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UPORABA ŠIFRANTA PADAVINSKIH OBMOČIJ VODOTOKOV REPUBLIKE SLOVENIJE ZA PRIPRAVO HIDROLOŠKIH MODELOV THE APPLICATION OF THE WATERSHED CODING SYSTEM OF THE REPUBLIC OF SLOVENIA FOR HYDROLOGICAL MODELLING

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V prispevku je predstavljena uporabnost šifranta padavinskih območij Republike Slovenije, predvsem uporaba pri hidrološkem modeliranju, ki je podlaga za napovedovanje poplav, določanje poplavne ogroženosti in ukrepov varstva pred poplavami, račun vodne bilance itd. Kot primer je predstavljen hidrološki model Soče. Iz primera je razvidno, da se šifrant popolnoma ujema z vhodno strukturo modela. Sistem šifriranja padavinskih območij R Slovenije torej omogoča neposreden vnos v hidrološke modele.

Ključne besede: hidrologija, padavinsko območje, modeliranje, šifrant, reka Soča, padavine

The applicability of the watershed coding system of the Republic of Slovenia is represented in this paper with the emphasis on the hydrological modelling which is the base for flood forecasting, flood risk analyses and precautions against floods, water budget assessments, etc. The hydrological model of the river Soča is represented as an example. The coding system completely tallies with the model-input structure, as can be seen from the example. Therefore the coding system of the Republic of Slovenia enables direct input in the hydrological models.

Key words: hydrology, watershed, modelling, coding system, the Soča river, precipitation

1. UVOD

Uporaba sodobne programske opreme za upravljanje s prostorsko določenimi bazami podatkov zahteva po eni strani šifriranje, ki je prilagojeno računalniški obdelavi podatkov, po drugi strani pa ponuja nove možnosti pri urejanju podatkov in izdelavi modelov.

Na podlagi analize različnih sistemov šifriranja v različnih državah je bil v Sloveniji izdelan sodoben sistem šifriranja padavinskih območij (Brilly & Garantini, 1994; 1996; Šraj, 2000, 2001). Sistem je odprt in prilagojen računalniški obdelavi.

Šifrant padavinskih območij omogoča urejanje podatkov o okolju, izdelavo vodnogospodarskih načrtov in programov, izdelavo sodobnih informacijskih sistemov za potrebe varstva okolja ter izdelavo različnih analiz in hidroloških modelov (Brilly et al., 1993; Brilly & Šraj, 1998; WMO, 1994).

1. INTRODUCTION

The application of contemporary software and hardware for managing spatially oriented data requires a computer adapted coding system and also offers new alternatives in data management and model making.

A contemporary coding system for Slovenian watersheds based on the analyses of different coding systems in different countries has been made (Brilly & Garantini, 1994; 1996; Šraj, 2000, 2001). The system is open and applicable for computer data management.

The watershed coding system enables environmental database management and water management plans and programmes, contemporary information systems for environmental protection, as well as various analyses and hydrological modelling (Brilly et al., 1993; Brilly & Šraj, 1998; WMO, 1994).

V nadaljevanju je predstavljena uporaba šifranta padavinskih območij Republike Slovenije za izdelavo hidroloških modelov, ki so podlaga za napovedovanje poplav, določanje poplavne ogroženosti in ukrepov varstva pred poplavami, račun vodne bilance itd.

2. UPORABA ŠIFRANTA PADAVINSKIH OBMOČIJ ZA HIDROLOŠKO MODELIRANJE

2.1 UVOD

V okviru mednarodnega programa IHP UNESCO se trenutno v Sloveniji izvajajo hidrološke meritve in izračuni na štirih eksperimentalnih porečjih: Soča, Savinje, Notranjske Reke in Dragonje (slika 1). Zato so bila ta padavinska območja pripravljena tudi za vnos v hidrološki model HEC-1 (Šraj, 2000). S tem želim pokazati, da je sistem šifriranja že sam po sebi strukturiran tako, da omogoča neposreden vnos v hidrološke modele.

