maps, were vectorised according to these lines. Rivers with a channel width greater than 10 m were vectorised along the centreline of the channel according to the topographic map. In certain cases, it was necessary to verify the location of the source, i.e. the starting points or parts of the river, via field work or by using the results of field research in which the authors had previously participated as part of hydromorphological research projects in Croatia (Vučković et al., 2018; 2019; 2021).

For parts of the rivers located outside the borders of Croatia, freely available data were used: Open Street Map (OSM) (Geofabrik, n.d.) and EU Hydro (Copernicus, 2020).

OSM geodata was taken from the *geofabrik.de* service. OSM is one of the most important crowdsourced geographic information systems (VGI-Volunteered Geographic Information). Its goal is to create a free vector geodatabase from the contributions of more than seven million registered users (Open Street Map, 2020). Users collect spatial data using manual surveys, GPS equipment, aerial imagery, and other free resources, which are then entered into a central database by specialised editors.

The pan-European hydrographic dataset EU-Hydro and the digital relief model EU-DEM

drographic database, Hydrographic Network or River Network, odnosno hidrografska baza podataka, hidrografska mreža ili riječna mreža) skup je podataka za sve države Europskoga gospodarskog prostora i države suradnice iz Jugoistočne Europe (EEA39) izveden na temelju satelitskih snimaka. Sadrži konzistentnu površinsku interpretaciju vodnih tijela (jezera i široke rijeke) i model otjecanja (mrežu otjecanja), koji je izveden iz EU-DEM, s porječjima, linijama otjecanja i čvorovima. Skup podataka koristi *Copernicusova* služba za praćenje zemljišta i ocjenjivanje vodnih resursa na europskoj razini (EEA, 2015).

Navedeni su podatci vizualno pregledani u odnosu na besplatno dostupan *online* satelitski prikaz „Imagery" u ArcMapu. Za konačan izračun duljine korišteni su OSM podatci jer je procijenjeno da su detaljniji u slučaju manjih tekućica iako su konačne razlike vrlo male (npr. duljina Save prema podatcima *Copernicus* iznosi 933,8 km, a prema OSM 933,1 km).

Određivanje duljina tekućica

Duljinu tekućice prije svega definiraju početna i završna točka, odnosno izvor i ušće. Glede početka toka, jednostavnije je mjerenje u slučaju kada tekućica počinje stalnim izvorom ili izvorišnim oblukom (Dukić, 1984). Izvor je obično jednostavno odrediti gotovo u jednoj točki, primjerice u slučaju krških vrela. Međutim, ne počinju sve tekućice jasno definiranim izvorom, posebno u unutrašnjosti Hrvatske. U povirju pojedini izvorišni krakovi mogu vremenski i prostorno varirati u izdašnosti, ovisno o hidrološkim prilikama, pa je gotovo nemoguće točno u jednoj točki locirati početak tekućice tijekom cijele godine. Općenito je u ovom istraživanju prilikom određivanja početne točke tekućice praćen najdulji izvorišni krak u sustavu prikazan plavom linijom na topografskoj karti bez obzira na to je li ucrtan izvor (sl. 1A) ili nije (sl. 1B). Još je Gardiner (1975) predložio mjerenje duljina tekućica mjerenjem svih plavih crta na karti, što uključuje i mjerenje tekućica, odnosno dijelova tekućica koje su na karti ucrtane isprekidanom crtom kao povremene. Početak povremenoga toka ne mora

were developed in the framework of the *Copernicus* program for the 2009–2012 period. EU-Hydro (Hydrographic database, Hydrographic Network or River Network) is a dataset for all countries of the European Economic Area and the cooperating countries from Southeastern Europe (EEA39), derived from satellite imagery. It contains a consistent surface interpretation of water bodies (lakes and wide rivers) and a runoff model (runoff network) derived from EU-DEM with catchments, runoff lines, and nodes. The dataset is used by the *Copernicus* Land Monitoring and Water Assessment Service at the European level (EEA, 2015).

These data were visually compared with the free online satellite view "Imagery" in ArcMap. The OSM data were used for the final length calculation as they were estimated to be more detailed in the case of smaller rivers, although the final differences were very small (e.g. the length of the Sava River is 933.8 km according to *Copernicus* data and 933.1 km according to OSM).

Determination of river lengths

The length of a river is primarily determined by its starting and ending points, i.e. its source and mouth. The beginning of a river is easier to measure if it starts from a constant source or springhead (Dukić, 1984). The source is usually easy to determine to a single point, e.g. in the case of karst springs. However, not all rivers begin with a clearly-defined source, especially in the interior of Croatia. In the headwaters, discharge of individual streams can vary greatly both spatially and temporally depending on hydrological conditions, making it practically impossible to locate the source of some rivers any given point throughout the year. Generally, in determining the starting point of flow, the longest headstream in the system was followed by a blue line on the topographic map, regardless of whether the spring was mapped (Fig. 1A) or not (Fig. 1B). Gardiner (1975) proposed to measure river lengths by measuring all blue lines on the map, including rivers or parts of rivers shown as intermittent on the map with a dashed line. The beginning of an intermittent river does not need to have a marked source, because it does not need to begin with a source, rather with a stream formed by groundwater filtering into its chan-

imati ucrtan izvor jer ni u prirodi ne mora započeti izvorom, već može započeti curkom koji nastaje procjeđivanjem temeljnice u korito. U slučaju da je na karti ipak ucrtan izvor koji pripada dolini (jarugi) povremene tekućice, a nije spojen s ucrtanom povremenom tekućicom u nastavku doline, provedeno je produljenje povremene tekućice do pripadajućega izvora. Kad je puna linija tekućice nastajala sutokom više isprekidanih linija, što je tipično za panonski i peripanonski prostor, kao točka izvora uzet je početak najdulje isprekidane linije (sl. 1B). U slučaju rijeka koje izviru u dinarskom, krškom području, izvor je često jasno određen toponimom na karti (primjer Kupe, Krke, Une, Cetine). To su uglavnom izdašni izvori (vrela). Ako postoji nestalan, povremeni ili sezonski krak u povirju koji je dulji nego tok računajući od vrela određenoga toponimom, on nije uzet u obzir (npr. Cetina, sl. 1C) ili su, kada je takav krak hidrografski izrazit, posebno prikazane duljine bez takva toka ili s takvim tokom. Takvi su primjeri Čikola (duljina od vrela Čikole) i Čikola-Vrba, gdje je riječ o prilično velikoj razlici u duljini, ili Krka, gdje su izmjerene dvije duljine: od vrela Krke i od izvora Krčića jer je Krčić u morfogenetskom smislu izvorište Krke s kojom je u prošlosti tvorio jedinstvenu tekućicu (Perica i dr., 2005). Kao izdvojeni slučaj javlja se i pitanje početka Korane, za koju je hidrološki opravdano[3] mjerenje najduljega toka u sustavu, dakle kroz crtu sredine Plitvičkih jezera i dalje do izvora najduljega uvirka, a to je Bijela rijeka, ali isto tako navedena je i duljina Korane od Sastavaka, kao popularnoga početka Korane.

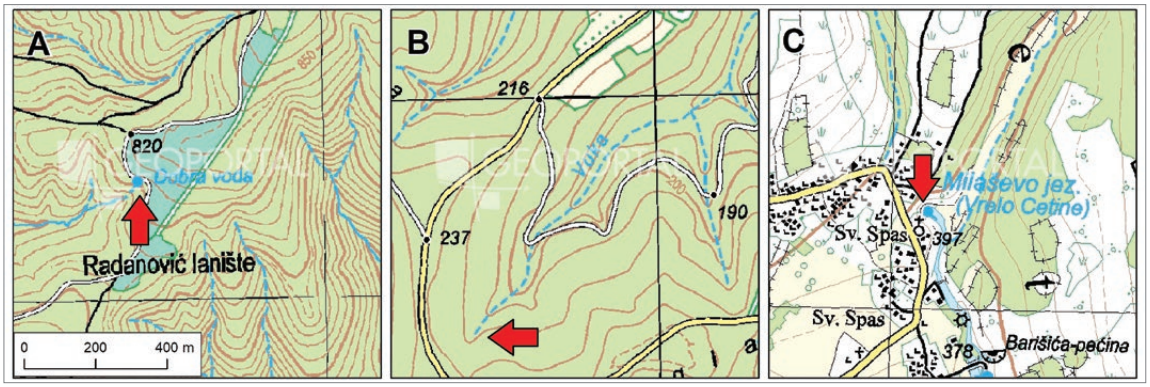
Završne točke tekućica, odnosno ušća tekućica u pravilu se lakše određuju. Zahvaljujući tomu, lociranje nekih objekata, mostova ili naselja uz tekućice određuje se riječnim kilometrom (rkm), koji se mjeri upravo od ušća (Dukić, 1984). Problemi nastaju kad zbog intenzivnih hidrotehničkih radova dolazi do promjena ušća, primjerice kad je voda neke tekućice preusmjerena umjetnim kanalom u nekom drugom smjeru ili čak u više različitih smjerova. Takvi su slučajevi posebno naznačeni prilikom prikaza rezultata

3 Uobičajeno je mjerenje duljina tekućica uračunavajući jezera, primjerice u duljinu Nila uračunava se Kagera, najdulji uvirak Viktorijina jezera.

nel. In cases where the source in a valley (gully) of an intermittent river is marked on the map but is not connected to the mapped intermittent river downstream, an extension of the intermittent river to the corresponding source was made. If the full flow line on the map was formed by the confluence of several dashed lines, which is typical for the Pannonian and Peri-Pannonian regions, the beginning of the longest dashed line was taken as the source point (Fig. 1B). In the case of rivers originating in Dinaric karst regions, the source is often clearly marked by a toponym on the map (e.g. Kupa, Krka, Una, or Cetina). These are mostly abundant karst springs. If there was an ephemeral, intermittent or seasonal branch in the headwaters that is longer than the flow measured from the source of the spring determined by the toponym, it was not included (e.g. Cetina, Fig. 1C) or, when such a branch was hydrographically significant, lengths with and without the separate flow were shown separately. Such examples are the Čikola River (length from the Čikola's spring) and the Čikola-Vrba branch, where there is a rather large difference in length, or the Krka River, where two lengths were measured: from the Krka's spring and from the Krčić's spring, as the Krčić represents the Krka's headwaters in a morphogenetic sense, with which it formed a single river in the past (Perica et al., 2005). The question of the beginning of the Korana River is a special case. It is hydrologically justified[3] to measure the longest flow in the system, i.e. through the centreline of Plitvice Lakes and onward to the source of the longest headstream, the Bijela River. However, the length of the Korana from Sastavci was also measured, as it is commonly in general public considered as the beginning point of the Korana.

The end points of rivers in general mouths or confluences, are usually easier to determine. Therefore, the locations of some buildings, bridges or settlements along rivers are determined by the river kilometre (rkm), which is measured from the river mouth (or confluence) (Dukić, 1984). Problems arise when the river mouth or confluence changes due to river engineering works. For example, when the water of a river is diverted by an artificial channel in another direction or even in several different directions. Such cases were explicitly referred to in the presentation of

3 It is common to measure river lengths including lakes, for example the length of the Nile includes the Kagera River, the longest inflow of Lake Victoria.



Sl. 1. Različiti prikazi izvora na topografskoj karti
Kartografska podloga: DGU (2020b)

Fig. 1 Different representations of river sources on a topographic map
Base map: CGA (2020b)

te su navedeni svi vodotoci, prirodni ili umjetni, kojima se računa duljina toka, katkad u više varijanata (Lonja-kanal Trebež, Česma do kanala Lonja-Strug, Česma do Lonje, i Ilova-Trebež).

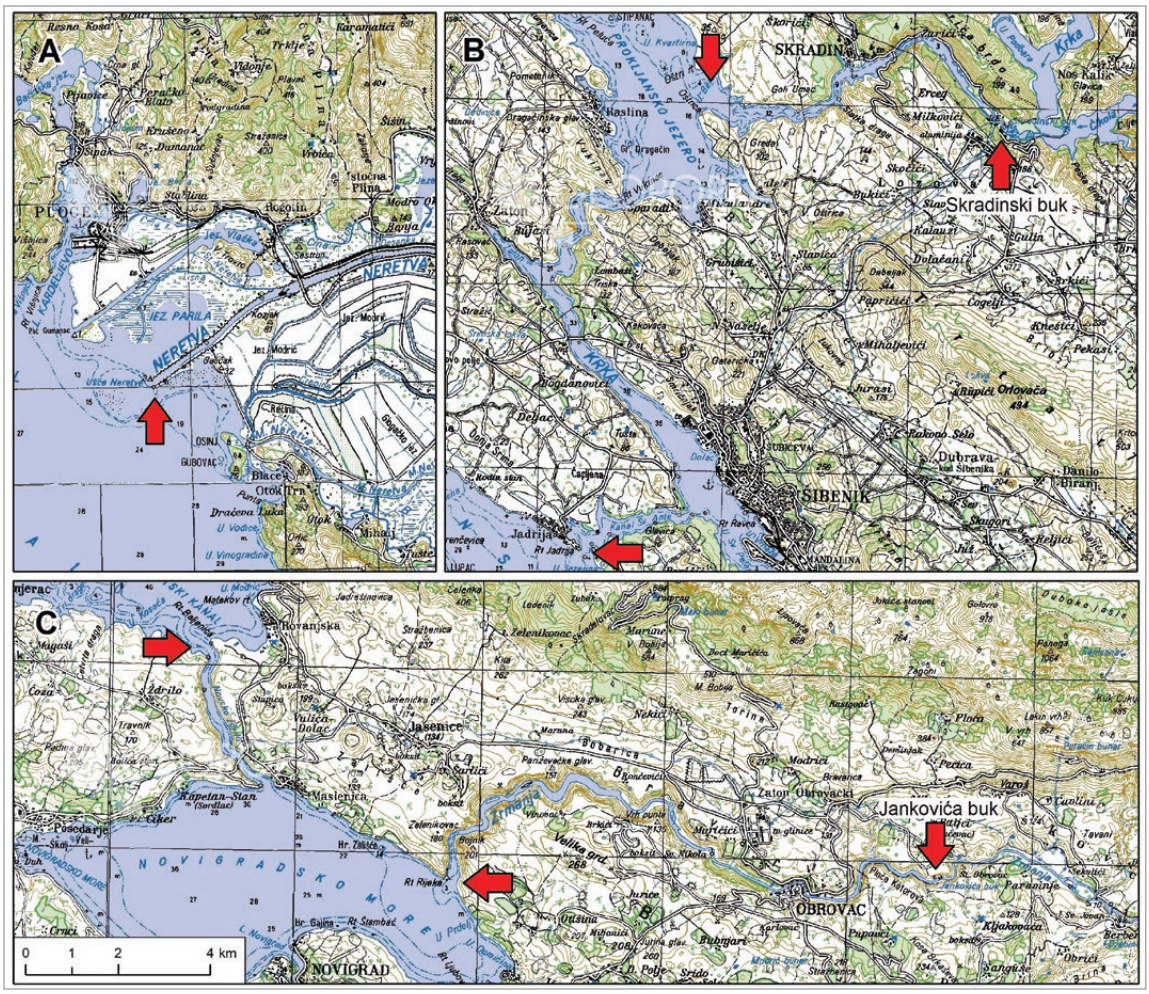
Poseban su izazov ušća rijeka jadranskoga slijeva. Naime, ušća većine rijeka na jadranskoj obali krški su estuariji rijaskoga tipa, a nastala su potapanjem fluviokrških riječnih dolina oblikovanih u karbonatnim stijenama izdizanjem morske razine nakon posljednjega ledenog doba (Felja, 2017; Felja i Juračić, 2018). Nakon relativne stabilizacije morske razine (7500 BP) započinje postupno zatrpavanje nastalih estuarija riječnim sedimentom, a stopa toga zatrpavanja ovisi prvenstveno o donosu materijala iz zaleđa. Primjerice, rijeka Neretva potpuno je razvila deltu unutar prvotnoga estuarija, delte Mirne i Raše su ga djelomično zatrpale, dok Krka i Zrmanja uopće nisu razvile deltu unutar estuarija (Felja i Juračić, 2018). Granice ušća Mirne i Neretve morfološki su jasne zbog postojanja naplavne ravnice prije samoga ušća, odnosno razvijene delte. Krajnja točka pri izračunu duljine navedenih rijeka određena je završetkom korita, koje je danas pod utjecajem mjera kanaliziranja toka (sl. 2A). Međutim, u slučaju rijeka Krke i Zrmanje ne postoji jasna granica u morfologiji riječne doline i korita prema kojoj bi se jednoznačno odredila točka ušća. Budući da je krajnja nizvodna granica estuarija kao prijelazne zone često upitna te ovisi o geološkim, geomorfološkim, hidrološ-

results by listing all natural or artificial watercourses that were included in the calculation of river length, sometimes in several variants (Lonja-Trebež Canal, Česma to Lonja-Strug Canal, Česma to Lonja, and Ilova-Trebež).

The estuaries of the Adriatic Sea are a particular challenge. The mouths of most rivers on the Adriatic coast are karst estuaries of the rias type, formed by the submersion of fluvio-karst river valleys formed in carbonate rocks after sea-level rise following the last ice age (Felja, 2017; Felja and Juračić, 2018). Relative stabilization of sea level (7500 BP) was followed by gradual sedimentation of the formed estuaries by fluvial sediments. The sedimentation rate depends primarily on the sediment supply from the hinterland. For example, the Neretva completely formed a delta within the original estuary, the Mirna and the Raša partially filled theirs, while the Krka and the Zrmanja did not form deltas within their estuaries at all (Felja and Juračić, 2018). The boundaries of the Mirna and Neretva river mouths are morphologically distinct, as there is an alluvial plain, i.e. a developed delta. The end point in calculating the length of these rivers was determined by the end of the river channel, which has been affected by channelisation works (Fig. 2A). However, in the case of the Krka and Zrmanja rivers, there is no clear boundary in the morphology of the river valley and channel that could be used to unambiguously determine the point of the mouth. Since the outermost downstream boundary of the estuary, as a transition zone, is often questionable and depends

kim ili biološkim pokazateljima (Ferreira i dr., 2006), duljina tekućica koje završavaju estuarijem u ovome je radu iskazana na dva načina: do početka samoga estuarija (odnosno bez estuarija) i do krajnjih točaka koje se u literaturi navode kao završetak estuarija. Tako se, prema Prohiću i Juračiću (1989), estuarij rijeke Krke proteže od posljednje aktivne sedrene barijere Skradinskoga buka kroz Prukljansko jezero do Šibenskoga kanala (tvrđava sv. Nikole). Bočata površinska struja usmjerena je k moru, dok protustruja morske vode prodire dnom sve do Skradinskoga buka, koji je prema tome uzet kao završna točka toka

on geological, geomorphological, hydrological, or biological indicators (Ferreira et al., 2006), the length of rivers ending in an estuary is expressed in two ways: up to the beginning of the estuary (i.e. not including the estuary) and up to its end point, which is referred to in the literature as the end of the estuary. Thus, according to Prohić and Juračić (1989), the Krka River estuary extends from the last active travertine barrier of Skradinski Buk through Lake Prukljan to the Šibenik Channel (Fortress of St. Nicholas). The brackish surface current is directed towards the sea, while a counter current of sea water penetrates through the bottom to Skradinski Buk, which is therefore consid-



Sl. 2. Određivanje završnih točaka mjerenja duljine toka u slučaju ušća kod Neretve (A) te početaka i kraja estuarija kod Krke (B) i Zrmanje (C)
Kartografska podloga: DGU (2020b)

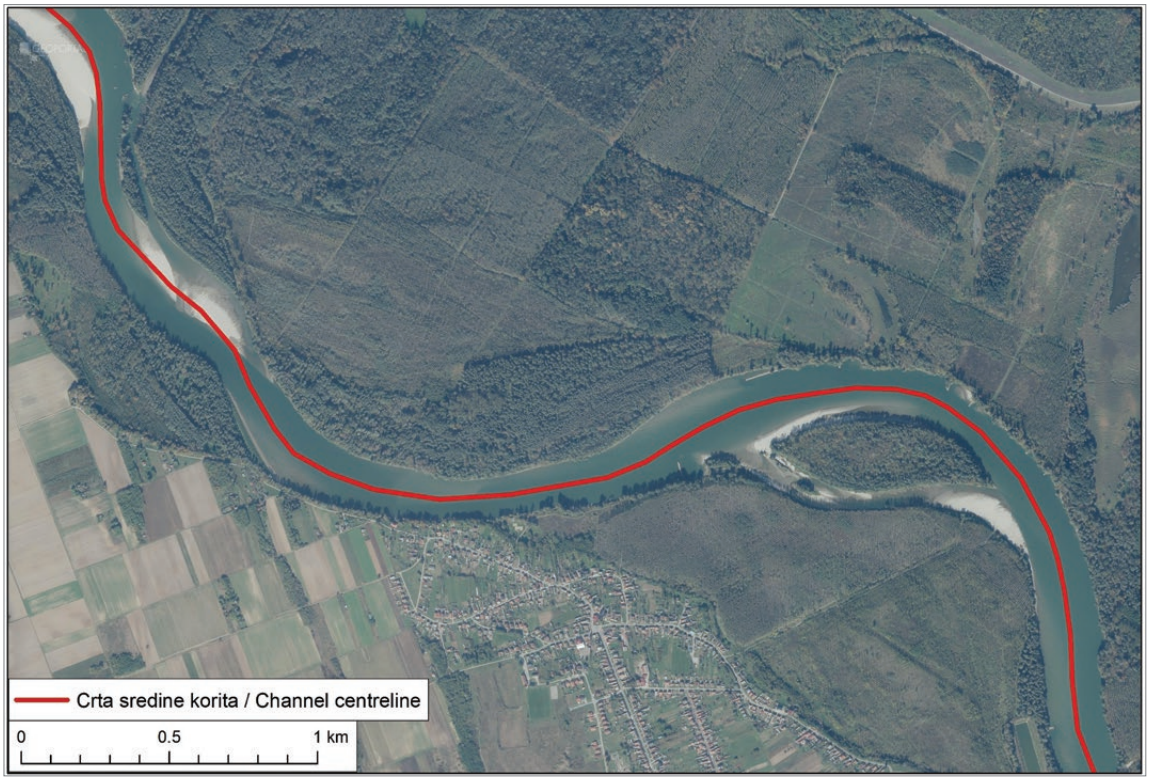
Fig. 2 Determination of end points in river length measurement in the case of the mouth of the Neretva River (A), and the beginning and end points of the estuary of the Krka (B) and the Zrmanja (C) rivers
Base map: CGA (2020b)

Krke bez estuarija (sl. 2B). Posebno je iskazana i duljina do ušća u Prukljan kao karakteristična točka na kraju gornjega dijela estuarija. Duljina toka Zrmanje bez estuarija izmjerena je do Jankovića buka, koji se u literaturi navodi kao početak gornjega dijela estuarija (Viličić i dr., 2008). Estuarij Zrmanje nizvodno se proteže kroz Novigradsko i Karinsko more do Velebitskoga kanala (Fiket i dr., 2017). Za Zrmanju je, prema tome, prikazana duljina do Velebitskog kanala, ali i duljina do Novigradskoga mora, kao završetka klanca (kanjona) rijeke i kao točke koja se katkad navodi kao ušće (sl. 2C).