The application of the watershed coding system of the Republic of Slovenia for hydrological modelling, which is the base for flood forecasting, flood risk analyses and precautions against floods, water budget assessments, etc., is represented in the present work.

2. THE APPLICATION OF THE WATERSHED CODING SYSTEM FOR HYDROLOGICAL MODELLING

2.1 INTRODUCTION

Within the international programme IHP UNESCO, hydrological measurements and calculations were carrying out on four experimental watersheds in Slovenia: Soča, Savinja, Notranjska Reka and Dragonja, at the moment (Figure 1). For this reason, just those watersheds have been prepared for hydrological model HEC-1 (Šraj, 2000). I want to indicate, that the structure of the coding system alone, enables direct input in the hydrological models.



Slika 1. Eksperimentalna povodja v Sloveniji.
Figure 1. Experimental watersheds in Slovenia.

2.2 TEMELJI RAČUNALNIŠKEGA PROGRAMA HEC-1 ZA HIDROLOŠKO MODELIRANJE

Program HEC-1 je eden najstarejših in najbolj znanih programov za simulacijo površinskega odtoka. Razvili so ga v ZDA za vojaške potrebe v Hidrološkem Inženirskem Centru v Kaliforniji leta 1967. Leta 1984 so razvili različico za osebni računalnik in jo do danes večkrat izpopolnili (Dodson & Associates, 1995).

Računalniški program HEC-1 temelji na matematičnih odnosih, s katerimi predstavimo posamezne meteorološke pojave ter hidrološke in hidravlične procese (Brilly, 1993). Omogoča transformacijo padavin v časovni potek odtoka oziroma hidrogram. Strukturo modela dobimo tako, da povodje razdelimo na čim bolj homogena podpovodja, na katerih izvajamo računske operacije. HEC-1 omogoča tri temeljne operacije:

1. S pomočjo podatkov o padavinah in infiltraciji ter enotnega hidrograma, izračuna hidrogram površinskega odtoka za posamezno podpovodje.
2. Transformira podani hidrogram po rečni strugi dolvodno ali skozi akumulacijo.
3. Sešteva hidrograme različnih podpovodij.

S pomočjo omenjenih treh operacij (izračun, propagacija, seštevanje) je mogoče modelirati tudi izredno kompleksna povodja. Vsekakor pa mora biti vrstni red operacij pravilno zastavljen, da ne pride do uporabe napačnih podatkov. Vrstni red operacij se določa samo s strukturo vhodnih podatkov.

2.3 EKSPERIMENTALNO POREČJE SOČE

Porečje Soče je po šifrantu padavinskih območij R Slovenije padavinsko območje prvega reda s šifro šest. Na drugi ravni je celotno porečje razdeljeno na štiri padavinska območja, na tretji ravni na 28, na četrti pa na 91 padavinskih območij. Glede na razpoložljive podatke je za hidrološki model najprimernejša razdelitev na tretji ravni (slika 2). Iz računske sheme v preglednici 1 je

2.2 BASIS OF THE COMPUTER PROGRAM HEC-1 FOR HYDROLOGICAL MODELLING

The HEC-1 computer program is one of the most widely accepted methods for surface runoff simulation. It was developed for military use in the Hydrologic Engineering Center in California, USA in 1967. In 1984, a version of the program for the Personal Computer was developed and improved several times till today (Dodson & Associates, 1995).

The HEC-1 computer program is based on mathematical relationships, which are intended to represent individual meteorological, hydrological and hydraulic processes (Brilly, 1993). It enables the transformation of the precipitation into a basin runoff hydrograph. With dividing the watershed into as homogeneous sub-areas as possible we get the structure of the model. HEC-1 model performs three basic types of hydrograph operations:

1. By using precipitation information, infiltration losses, and unit hydrograph HEC-1 computes a runoff hydrograph for each sub-basin.
2. Routes a given hydrograph through a stream reach or reservoir.
3. Combines two or more hydrographs.

Even with only these three basic operations, HEC-1 can model extremely complex watersheds. However, the operations must be performed in the correct sequence in order to provide the intended results. The sequence of computations is controlled only by the organisation of the input data.