Duljina tekućice mjerena je glavnim tokom. Kod manjih tekućica to je nakon razrješenja problema oko početka i kraja toka bilo razvidno, no kod nekih većih tekućica javili su se dodatni problemi. Naime, na većim tekućicama često se javljaju sekundarna korita (rukavci), odnosno korito iz jednostavnoga (engl. *single-thread*) prelazi u složeni, razgranati tip (engl. *anabranching*). Nanson i Knighton (1996) definiraju složenu, razgranatu rijeku kao sustav s više korita, koji je obilježen stabilnim riječnim otocima prekrivenima vegetacijom koji dijele tokove i tijekom visokih voda. Riječni otoci mogu nastati erozijom naplavne ravnice, mogu biti posljedica taloženja unutar korita ili se mogu formirati progradacijom rukavaca unutar plavine ili delte. Pojava složenih, razgranatih tipova korita posebno je česta na nizinskim velikim rijekama poput Drave, Mure ili Save, ali i u dinarskom području na segmentima toka koji prolaze kroz polja u kršu, poput Cetine u Hrvatačkom i Sinjskom polju (Pavlek i Faivre, 2020). U tim je slučajevima vektorizirano samo hidrološki glavno korito, tj. duljina sekundarnih korita nije uzeta u obzir u izračunu duljine tekućice (sl. 3). S druge strane, prudovi se smatraju dijelom korita jer na njih aktivno djeluju fluvijalni procesi erozije i taloženja (Charlton, 2007). Iako se za vrijeme niskih ili srednjih voda nalaze iznad površine vode, prudovi nisu uzeti u obzir kod određivanja središnje crte korita prilikom vektorizacije. Prirodnom evolucijom korita prudovi se mogu stabilizirati razvojem vegetacije te spojiti s obalom ili oblikovati riječni otok. Za velike rijeke poput Drave i Mure stabilnost pru-

ered to be the end point of the Krka River without the estuary (Fig. 2B). The length to the mouth in Lake Prukljan is explicitly noted as a characteristic point at the end of the upper part of the estuary. The length of the Zrmanja River without its estuary was measured up to Jankovića Buk, which is mentioned in the literature as the beginning of the upper part of the estuary (Viličić et al., 2008). The Zrmanja estuary extends downstream through the Novigrad and Karin seas to the Velebit Channel (Fiket et al., 2017). Therefore, for the Zrmanja, both the length to the Velebit Channel and the length to the Novigrad Sea, which represent the end of the river canyon and a point sometimes referred to as the estuary, were measured (Fig. 2C).

The length of each river was measured by the main flow. For smaller rivers this was apparent once the problem of the starting and ending point of the river was solved, but for some larger rivers additional problems arose. Namely, in larger rivers, secondary channels (branches) often occur, i.e. the channel changes from a simple single-thread to a multi-thread anabranching type. Nanson and Knighton (1996) defined a anabranching river as a multichannel system, characterised by stable river islands covered with vegetation that divide the flow even at high water levels. River islands may be the result of floodplain erosion, in-channel sedimentation, or progradation of river branches within a crevasse splay or delta. The occurrence of complex anabranching channel types is particularly common for large lowland rivers such as the Drava, Mura or Sava, but also in the Dinaric region for river segments in karst poljes, like the Cetina River in Hrvatačko and Sinjsko poljes (Pavlek and Faivre, 2020). In these cases, only the main hydrological channel was vectorised, i.e. the length of the secondary channels was not taken into account when calculating river length (Fig. 3). On the other hand, fluvial bars are considered to be a part of the channel because they are actively affected by fluvial erosion and deposition (Charlton, 2007). Although they are above the water table during low or mean discharge, the bars were not considered when determining the centreline of the channel during vectorisation. According to natural evolution of the channel, bars can be stabilised by the development of vegetation and become part of a river bank or be transformed into islands. In the case of large rivers such as the Drava



Sl. 3. Segment složenoga korita rijeke Drave uzvodno od Belišća
Izvor: DGU, Digitalni ortofoto 2019. (WMS)

Fig. 3 Segment of the multi-thread channel of the Drava River upstream of Belišće
Source: CGA, Digital Orthophoto 2019 (WMS)

dova određivana je iz ortofoto-karata i terenskih pregleda.

U slučajevima kad tekućica protječe kroz jezero, linija je vektorizirana crtom sredine jezera prema *Copernicus* EU-Hydro modelu, a kada paralelno teku umjetni zaobilazni kanali i prirodni tok, u izračunu je korišten prirodni tok (npr. Drava kod Čakovca, Varaždina, i Donje Dubrave). Također, zbog prirodne dinamike i promjene korita mnogi meandri Drave i Mure danas se više ne nalaze na teritoriju RH te sukladno tomu nisu uračunani u izmjeru duljine rijeke unutar granica države.

Duljine tekućica na području Republike Hrvatske računane su u kartografskoj projekciji HTRS96/TM. Duljine prekograničnih rijeka računane su u projekcijama ETRS 1989 UTM 33 (Drava, Mura i Sava) i UTM 34 (Sava) te na elipsoidu GRS 80 (Dunav).

and Mura, the stability of the bars was determined using orthophoto maps and field surveys.

In cases where the river flows through a lake, the line was vectorised along the centreline of the lake according to the Copernicus EU-Hydro model. In cases where artificial bypass channels and the natural river run parallel, the natural river was used for calculation (e.g. the Drava at Čakovec, Varaždin, and Donja Dubrava). Additionally, due to natural dynamics and channel changes, many meanders of the Drava and Mura rivers are no longer in the territory of the Republic of Croatia and were therefore not taken into account when calculating the length inside Croatia.

The lengths of rivers in the territory of the Republic of Croatia were calculated in HTRS96 / TM cartographic projection. The lengths of transboundary rivers were calculated in ETRS 1989 UTM 33 projections (Drava, Mura and Sava) and UTM 34 (Sava River) and ellipsoid GRS 80 (Danube).

Rezultati

Hrvatskom protječe ukupno 46 tekućica čiji je ukupan tok duži od 40 km, odnosno 47 tekućica ako se rijeka Dobra razdvaja na Gornju i Donju Dobru (tab. 1). Najduljom hrvatskom tekućicom smatra se najdulja tekućica čiji se cjelokupni tok od izvora do ušća i obje obale nalaze unutar teritorija Republike Hrvatske. Prema rezultatima ovog istraživanja najdulja je hrvatska tekućica Karašica sa 148 km duljine od izvora potoka Jovanovice, njezina najdulјega izvorišnog toka na obroncima Papuka, pa do ušća u Dravu nizvodno od Petrijevaca. Najdulja rijeka s izvorom i ušćem u Hrvatskoj jest Kupa s 296 km, no budući da je Kupa dijelom granična rijeka prema Sloveniji, njezina lijeva obala ne nalazi se u potpunosti unutar Hrvatske. Nakon Karašice najdulje rijeke s cjelokupnim tokom i obje obale u Hrvatskoj jesu Lonja-kanal Trebež (135 km) i Vuka (116 km). Također treba naglasiti duljinu zajedničkoga toka Biđa (od početka toka u melioracijskim kanalima kod Donje Vrbe istočno od Slavonskoga Broda) i Bosuta (od Cerne, nakon utoka Biđa), koji u Hrvatskoj iznosi 138 km. Naime, iako je Biđ kod sutoka u Cerni dužega toka, tradicionalno se rijeka nizvodno naziva Bosut. Početkom Bosuta smatra se izvor u aluviju uz lijevu obalu Save nekoliko kilometara uzvodno od Županje.

Rijeka Lonja odvodnjava većinu središnjega dijela Hrvatske, uključujući rijeke Česmu, Glogovnicu i Zelinu. Njezino prirodno porječje uključuje i Ilovu i Pakru, no danas su te rijeke umjetnim hidrotehničkim zahvatima preusmjerene izravno u Savu. Naime, još 1970-ih Ilova se prirodno ulijevala u Trebež, odnosno lijevi krak rijeke Lonje[4]. Međutim, prokapanjem novoga, umjetnoga i potpuno kanalizirana toka u duljini od 4,25 km ušće Ilove u Trebež pomaknuto je južnije. S druge strane, zapadno od prirodnoga korita Trebeža prokopan je novi kanal koji odvodnjava vodu Lonja-Trebeža u Savu (kanal

4 Lonja se u donjem toku dijeli na dva toka, desni tok Stara Lonja ulijeva se u Savu kod sela Lonja, a lijevi tok Trebež prirodno se ulijeva u Savu 6 km nizvodnije. Na kartama Treće vojne izmjere Austro-Ugarske Monarhije s kraja 19. stoljeća Trebež je prikazan kao veći tok, a toponim Stara Lonja upućuje na to da se radi o starijem koritu koje je već tada bilo sekundarno.

Results

A total of 46 rivers longer than 40 km flow through Croatia, i.e. 47 rivers if the Dobra River is separated into Gornja Dobra and Donja Dobra (Tab. 1). The longest Croatian river is considered to be the longest river which has its entire course, from source to mouth, and both banks located entirely within the territory of the Republic of Croatia. According to the results of this study, the longest Croatian river is the Karašica, with a length of 148 km from its source - the Jovanovica stream, its longest headstream on the slopes of Papuk Mountain - o its confluence with the Drava River downstream from Petrijevci. The longest river with its source and mouth in Croatia is the Kupa at 296 km. However, since the Kupa is partly a border river with Slovenia, its left bank is not entirely within Croatia. After the Karašica, the longest rivers with their entire course and both banks in Croatia are the Lonja - Trebež Canal (135 km) and the Vuka (116 km). The length of the joint flow of Biđ (from the beginning of the flow in the reclamation channels near Donja Vrba east of Slavonski Brod) and Bosut (from Cerna, after the confluence with the Biđ) rivers, which measures 138 km in Croatia, are also worth mentioning. Although the Biđ is longer than the Bosut near their confluence in Cerna, the river is traditionally called Bosut downstream. The beginning of the Bosut River is considered to be a spring in the alluvium on the left bank of the Sava River a few kilometres upstream from Županja.

The Lonja River drains most of central Croatia, including the Česma, Glogovnica, and Zelina rivers. Its natural catchment area also includes the Ilova and Pakra rivers, but they were diverted directly into the Sava. Into the 1970s, the Ilova River flowed naturally into the Trebež River, i.e. into the left branch of the Lonja River[4]. However, due to the construction of a new 4.25 km artificial channel, the confluence of the Ilova and the Trebež rivers was moved further south. On the other side, a new channel was dug to the west of the natural channel of the Trebež, which diverts the waters of the Lonja-Trebež into the Sava River (Trebež Canal). In

4 In its lower course, the Lonja River divides into two branches, of which the right branch, called Stara Lonja, flows into the Sava River near the village of Lonja, and the left branch, called Trebež, naturally flows into the Sava 6 km downstream. On the maps of the Third Military Survey of the Austro-Hungarian Monarchy from the end of the 19th century, the Trebež is shown as a larger stream, and the toponym Stara Lonja indicates that it is an older channel that had already become secondary.

Tab. 1. Koordinate izvora i ušća te izmjerene duljine toka (ukupno i u Hrvatskoj) za tekućice dulje od 40 km
Tab. 1 Coordinates of sources and mouths (confluences) and measured lengths (totals and in Croatia) for rivers longer than 40 km

Br. / No.	Naziv tekućice / The river name	Koordinate izvora / Source coordinates*		Koordinate ušća / Mouth coordinates*		Ukupna duljina (km) / Total length (km)	Duljina u RH (km) / Length in Croatia (km)
		X	Y	X	Y		
1.	Dunav / Danube	4183510	2777471	5857544	2653595	2860,14	129,41
2.	Sava	403134	5149536	930917	4978965	933,55	505,46
3.	Drava	290117	5178010	806734	5050815	706,90	292,22
4.	Mura	374524	5220143	644846	5129351	469,30	61,04
5.	Kupa	358488	5040609	492233	5035575	295,95	295,95
6.	Neretva	666778	4795953	577019	4764873	232,95	21,73
7.	Una	468463	4917790	532799	5014726	215,91	105,44
8.	Bosut-Bid	625873	5003514	726463	4981965	175,58	137,82
	Bosut	671273	4997492	726463	4981965	133,04	95,27
9.	Korana - Bijela rijeka	425490	4966362	427736	5040484	154,94	154,94
	Korana (Sastavci)	429685	4974060	427736	5040484	142,01	142,01
10.	Karašica - Voćinska rijeka - Jovanovica	572208	5051248	662990	5053345	148,15	148,15
11.	Lonja - kanal Trebež / Lonja - Trebež Canal	481359	5116932	519887	5024883	135,41	135,41
12.	Glina	431860	5000216	470444	5032845	121,81	121,81
13.	Vuka	627619	5024119	696311	5026665	116,37	116,37
14.	Česma (do Lonje) / (to Lonja)	560432	5074624	500977	50424643	112,22	112,22
	Česma (do kanala Lonja-Strug) / (to Lonja-Strug Canal)	560432	5074624	498574	5048104	106,00	106,00
15.	Bednja	460617	5127809	519763	5129332	106,26	106,26
16.	Cetina	494375	4870768	515097	4811051	105,28	105,28
17.	Dobra**	378538	5029469	423779	5045942	105,04	105,04
	Gornja Dobra	378538	5029469	399865	5014915	52,99	52,99
	Donja Dobra	402933	5018238	423779	5045942	52,05	52,05
18.	Ilova-Trebež	573660	5064279	521371	5023244	103,16	103,16
19.	Sutla	445763	5124564	436569	5080807	93,89	85,85
20.	Orljava	572486	5030078	596382	4996996	93,35	93,35
21.	Krka-Krčić (do Šibenskog kanala) / (to the Šibenik Channel)	420990	4995032	447717	4842508	87,45	87,45
	Krka-Krčić (do Prukljanskog jezera) / (to the Prukljan Lake)	420990	4995032	450641	4852325	71,70	71,70
	Krka-Krčić (do Skradinskog buka) / (to Skradinski buk)	486514	4876205	456876	4851816	63,77	63,77
	Krka (od vrela Krke do Šibenskog kanala) / (from Krka spring to the Šibenik Channel)	478765	4878067	447717	4842508	76,90	76,90
	Krka (od vrela Krke do Prukljanskog jezera) / (from Krka spring to the Prukljan Lake)	478765	4878067	450641	4852325	61,14	61,14
	Krka (od vrela Krke do Skradinskog buka) / (from Krka spring to Skradinski buk)	478765	4878067	456876	4851816	53,21	53,21
22.	Baranjska Karašica	660377	5116884	682790	5082050	83,21	30,97

nastavak Tab. 1. Koordinate izvora i ušća te izmjerene duljine toka (ukupno i u Hrvatskoj) za tekućice dulje od 40 km
continued Tab. 1 Coordinates of sources and mouths (confluences) and measured lengths (totals and in Croatia) for rivers longer than 40 km

Br. / No.	Naziv tekućice / The river name	Koordinate izvora / Source coordinates*		Koordinate ušća / Mouth coordinates*		Ukupna duljina (km) / Total length (km)	Duljina u RH (km) / Length in Croatia (km)
		X	Y	X	Y		
23.	Zrmanja (do Velebitskog kanala) / (to the Velebit Channel)	466818	4896215	421521	4901434	81,41	81,41
	Zrmanja (do Novigradskog mora) / (to the Novigrad Sea)	466818	4896215	427127	4896124	72,80	72,80
	Zrmanja (do Jankovića buka) / (to Jankovića buk)	466818	4896215	437785	4896179	57,71	57,71
24.	Lika	423698	4921051	395273	4959235	77,46	77,46
25.	Sunja	482727	5006766	521984	5019363	74,60	74,60
26.	Vučica	596818	5039413	650610	5056905	72,88	72,88
27.	Pakra	570297	5041305	520761	5028774	69,91	69,91
28.	Krapina	480387	5114555	447441	5076615	68,00	68,00
29.	Plitvica	470592	5133431	518161	5129665	66,63	66,63
30.	Glogovnica	500992	5113631	507598	5067721	65,41	65,41
31.	Mrežnica	420990	4995032	426973	5036612	64,58	64,58
32.	Gliboki	500954	5115059	538619	5115395	57,45	57,45
33.	Kupčina	414489	5070838	444501	5043721	56,77	56,77
34.	Bid	625873	5003514	672029	5008349	56,74	56,74
35.	Čikola-Vrba	494278	4840896	457961	4851503	54,48	54,48
	Čikola (vrelo Čikole) / (Čikola spring)	485886	4850822	457961	4851503	39,73	39,73
36.	Mirna	310096	5025169	272240	5023712	53,63	53,63
37.	Bistra Koprivnička	507712	5110383	547183	5108375	53,34	53,34
38.	Toplica	569424	5052169	534062	5042468	50,39	50,39
39.	Londža	618221	5032044	602928	5015210	49,60	49,60
40.	Veliki Strug	522048	5024733	550761	5002743	47,11	47,11
41.	Trnava	487063	5147022	516624	5139127	46,99	46,99
42.	Odra	472283	5061900	488634	5039380	44,32	44,32
43.	Zelina	476777	5094748	483548	5061794	43,74	43,74
44.	Čađavica	574470	5052062	593229	5075379	43,20	43,20
45.	Butižnica	472252	4905591	473751	4878517	42,00	39,91
46.	Subocka	555125	5027152	530186	5018252	40,27	40,27

*Koordinatni sustavi: Dunav – ETRS 1989 LAEA, Sava, Drava i Mura – ETRS 1989 UTM Zone 33N, ostale rijeke – HTRS96/TM
/ Coordinate systems: Danube – ETRS 1989 LAEA, Sava, Drava and Mura – ETRS 1989 UTM Zone 33N, other rivers – HTRS96/TM

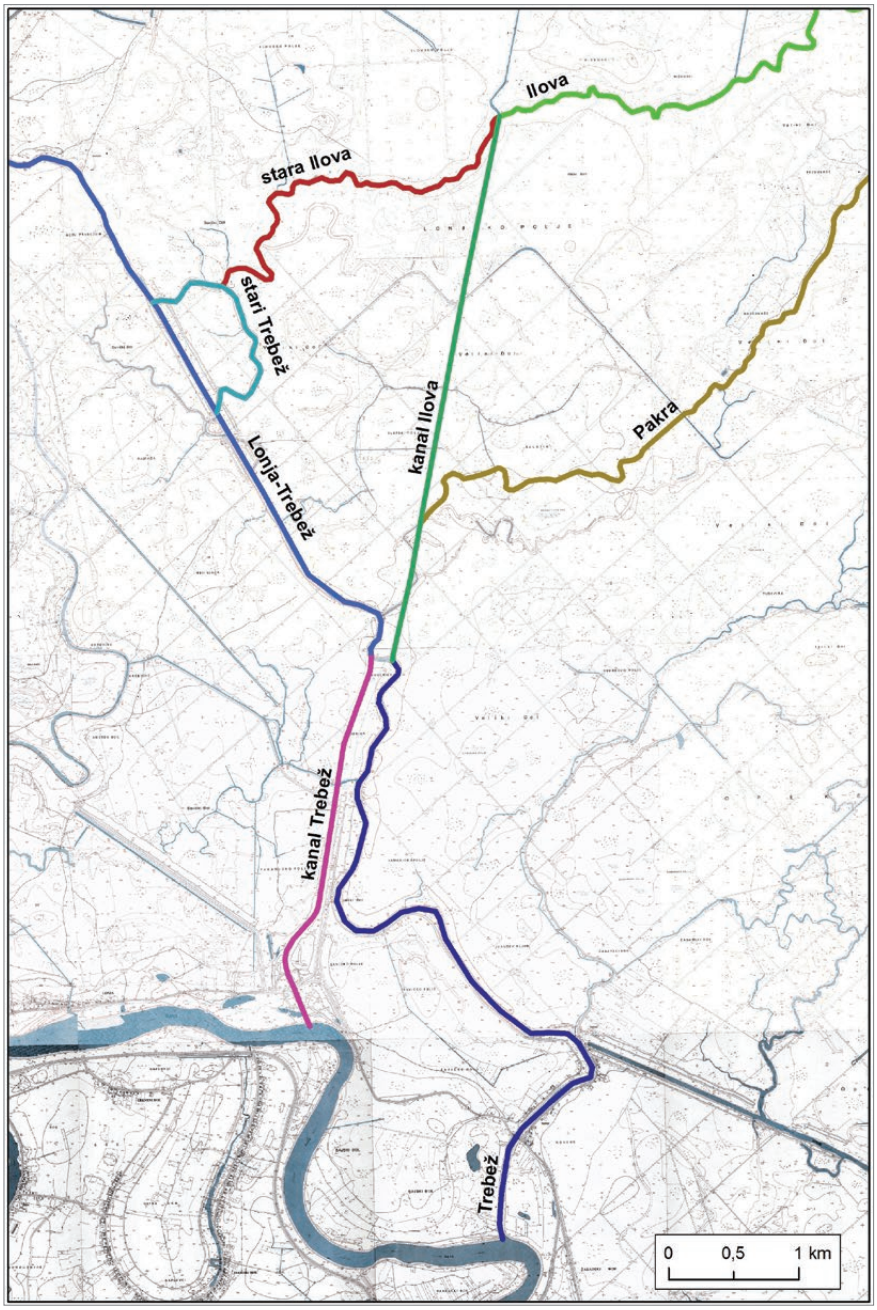
**Gornja i Donja Dobra, ne uključuje podzemnu vezu
/ Gornja and Donja Dobra, does not include the underground connection

Trebež). Na taj su način vode Lonje i Ilove (površinski) odvojene, a starim koritom Trebeža u biti teče voda Ilove (sl. 4). Duljina toka Ilove do ulaska u korito Trebeža iznosi 97 km, uključujući novo kanalizirano korito (kanal Ilova), što s duljinom toka Trebeža do Save ukupno iznosi 103 km.