2.3 THE SOČA RIVER EXPERIMENTAL WATERSHED

The Soča river watershed is one of the six watersheds on the first level of the watershed coding system of the Republic of Slovenia. The whole watershed is divided on four sub-watersheds on the second level, on 28 on the third level and on 91 sub-watersheds on the fourth level. The most appropriate for hydrological model is the third level regarding available data (Figure 2). As can be seen from

razvidno, da se šifrant popolnoma ujema z vhodno strukturo modela. Sistem šifriranja padavinskih območij R Slovenije torej omogoča direkten vnos strukture v hidrološke modele.

Prikaz strukture modela povodja Soče je podan na sliki 3, računski shema pa v preglednici 1.

2.4 HIDROLOŠKI MODEL REKE SOČE

Na podlagi računski sheme (preglednica 1) je bila izdelana vhodna datoteka hidrološkega modela Soče za program ProHEC-1. Modeliran je bil dogodek za november 1992, ki je bil že predhodno modeliran in umerjen (Šraj, 1995) in je dal zadovoljive rezultate.

Glavni vhodni podatek za izračun odtoka so padavine. Model predpostavlja enakomerno razporeditev padavin znotraj padavinskega območja. Ob tem je velika težava v tem, da so padavine na povodju Soče zelo lokalnega značaja. Težave pri modeliranju so nastale predvsem zaradi premajhnega števila podatkov in njihove nepopolnosti. Na povodju Soče so sicer štiri ombrografske postaje v Sloveniji (Bovec, Knežke Ravne, Lokve in Podkraj) in tri v Italiji (Capriva, Gradisca di Isonzo, Fossalon do Grado), ki dajejo urne podatke o padavinah, vendar so bili za november 1992 uporabni le podatki s treh postaj: Lokve, Podkraj in Capriva. Po celotnem padavinskem območju Soče pa je enakomerno razporejenih tudi 50 ombrometrskih postaj (slika 4), ki dajejo dnevne podatke o padavinah. S pomočjo teh podatkov so bile za vsako padavinsko območje posebej izračunane povprečne dnevne padavine. Padavinska simulacija na posameznih območjih pa je bila simulirana tako, da so bile dnevne količine padavin linearno reducirane po padavinskem vzorcu najbližjega ombrografa. Tu so verjetno nastale manjše ali večje napake, saj je bil najbližji ombrograf včasih precej oddaljen ali pa na popolnoma drugačni nadmorski višini.

the sequence of computations in Table 1, the coding system completely tallies with the model-input structure. Therefore the coding system of the Republic of Slovenia enables direct input in the hydrological models.