Rijeka s najduljim tokom u Hrvatskoj jest Sava s 505 km duljine od Bregane do Račino-

this way, the waters of the Lonja and the Ilova rivers are separated (on the surface), and the water of the Ilova actually flows through the old channel of the Trebež (Fig. 4). The length of the Ilova River to the confluence with the Trebež River is 97 km, including the new artificial canal (Ilova Canal), which totals 103 km together with the length of the Trebež River to the Sava River.

The river with the longest flow in Croatia is the Sava, with a length of 505 km from Bregana to Rači-



Sl. 4. Antropogene promjene donjega toka Ilove i Lonja-Trebeža
Kartografska podloga: DGU (2020a)

Fig. 4 Anthropogenic changes in the lower course of the Ilova and Lonja-Trebež
Base map: CGA (2020a)

vaca. Njezina ukupna duljina od izvora Save Dolinke kod Zelenaca između Rateča, Planice i Podkorena pa do ušća u Dunav kod Beograda iznosi 934 km. Nakon Save i Kupe treća rijeka po duljini toka u Hrvatskoj jest Drava s 291 km duljine. Druga najdulja europska rijeka, Dunav, protječe graničnim područjem na istoku Hrvatske u duljini od 129 km.

novac. Its total length from the source of the Sava Dolinka near Zelenci between Rateče, Planica and Podkoren, to the confluence with the Danube River near Belgrade is 934 km. After the Sava and the Kupa, the third longest river in Croatia is the Drava with a length of 291 km. The second longest river in Europe, the Danube, flows for 129 km through the border area in eastern Croatia.

Na području jadranskoga slijeva rijeka s najduljim tokom u Hrvatskoj jest Cetina (105 km). Neretva je rijeka s ukupno najduljim tokom (233 km), no više od 90 % njezina toka nalazi se u susjednoj Bosni i Hercegovini.

Iako je danas kraća od 40 km, vrijedi spomenuti rijeku Gacku, koja se prirodno dijeli na tri rukavca koji teku do ponora u Donjem Švičkom jezeru, Hrvatskom polju i Gusić-polju. Međutim, zbog izgradnje hidroenergetskoga sustava veći dio toka rijeke Gacke sada je preusmjeren kroz podzemni tunel uzvodno od grada Otočca prema umjetnom Gusić-jezeru. Nizvodna prirodna korita uglavnom su suha, osim u doba velikih protoka. Duljine rijeke Gacke od njezina izvora do triju ponora su: Donje Švičko jezero – 26 km, Gusić-polje – 41 km, Hrvatsko polje – 50 km, a ukupna duljina svih tokova iznosi 61 km.

Također je bitno spomenuti sustav tekućica koji se dijelom nalazi u Imotsko-bekijskom polju. Obilježen složenom izmjenom podzemnoga i površinskoga otjecanja, taj je sustav zapravo jedna tekućica koja se sastoji od segmenata na kojima se voda gubi, ponire i teče podzemnim putem. Budući da tekućica svojim tokom mijenja ime (Ričina-Suvaja-Sija-Vrljika-Tihaljina-Sita-Mlade-Trebižat), u literaturi se navodi kao „rijeka s osam imena" (Bonacci i dr., 2013). Ukupna duljina ovoga sustava iznosi 113 km (ne uključujući podzemnu vezu i uzvodno do Tribistova jezera). Prateći najduži izvorišni krak, ukupna duljina doseže približno 118 km. Duljina ovoga sustava u Hrvatskoj iznosi 34 km, a sastoji se od dijelova toka Ričine, ukupnoga toka Suvaje i Sije te dijela toka Vrljike, dok se ostatak tokova nalazi u Bosni i Hercegovini.

Prema toponimu na topografskoj karti rijeka Korana započinje nizvodno od posljednjega plitvičkog slapišta Sastavaka, što je i implicitno prihvaćeno u literaturi (Biondić i dr., 2016). Tako mjerena duljina Korane iznosi 142 km. Međutim, hidrografski i geomorfološki se izvorom Korane može smatrati izvor Bijele rijeke, ujedno najdulјega toka u cjelokupnom sustavu površinskoga otjecanja. Duljina od izvora Bijele rijeke, nizvodno mjerena crtom sredine kroz Plitvička jezera iznosi 155 km.

In the area of the Adriatic basin, the river with the longest flow in Croatia is the Cetina (105 km). The longest river overall is the Neretva (233 km), but more than 90% of its course is in the neighbouring state of Bosnia and Herzegovina.

Although it is today shorter than 40 km, the Gacka River it is worth mentioning, which naturally divides into three branches flowing to ponors in Donje Švičko Lake, Hrvatsko Polje, and Gusić Polje. However, due to construction of a hydrological power plant, most of the Gacka River flow is now diverted through an underground tunnel upstream of the town Otočac towards the artificial Gusić Lake. Natural channels downstream are mostly dry, except in times of high flows. The lengths of the Gacka River from its spring to the three ponors are as follows: Donje Švičko Lake – 26 km, Gusić Polje – 41 km, Hrvatsko Polje – 50 km, the total of all flows is 61 km.

Also, it is important to mention one river system which is partly located in Imotsko-Bekijsko Polje. Characterized by a complex groundwater and surface water exchange, it actually represents one river with underground stream sections. However, since the river changes its name as it flows downstream (Ričina-Suvaja-Sija-Vrljika-Tihaljina-Sita-Mlade-Trebižat River), it is called the "Eight-Name River" in relevant literature (Bonacci et al., 2013). The total length of this river system is 113 km (not including the underground connection and upstream up to Tribistovo Lake). Following the longest headstream, the total length reaches approximately 118 km. The length of this system in Croatia is 34 km, and it consists of parts of the Ričina, the total flow of the Suvaja and Sija, and part of the Vrljika river flows. The rest of the river system is located in Bosnia and Herzegovina.

According to the toponym on the topographic map, the Korana River starts downstream from the last Plitvice Lakes waterfall (Sastavci), which is implicitly accepted in the literature (Biondić et al., 2016). The measured length of the Korana is 142 km. However, from a hydrographical and geomorphological point of view, the source of the Bijela rijeka, the longest headstream in the entire surface drainage system, can be considered the source of the Korana. The length of the Korana from the source of the Bijela rijeka downstream measured at the centreline through Plitvice Lakes is 155 km.

Karašica – najdulja hrvatska tekućica

Toponim Karašica na TK25 i HOK5 najuzvodnije javlja se nakon sutoka Donje Voćinske rijeke i Donje Branjinske rijeke. Danas se dio vode iz Voćinske rijeke i Branjinske rijeke odvodnjava umjetnim Voćinsko-dravskim kanalom u Dravu (zbog toga stoji ovaj naziv *Donja*), dok se na Donjoj Voćinskoj rijeci nalazi zapornica koja se zatvara samo u iznimnim slučajevima. Ako se prate prirodni vodotoci, kao izvorišni tok Karašice treba uzeti Voćinsku rijeku jer je dulja od Branjinske rijeke. Voćinska rijeka nastaje sutokom potoka Jovanovice i Đedovice (Djedovice) u Voćinu te njezina duljina do sutoka s Branjinskom rijekom iznosi 54,4 km (sl. 5).

Dulji izvorišni tok Voćinske rijeke njezin je lijevi krak, potok Jovanovica, duljine 12,8 km od izvora na 630 m nadmorske visine na obroncima Papuka. Jovanovica je dulja od Đedovice za nešto više od jednoga kilometra, te je njezin tok na TK25 prikazan punom linijom, dok je najdulji tok Đedovice prikazan isprekidanom linijom, što znači da se radi o povremenom toku.

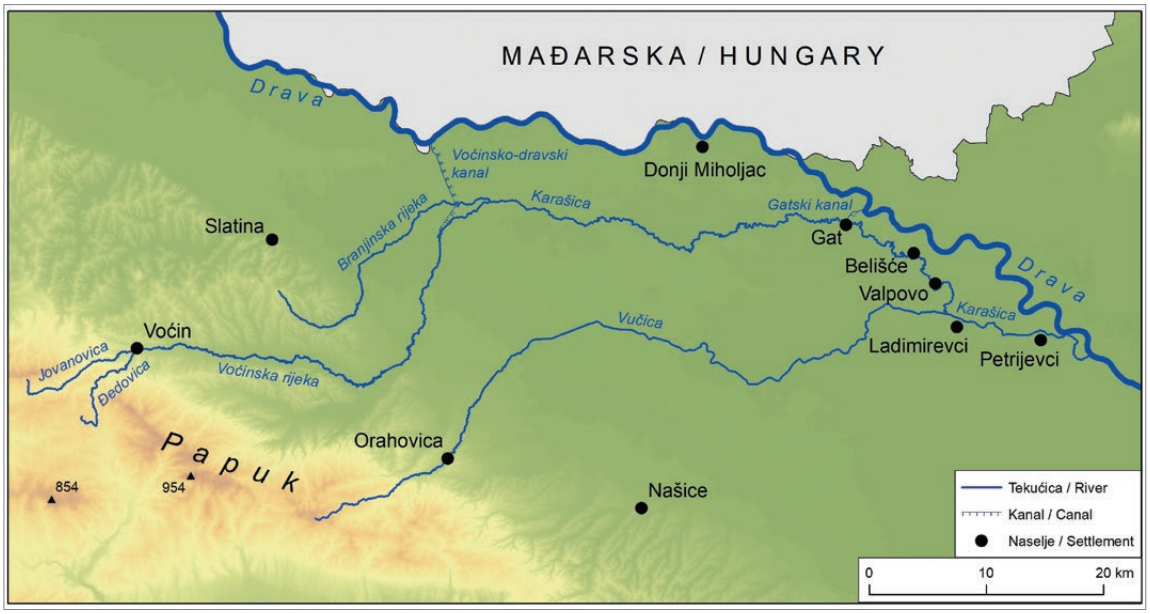
Nedvojbeni tok rijeke Karašice prema TK25 proteže se od sutoka Donje Voćinske i Donje Branjinske rijeke do sutoka s Vučicom kod naselja Ladimirevci i dug je 64,9 km. Međutim, nizvodno od Ladimirevaca na TK25 naziv tekućice je Karašica, dok se u dokumentima Hrvatskih voda (2014) tekućica naziva Vučica. Na topografskoj karti Treće vojne izmjere Austro-Ugarske Monarhije u mjerilu 1 : 25 000, koja je izrađena u razdoblju 1869. – 1887., jasno je vidljivo da je korito Karašice puno šire od korita Vučice te se analizom tlocrta korita može nedvojbeno zaključiti da se u to vrijeme Vučica ulijevala u svojedobno veću rijeku Karašicu, o čemu svjedoči i toponim Karašica na tekućici nakon sutoka. Međutim, od kraja 19. stoljeća izvedeni su mnogi melioracijski zahvati u porječju navedenih rijeka (Nadilo, 2014). Kao što je već navedeno, dio vode Voćinske rijeke

Karašica - the longest Croatian river

The toponym Karašica appears most upstream on TK25 and HOK5 after the confluence of the Donja Voćinska River and the Donja Branjinska River. Today, part of the water of the Voćinska River and the Branjinska River is diverted into the Drava River through the artificial Voćinska-Drava Canal (hence the name Donja, i.e. Lower). The sluice on the Donja Voćinska River closes only in exceptional cases. Following the natural watercourses upstream, the headstream of the Karašica should be the Voćinska, as it is longer than the Branjinska River. The Voćinska River is formed by the confluence of the Jovanovica and Đedovica (Djedovica) streams in Voćin, and its length to the confluence with the Branjinska River is 54.4 km (Fig. 5).

The longer headstream of the Voćinska River is its left branch, the Jovanovica stream, which is 12.8 km long from its spring on the slopes of Papuk at 630 m above sea level. The Jovanovica is slightly more than a kilometre longer than the Đedovica, and its course is shown on TK25 by a solid line, while the longest course of the Đedovica is shown by a dashed line, indicating that it is an intermittent stream.

The undisputed 64.9 km long course of the Karašica river according to TK25 extends from the confluence of the Donja Voćinska and Donja Branjinska rivers to the confluence with the Vučica near the settlement of Ladimirevci. However, the river downstream from Ladimirevci is called the Karašica on TK25, while in Croatian Waters' (2014) documents it is called the Vučica. The topographic map of the Third Military Survey of the Austro-Hungarian Monarchy at a scale of 1:25,000 (1869–1887), clearly shows that the channel of the Karašica is much wider than that of the Vučica. From the analysis of the channel planform, one can conclude that the Vučica undoubtedly flowed into the once wider Karašica at that time. This is proven by the contemporary toponym on the map (TK25) downstream of the confluence. However, since the end of the 19th century, numerous land reclamation activities have been carried out in the catchment areas of these rivers (Nadilo, 2014). As mentioned above, part of the



Sl. 5. Tok Karašice i njezinih glavnih pritoka
Kartografska podloga: DGU, DEM10

Fig. 5 The flow of the Karašica River and its main tributaries
Base map: CGA, DEM10

odvodnjava se Voćinsko-dravskim kanalom, a dio vode iz Karašice se od 1881. godine odvodnjava Gatskim kanalom izravno u Dravu 22 km uzvodno od sutoka s Vučicom. Zbog toga je protok Karašice prije sutoka s Vučicom zacijelo smanjen u odnosu na protok s kraja 19. stoljeća, pa se dio rijeke od Gata do spoja s Vučicom često naziva „Mrtva Karašica" (Nadilo, 2014). S druge strane, rijeka Vučica danas odvodnjava puno veće područje nego ranije izgradnjom melioracijskih kanala. Vučica danas ima više vode od Karašice u donjem toku te je njezino korito na sutoku tih dviju rijeka šire. Tok Karašice od sutoka s Vučicom do ušća u Dravu dugačak je 16 km, a ukupna je duljina Karašice od izvora Jovanovice do ušća u Dravu 148,2 km.

U razmatranju Nadila (2014) o problematici duljina rijeka Karašice i Vučice navedeni su podatci o duljini Karašice od 128,45 km i duljini Vučice od 89,08 km, koji su izračunati na temelju *Glavnoga provedbenog plana za obranu od poplava* iz veljače 2014., ponajprije Privitka 1. i uz pomoć Popisa voda I. reda iz NN 79/2010. Navedeni podatci podrazumijevaju da se Karašica ulijeva u Vučicu te prema tome duljina

water of the Voćinska has been diverted through the Voćinska-Drava Canal and, since 1881, part of the water of the Karašica has been diverted through the Gat Canal directly into the Drava 22 km upstream from the confluence with the Vučica. Therefore, the flow of the Karašica prior to its confluence with the Vučica is certainly less than it was at the end of the 19th century, which is why the part of the river from Gat to the confluence with the Vučica is often referred to as the "Dead Karašica" (Nadilo, 2014). On the other hand, due to land reclamation works, the Vučica drains a much larger area today than it did in the past. Today, the Vučica carries more water in its lower reaches than the Karašica, and its channel at the confluence is wider. The course of the Karašica from the confluence with the Vučica to the confluence with the Drava is 16 km long, and the total length of the Karašica from the source of the Jovanovica to its confluence with the Drava is 148.2 km.

In his discussion of the lengths of the Karašica and Vučica rivers, Nadilo (2014) stated that the length of the Karašica was 128.45 km and the length of the Vučica was 89.08 km, calculated on the basis of the Main Implementation Plan for Flood Protection (of February 2014), specifically Annex 1, and with the help of the List of 1st Order Watercourses (NN 79/2010).

Vučice odgovara podatku izmjerenom u ovome radu ako se doda još 16 km toka do Drave. Duljina Karašice prema izračunu navedenom u radu Nadila (2014) oko 4 km kraća je od duljine izračunate u ovome radu, između ostaloga jer je kao izvorišni tok uzet potok Đedovica (Djedovica) za koji se u radu tvrdi da je dulji.

Treba napomenuti da su zbog izravnavanja i kanaliziranja korita duljine većine rijeka u Panonskoj Hrvatskoj zasigurno skraćene u odnosu na stanje s početka stoljeća (Živaković-Kerže, 2004; Plantak i dr., 2016; Martinić i Orešić, 2020). Primjerice, 20 % današnjega toka Lonje potpuno je izravnano. Također, i Karašica je kanalizirana i izravnana u duljini od oko 15 % današnjega toka, no ne takvim intenzitetom kao Lonja. S druge strane, zbog presijecanja meandara Drave ušće Karašice pomaknulo se prema jugoistoku te produljilo rijeku za preko 2 km.

Usporedba s drugim izvorima podataka

Za 30 od ukupno 46 izmjerenih tekućica dostupni su službeni podatci o duljini toka iz Statističkoga ljetopisa (DZS, 2018) ili iz Strategije upravljanja vodama (Hrvatske vode, 2009) (tab. 2). Što se tiče ukupne duljine toka, 21 duljina izmjerena u radu razlikuje se manje od 5 % od vrijednosti iznesenih u Ljetopisu ili u Strategiji. Ukupne duljine Mure, Korane, Česme, Ilove i Krke (do Šibenskog kanala) razlikuju se između 5 i 10 %, a duljine Gline, Bednje, Odre i Zrmanje (osim do Novigradskoga mora) za više od 10 % od vrijednosti iz Ljetopisa ili Strategije.

Prema podatcima iz Statističkoga ljetopisa najdulja je hrvatska rijeka Bednja s 133 km duljine. U ovome radu izračunata duljina Bednje iznosi 106 km od kartografski označena izvora najduljega, lijevoga izvorišnog kraka kod naselja Bednjica, koji se i tradicionalno smatra izvorom Bednje. Drugi izvorišni krak koji se spominje u literaturi (Počakal, 1982) jest izvorišno područje podno Brezove gore koje čine potoci Čemernica i Hladni potok, koji se ulijevaju u Trakošćansko jezero. Međutim, duljina potoka Čemernice od početka plave isprekidane linije na topografskoj karti do sutoka s lijevim

The given data imply that the Karašica flows into the Vučica. Therefore, the length of the Vučica is the same as the data measured in this paper, if another 16 km of flow would be added to the Drava. The length of the Karašica according to the calculation in the paper by Nadilo (2014) was about 4 km shorter than the length calculated in this paper, partly because the Đedovica stream was given as the longest headstream.

It should be noted that the lengths of most rivers in Pannonian Croatia are certainly shorter than they were the beginning of the 20th century due to straightening and channelisation works (Živaković-Kerže, 2004; Plantak et al., 2016; Martinić and Orešić, 2020). For example, 20% of today's Lonja River has been completely straightened. Similarly, 15% of the Karašica has also been channelized and straightened, but not with the same intensity as the Lonja. On the other hand, due to the meander cutoff on the Drava River, the confluence of the Karašica River has shifted to the southeast, lengthening the river by over 2 km.

Comparison with other data sources

Official data on river lengths from the Statistical Yearbook (CBS, 2018) or from the Water Management Strategy (Croatian Waters, 2009) (Tab. 2) are available for 30 of the 46 measured rivers. In terms of total river length, the 21 lengths measured in this study differ by less than 5% from the values reported in the Yearbook or in the Strategy. The total lengths of the Mura, Korana, Česma, Ilova, and Krka (up to the Šibenik Channel) rivers differ between 5 and 10%, and the lengths of the Glina, Bednja, Odra, and Zrmanja (except up to the Novigrad Sea) rivers differ by more than 10% from the values in the Yearbook or the Strategy.

According to the official data of the Statistical Yearbook, the longest Croatian river is the Bednja with a length of 133 km. In this paper, the calculated length of the Bednja is 106 km, measured from the cartographically marked source of the longest, left headstream near the settlement of Bednjica, which is traditionally considered the source of the Bednja. The second headstream mentioned in the literature (Počakal, 1982) is the headwaters at the foot of Brezova Gora, consisting of the Čemernica and Hladni Potok streams, which flow into Lake Trakošćan. However, the length of the Čemernica

Tab. 2. Usporedba duljina tekućica izmjerenih u ovome radu s ostalim dostupnim službenim podatcima
Tab. 2 Comparison of the river lengths measured in this study with other available official data

Naziv tekućice / The river name	Provedeno istraživanje / This study		Statistički ljetopis 2018. / Statistical Yearbook 2018		Strategija upravljanja vodama 2009. / Water Management Strategy 2009	
	Ukupna duljina (km) / Total length (km)	Duljina u RH (km) / Length in Croatia (km)	Ukupna duljina (km) / Total length (km)	Duljina u RH (km) / Length in Croatia (km)	Ukupna duljina (km) / Total length (km)	Duljina u RH (km) / Length in Croatia (km)
Dunav / Danube	2860	129	2857	188	2857	138
Sava	934	505	945	562	946	510
Drava	707	292	707	505	749	323
Mura	469	61	438	…	493	83
Kupa	296	296	296	296	294	294
Neretva	233	22	225	20	215	22
Una	216	105	212	120	212	116
Karašica	148	148	…	…	150	150
Korana (Sastavci)	142	142	134	134	134	134
Lonja – kanal Trebež / Trebež Canal	135	135	133	133	…	…
Bosut	133	95	186	151	132	81
Glina	122	122	100	100	100	100
Vuka	116	116	112	112	126	126
Bednja	106	106	133	133	…	…
Česma*	106 (112)	106 (112)	124	124	96	96
Cetina	105	105	101	101	104	104
Dobra	105	105	104	104	104	104
Ilova-Trebež	103	103	85	85	96	96
Sutla	94	86	92	89	92	89
Orljava	93	93	89	89	97	97
Lika	77	77	…	…	77	77
Sunja	75	75	69	69	77	77
Krapina	68	68	75	75	65	65
Plitvica	67	67	65	65	…	…
Mrežnica	65	65	63	63	63	63
Zrmanja (do Velebitskog kanala) / (to the Velebit Channel)	81	81	69	69	69	69
Kupčina	57	57	56	56	…	…
Mirna	54	54	53	53	53	53
Krka (do Šibenskog kanala) / (to the Šibenik Channel)	77	77	73	73	72	72
Odra	44	44	83	83	…	…

*napomena: za rijeku Česmu navedene su obje izmjerene duljine u skladu s tab. 1.
/ note: for the river Česma, both measured lengths are listed in accordance with tab. 1

izvorišnim krakom nizvodno od Trakošćana jest 5,3 km. Duljina lijevoga izvorišnog kraka (i toponimski Bednja na HOK-u) od naselja Bednjice do Trakošćana iznosi 5,7 km. Počakal (1982) navodi duljinu Bednje od 103 km, a kao izvorište uzima Brezovu goru. Prema tome, izvor službenoga podatka o duljini Bednje od 133 km nejasan je te se vjerojatno radi o pogrešci u prepisivanju podataka.

from the beginning of the blue dashed line on the topographic map to the confluence with the left headstream downstream from Trakošćan is 5.3 km. The length of the left headwater branch (and the toponymic Bednja on HOK) from the settlement of Bednjice to Trakošćan is 5.7 km. Počakal (1982) stated that the length of the Bednja was 103 km, citing Brezova Gora as its source. Therefore, the

Izmjerena duljina rijeke Gline koja je za 22 km veća od podataka iz Ljetopisa i Strategije može se pripisati detaljnijoj vektorizaciji toka koji karakterizira velik broj meandara u srednjem i donjem toku. Također je moguće da su u navedenim izvorima kao početak toka uzeti izvori nizvodnije od vrela Gline kod Donjeg Kremena, koja su uzeta kao početak toka u ovome radu.