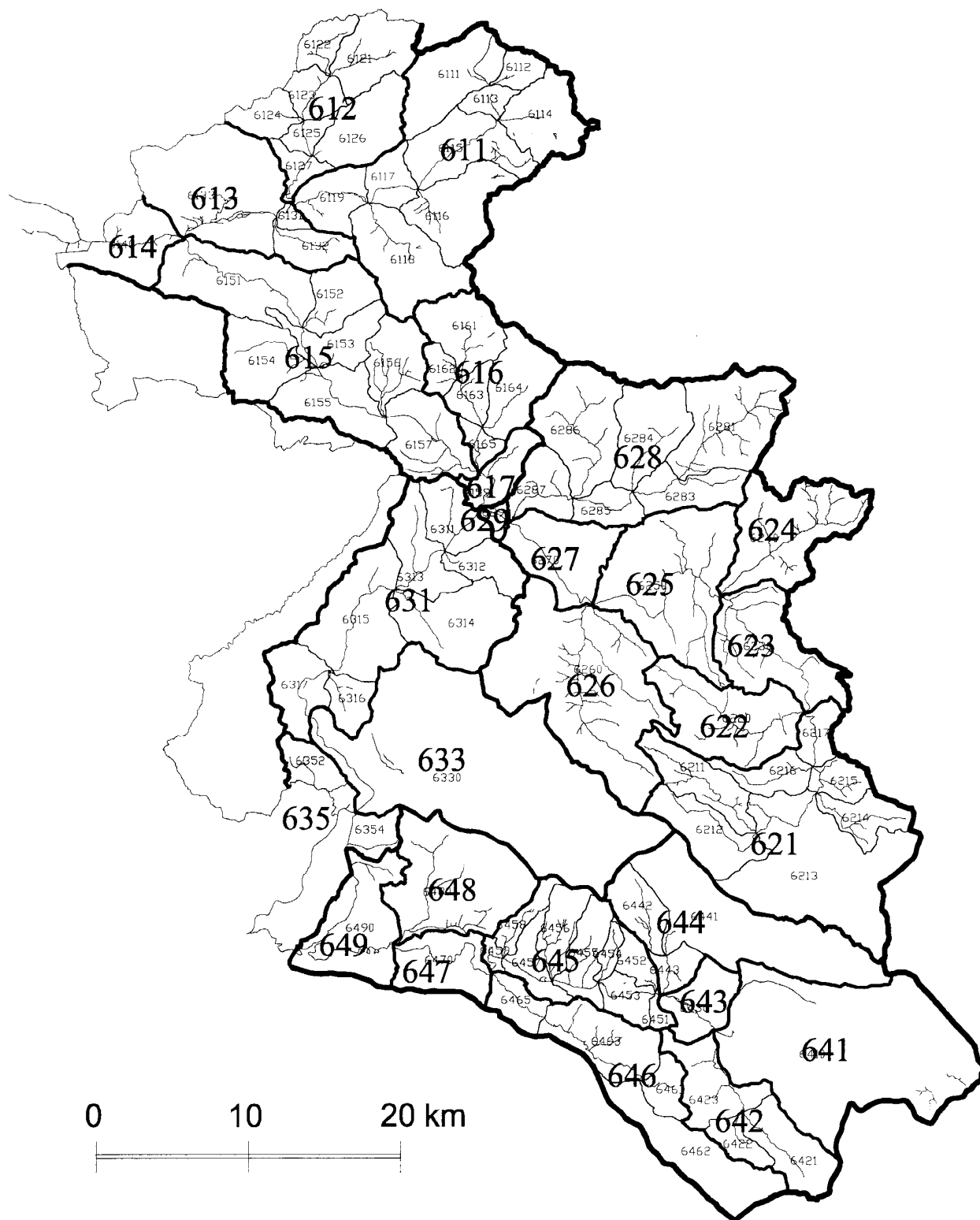
The model input structure for the Soča watershed is in the Figure 3 and the sequence of computations in Table 1.

2.4 THE SOČA RIVER HYDROLOGICAL MODEL

The ProHEC-1 input file for the Soča hydrological model was made based on the sequence of computations in Table 1. The event for november 1992 was modelled. The same one was modelled and moderated before (Šraj, 1995) and it was given satisfactory results.