U slučaju rijeke Krke duljine od vrela Krke do Šibenskoga kanala (77 km) i od izvora Krčića do Prukljanskog jezera (72 km) najsličnije su službenim podatcima (72/73 km). Prema prostornom registru Hrvatskih voda, vodno tijelo Krke završava kod mosta uzvodno od Skradina, koji je udaljen od Skradinskog buka 3,3 km. Međutim, nema nikakva hidrološkoga ni morfološkoga opravdanja za izbor upravo te točke gdje je izgrađen most. No i da se na ovim radom izmjeren podatak o duljini Krke od izvora Krčića do Skradinskog buka nadoda duljina do mosta, još uvijek je riječ o razlici od 5,7 km.

Duljina Zrmanje do Velebitskoga kanala duža je za 12 km od službenih podataka, dok je duljina do Jankovića buka 11 km kraća. Međutim, kao i u slučaju Krke, nejasno je koje su početna i završna točka mjerenja rijeke u Ljetopisu ili Strategiji. Prema registru Hrvatskih voda, vodno tijelo Zrmanje završava otprilike 3 km nizvodno od Jankovića buka prije Obrovca.

Najveća razlika u ukupnoj duljini zabilježena je za rijeku Odru. U Ljetopisu je duljina Odre gotovo dvostruko veća (83 km) nego što je izmjereno ovim istraživanjem (44 km). Naime, još prije pedesetak godina izvorišni tok Odre bio je rječica Lomnica koja izvire kod Rakova Potoka na obroncima Samoborskoga gorja, ukupne duljine oko 40 km. Međutim, izgradnjom odteretnoga kanala Sava-Odra početkom sedamdesetih godina 20. stoljeća prirodni je tok Lomnice prekinut te je rječica velikim dijelom kanalizirana uz desnu obalu odteretnoga kanala, u koji i utječe kod mjesta Vukovina. Izvorište rijeke Odre danas se nalazi u Donjem Podotočju (Turopoljski leksikon, 2021).

source of the official data for the length of the Bednja of 133 km is unclear and probably stems from an error.

The measured length of the Glina River, which is 22 km greater than the data from the Yearbook and the Strategy, can be attributed to a more detailed vectorisation of the river, characterised by a large number of meanders in the middle and lower courses. It is also possible that several downstream springs were taken as the starting point of the river in the aforementioned data sources. In this study, the springs of Glina near Donji Kremen were taken as the starting point of the river.

In the case of the Krka River, the lengths from its source to the Šibenik Channel (77 km) and from the Krčić River's source to Lake Prukljan (72 km) most closely match the official data (72/73 km). According to the spatial register of Croatian Waters, the Krka ends at the bridge upstream from Skradin, which is 3.3 km from Skradinski Buk. However, there is no hydrological or morphological justification for choosing the exact point where the bridge was built. However, even if the length to the bridge is added to the measured length of the Krka from the source of the Krčić to Skradinski Buk, there is still a difference of 5.7 km.

The length of the Zrmanja to the Velebit Channel is 12 km longer than the official data, while the length to Jankovića Buk is 11 km shorter. However, as in the case of Krka, it is unclear what the start and end points of the river measurements are in both the Yearbook and the Strategy. According to the Croatian Waters' register, the Zrmanja ends about 3 km downstream of Jankovića Buk before Obrovac.

The largest difference in total length was found for the Odra River. In the Yearbook, the length of the Odra is almost twice as long (83 km) as the length found in this research (44 km). Fifty years ago, the source of the Odra was the Lomnica River, which originates near Rakov Potok on the slopes of Samoborsko Gorje, with a total length of about 40 km. However, with the construction of the Sava-Odra Canal in the early 1970s, the natural course of the Lomnica was interrupted and most of the river was channelized along the right bank of the canal, which it flows into at Vukovina. Today, the source of the Odra River is in Donje Podotočje (Turopoljski leksikon, 2021).

Tokovi rijeka Ilove i Česme također su izmijenjeni hidrotehničkim radovima zbog čega izravna usporedba s drugim podatcima u kojima nisu jasno navedene točke izvora i ušća nije valjana. Izračunata duljina Ilove od 103 km je za otprilike 2 km veća od podatka navedenog u radu Plantaka i dr. (2016), vjerojatno zbog veće detaljnosti u vektorizaciji s topografske karte.

U usporedbi s podatcima Ljetopisa i Strategije velike su razlike zabilježene u duljini tokova rijeke Drave i Mure u Hrvatskoj, moguće zbog prekograničnih meandara koji nisu uzeti u obzir u ovome radu. Značajne razlike zamijećene su i u slučaju duljine Bosuta u Hrvatskoj. Može se pretpostaviti da problem leži u određivanju početne i završne točke toka. U Strategiji je kao početna točka rijeke vrlo vjerojatno uzet izvor u aluviju lijeve obale Save jer se izmjerena duljina rijeke u ovome radu slaže s duljinom iz Strategije. Međutim, u slučaju Ljetopisa duljina ukupnoga toka od 186 km te toka u Hrvatskoj od 151 km zacijelo se odnosi na duljinu Bosuta zajedno s tokom Biđa. S druge strane, duljina Bosuta u Hrvatskoj od 81 km iz Strategije po svoj je prilici mjerena od utoka Biđa kod Cerne.

The flows of the Ilova and Česma rivers were also altered by river engineering works. Therefore, a direct comparison with other data, where the source and confluence points cannot be clearly identified, is not valid. The calculated length of the Ilova of 103 km is about 2 km longer than the data reported in the work of Plantak et al. (2016), which is probably due to the more detailed vectorisation from the topographic map in this study.

Large differences were found in the length of the Drava and Mura rivers in Croatia compared to the Yearbook and the Strategy data, possibly due to transboundary meanders that were excluded from the measurement in this study. Significant differences were also found in the length of the Bosut in Croatia. It is likely that the problem lies in determining the start and end points of the river. In the Strategy, the source in the alluvium of the left bank of the Sava River is most likely assumed to be the starting point of the Bosut, as the measured length of the river in this paper agrees with the length from the Strategy. However, the total length of the river of 186 km and of the river in Croatia of 151 km given in the Yearbook certainly refers to the length of the Bosut together with the Biđ. On the other hand, the length of the Bosut in Croatia from the Strategy of 81 km was probably measured from the confluence with the Biđ at Cerna.

Ukupne duljine velikih rijeka: Sava, Drava i Mura

Međunarodna komisija za porječje rijeke Save (Savska komisija, *International Sava River Basin Commission*) za duljinu rijeke Save od sutoka Save Dolinke i Save Bohinjke do ušća u Dunav kod Beograda navodi podatak o 944,7 km, a za ukupnu duljinu rijeke od izvora duljega izvorišnog kraka, Save Dolinke, čak 990 km (ISRBC, 2016). U ovome radu izračunata duljina Save iznosi 933,6 km, a odnosi se na duljinu od izvora Save Dolinke (Zelenci) do ušća u Dunav kod Beograda. U usporedbi sa službenim podatkom Savske komisije razlika iznosi čak 56 km. Budući da u citiranom izvješću (ISRBC, 2016) nije objašnjeno kako su i na temelju kojih izvora navedene duljine izračunate, nije moguće detaljno raspraviti rezultate, no treba spomenuti nekoliko pojedinosti. U

Total lengths of large rivers: Sava, Drava, and Mura

For the length of the Sava River from from the confluence of its headwaters Sava Dolinka and Sava Bohinjka to its confluence with the Danube at Belgrade, the International Sava River Basin Commission states the figure of 944.7 km, and for the total length of the river from the source of the longer headstream, the Sava Dolinka, 990 km (ISRBC, 2016). In this paper, the length of the Sava is calculated as 933.6 km and refers to the length from its source of Sava Dolinka (Zelenci) to the confluence with the Danube at Belgrade. Compared to the official data of the Sava Commission, the difference is nearly 56 km. Since the cited report (ISRBC, 2016) does not explain how and on the basis of which sources the given lengths were calculated, it is not possible to discuss the results in detail. However, a few facts should be mentioned. The

izvješću su napisane duljine određenih segmenata rijeke te je navedeno da se Rugvica nalazi na 658 rkm, što prema podatcima iz ovoga rada odgovara 663 rkm. Prema tome, duljina Save do Rugvice može se sagledati kao prilično točna (odstupanje od 0,8 %), a razlog tolike razlike u ukupnoj duljini vjerojatno treba tražiti u dijelu toka koji se nalazi u Sloveniji. Prema dostupnim podatcima OSM-a duljina Save iznosi 933,1 km, a prema *Copernicus* EU-Hydro podatcima 933,8 km. Dakle, njihovo međusobno odstupanje te razlika u odnosu na duljinu izmjerenu u ovome radu zanemarivi su. K tomu, u tablici koja prikazuje duljine pritoka Save u izvješću ISRBC-a (2016) navedeno je da duljina Kupe iznosi 118,3 km, što je samo 40 % ukupne duljine Kupe izračunate u ovome radu, što zacijelo dovodi u pitanje pouzdanost baze podataka Savske komisije.

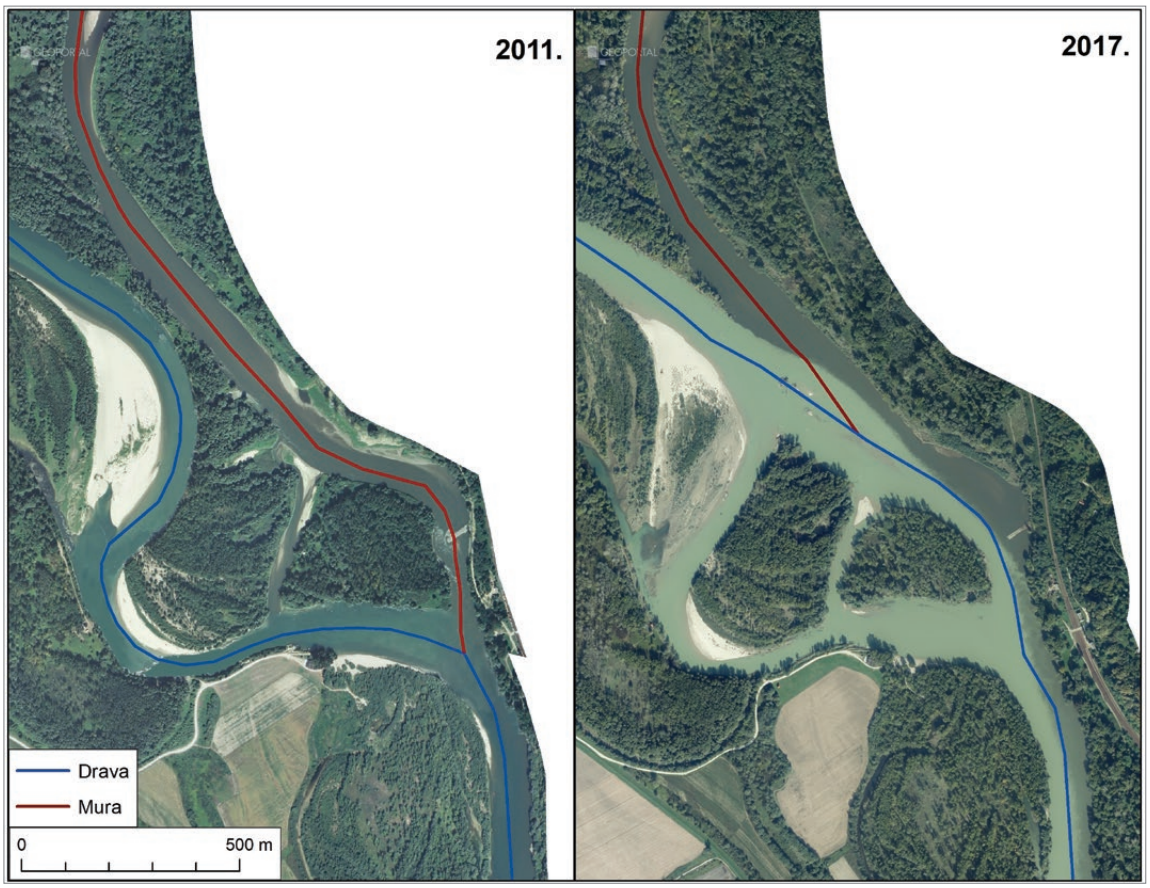
U uvodu knjige *The Drava River*, koja se bavi okolišnim problemima rijeke (Loczy, 2019), navodi se podatak o duljini rijeke koji iznosi 725 km, međutim bez ikakva spomena o metodologiji mjerenja ili izvoru toga podatka. S druge strane, prema izvješću međunarodnoga projekta *Joint Drava River Corridor Analysis Report* (SEE River, 2014) ukupna duljina Drave iznosi 709,8 km, a duljina toka u Hrvatskoj (računajući prekogranične meandre) 322,9 km. Za usporedbu, u ovome radu izračunata ukupna duljina Drave iznosi 706,9 km (razlika 2,9 km), a duljina graničnoga toka u Hrvatskoj 321,5 km (razlika 1,4 km). Metodologija navedenoga izvješća usporediva je s metodologijom ovoga rada: duljina je mjerena crtom sredine korita, a u onim slučajevima kada paralelno teku umjetni zaobilazni kanali i prirodni tok u izračunu je korišten prirodni tok (Čakovec, Varaždin, Donja Dubrava). Međutim, nije objašnjeno koji su izvori korišteni u vektorizaciji toka, osim što je navedeno da se radi o GIS podlogama. Dobivene razlike u rezultatima iznose 0,4 % duljine rijeke, što se može smatrati zanemarivim s obzirom na to da je Drava dinamična rijeka s konstantnim promjenama tlocrtnoga oblika korita, bilo prirodno bilo zbog ljudskih intervencija (SEE River, 2014). Primjerice, na segmentu korita Drave kod naselja Križnica zabilježene su znatne promjene duljine korita od kraja 18. stoljeća

lengths of specific river sections in the report show that the Rugvica is located at 658 rkm, which according to the data from this paper corresponds to 663 rkm. Therefore, the length of the Sava to the Rugvica can be considered quite accurate (deviation of 0.8%), and the reason for such a difference in the total length probably lies in measurements of the part of the river that is in Slovenia. According to the available OSM data, the length of the Sava River is 933.1 km, and Copernicus EU Hydro data states that the length is 933.8 km. Therefore, the mutual deviation as well as the difference with the length measured in this paper is negligible. Also, in the table showing the lengths of the tributaries of the Sava River in the ISRBC report (2016), the length of the Kupa is given as 118.3 km, which is only 40% of the total length of the Kupa calculated in this paper. This calls into question the reliability of the Sava Commission database.

In the introduction to *The Drava River*, which deals with the environmental problems of the river (Loczy, 2019), the river is stated to be 725 km long, but no mention is made of the measurement method or the source of this figure. On the other hand, according to the report of the international Joint Drava River Corridor Analysis Report project (SEE River, 2014), the total length of the Drava River is 709.8 km and the length of the river in Croatia (including transboundary meanders) is 322.9 km. For comparison, the total length of the Drava River calculated in this paper is 706.9 km (difference 2.9 km), and the length of the border flow in Croatia is 321.5 (difference 1.4 km) km. The methodology of the report is comparable to the methodology of this paper: the length was measured using the centreline of the channel, and in cases where artificial bypass channels and the natural river run parallel, the natural river was included in the calculation (Čakovec, Varaždin, Donja Dubrava). However, which sources were used in the vectorisation of the flow is not explained, except that it is stated that they were GIS databases. The obtained differences in the results amount to 0.4% of the river length, which can be considered negligible, since the Drava River is a dynamic river with constant channel changes, affected by either natural factors or human interventions (SEE River, 2014). For example, in the segment of the Drava channel near the settlement of Križnica, significant changes in the length of the channel were recorded

do 1960-ih: krajem 19. stoljeća zbog regulacijskih radova i presijecanja meandara korito je skraćeno za čak 37 km, dok je u 1960-im zabilježeno produžavanje toka za 5,2 km zbog neadekvatna pristupa regulacijskim radovima i prirodnoga prilagođavanja toka padu prema zakonima hidrodinamike (Bognar, 2008). Između 2011. i 2017. godine dogodile su se i značajne promjene na ušću Mure u Dravu. Naime, rijeka Drava probila je uski dio naplavne ravnice na svojoj lijevoj obali koja ju je dijelila od Mure (sl. 6). Ušće Mure pomaknulo se uzvodno, a dotadašnje glavno korito Drave postalo je sekundarno. Crta sredine novoga glavnog, odnosno najširega korita Drave danas se proteže nekadašnjim koritom Mure. Duljina toka Drave time se smanjila za 550 m, a toka Mure za 700 m.

from the end of the 18th century to the 1960s: At the end of the 19th century, the channel was shortened by roughly 37 km, while an extension of the river by 5.2 km was recorded in the 1960s, due to insufficient regulation works and the natural adjustment of the river to the gradient according to the laws of hydrodynamics (Bognar, 2008). Significant changes also occurred at the confluence of the Mura and Drava rivers between 2011 and 2017. Namely, the Drava broke through the narrow part of the floodplain on its left bank that separated it from the Mura (Fig. 6). The confluence of the Mura was shifted upstream and the former main channel of the Drava became secondary. The centreline of the new main river, i.e. the widest channel of the Drava, now runs along the former channel of the Mura. The length of the Drava River was thus reduced by 550 m and the Mura by 700 m.



Sl. 6. Promjene ušća Mure u Dravu između 2011. i 2017. godine
Izvor: DGU, Digitalni ortofoto 2011. i 2017. (WMS)

Fig. 6. Changes in the Mura-Drava confluence between 2011 and 2017
Source: CGA, Digital Orthophoto 2011 and 2017 (WMS)

Izračunata duljina toka Mure (469 km) dulja je za 31 km od podatka iz Ljetopisa te za 24 km kraća od podatka u Strategiji. Mura je, poput Drave, rijeka s prirodnom dinamičnom morfologijom korita i naplavne ravnice. Međutim, u prethodnom stoljeću izvršeni su mnogi hidrotehnički radovi radi stabilizacije toka te su izgrađene brojne hidroelektrane na području Austrije zbog čega je očekivano da se podatci o duljini toka donekle razlikuju iako se u novijoj literaturi navodi duljina od 465 km koja je neznatno kraća od izmjerene (Globevnik i Mikoš, 2009).

Zaključak

Ovim istraživanjem iznesena je problematika mjerenja duljina tekućica, uključujući kompleksnost određivanja početka i završetka tekućice. Budući da granice morfoloških oblika u prirodi nisu uvijek jasne, izvor i ušće često se ne mogu jednoznačno odrediti u jednoj točki. Kako bi se osigurala ponovljivost i provjerljivost podataka, u ovome je radu detaljno opisana metodologija mjerenja te su navedene prostorne koordinate izvora i ušća tekućica. U izmjeri su korištene suvremene kartografske podloge, a određene lokacije provjerene su i terenskim radom. Najveće razlike u usporedbi s dostupnim službenim podatcima zabilježene su na rijekama na kojima su provedeni istaknutiji hidrotehnički zahvati kanaliziranja i promjene pružanja toka, poput Odre ili Ilove, na rijekama jadranskoga slijeva na kojima postoje metodološke razlike u određivanju točke ušća poput Krke te na velikim rijekama Dravi i Muri na kojima su česte promjene u tlocrtu korita zbog prirodne dinamike i hidrotehničkih zahvata. Također je važno naglasiti da je ovim istraživanjem utvrđeno da je najdulja hrvatska tekućica Karašica ukupne duljine 148 km.

Međutim, budući da su rijeke dinamični sustavi, rezultati ovoga istraživanja predstavljaju stanje u određenom trenutku. Podatke o duljini tekućica treba redovito ažurirati, ne samo radi općenita poznavanja nacionalne geografije nego i zbog njihove važnosti u upravljanju vodama, kao i provedbi mnogih znanstvenih i stručnih projekata i studija. Rezultati ovoga istraživanja temelje se na dostu-

The calculated length of the Mura (469 km) is 31 km longer than the data in the Yearbook, and 24 km shorter than the data in the Strategy. Like the Drava, the Mura is a river with a naturally dynamic channel and floodplain morphology. However, in the past century, many engineering works have been implemented to stabilise the river and numerous hydropower plants have been built in Austria, so the data on the length of the river differ from what would be expected. However, recent literature gives a length of 465 km, which differs slightly from the length measured in this study (Globevnik and Mikoš, 2009).

Conclusion

This study deals with the measurement of river lengths, including the complexity of determining the start and end points of rivers. Since the boundaries of morphological forms in nature are not always clear, the source and mouth of a river often cannot be clearly determined at a single point. To ensure the reproducibility and verifiability of the data, this paper describes the measurement methodology in detail and lists the spatial coordinates of the sources and mouths. Contemporary cartographic databases were used in the survey, and specific locations were verified by fieldwork. The greatest differences compared to the available official data were found for rivers where significant river engineering works have been carried out to channelize and divert flow, such as the Odra or Ilova rivers, for rivers in the Adriatic Basin where there are methodological differences in how the mouth was determined, such as the Krka, and for the Drava and Mura rivers where changes in channel planform are common due to natural dynamics and engineering interventions. It is also important to emphasise that this research revealed that the longest river entirely within Croatia is the Karašica, with a total length of 148 km.

However, because rivers are dynamic systems, the results of this research represent the state at the time of writing. Data on the length of rivers must be updated regularly, not only for the sake of general knowledge of national geography, but also because of its importance for water management and for the implementation of many scientific and expert projects and studies. The results of this study are based

pnim kartografskim izvorima iz razdoblja 1996. – 2020., koji predstavljaju najnovije i najobuhvatnije izvore podataka. Dobiveni podatci o duljinama rijeka bit će uneseni u službenu državnu bazu podataka (Statistički ljetopis Republike Hrvatske) da bi bili lako dostupni široj javnosti.

on available base maps from the 1996–2020 period, which represent the most recent and comprehensive data sources. The obtained data on river lengths will be incorporated into the official state database (the Statistical Yearbook of the Republic of Croatia) so they are easily accessible for the general public.

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