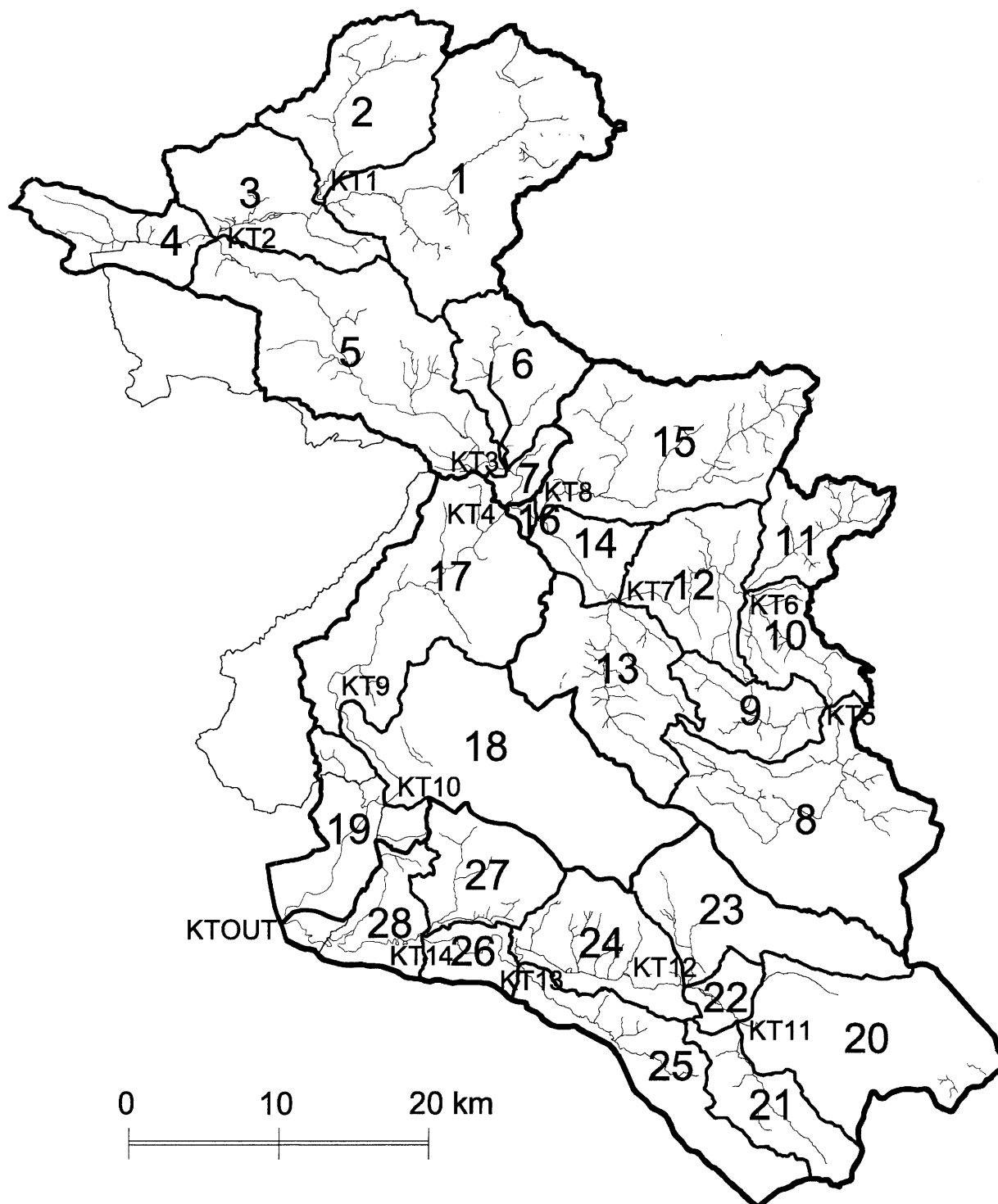
Precipitation is the main input datum for runoff computation. Evenly precipitation distribution was adopted inside each watershed. The fact that the precipitation in the Soča watershed has a very local character caused a large problem, because of insufficiency of the data. In the Soča river watershed there are four automatic rainfall gauging stations in Slovenia (Bovec, Knežke Ravne, Lokve and Podkraj) and three in Italy (Capriva, Gradisca di Isonzo, Fossalon do Grado), which are giving hourly data, but for november 1992 only data from three stations: Lokve, Podkraj and Capriva were applicable. There are also 50 rainfall-gauging stations with daily data, regularly arranged over the watershed (Figure 4). An average daily precipitation was calculated for each watershed with those data. Hourly precipitation simulation of each watershed was then linearly reduced upon the nearest station with daily data. Here probably some smaller or larger mistakes occurred, because the nearest station with the hourly data was sometimes rather faraway or on completely different sea level.

ŠIFRANT PADAVINSKIH OBMOČIJ SOČE / WATERSHED CODING SYSTEM OF THE SOČA RIVER



Slika 2. Šifrant padavinskih območij Soče.
Figure 2. Watershed coding system of the Soča River.

**STRUKTURA MODELA SOČE /
THE STRUCTURE OF THE SOČA RIVER HYDROLOGICAL MODEL**



Slika 3. Struktura hidrološkega modela Soče.
Figure 3. The structure of the Soča river hydrological model.

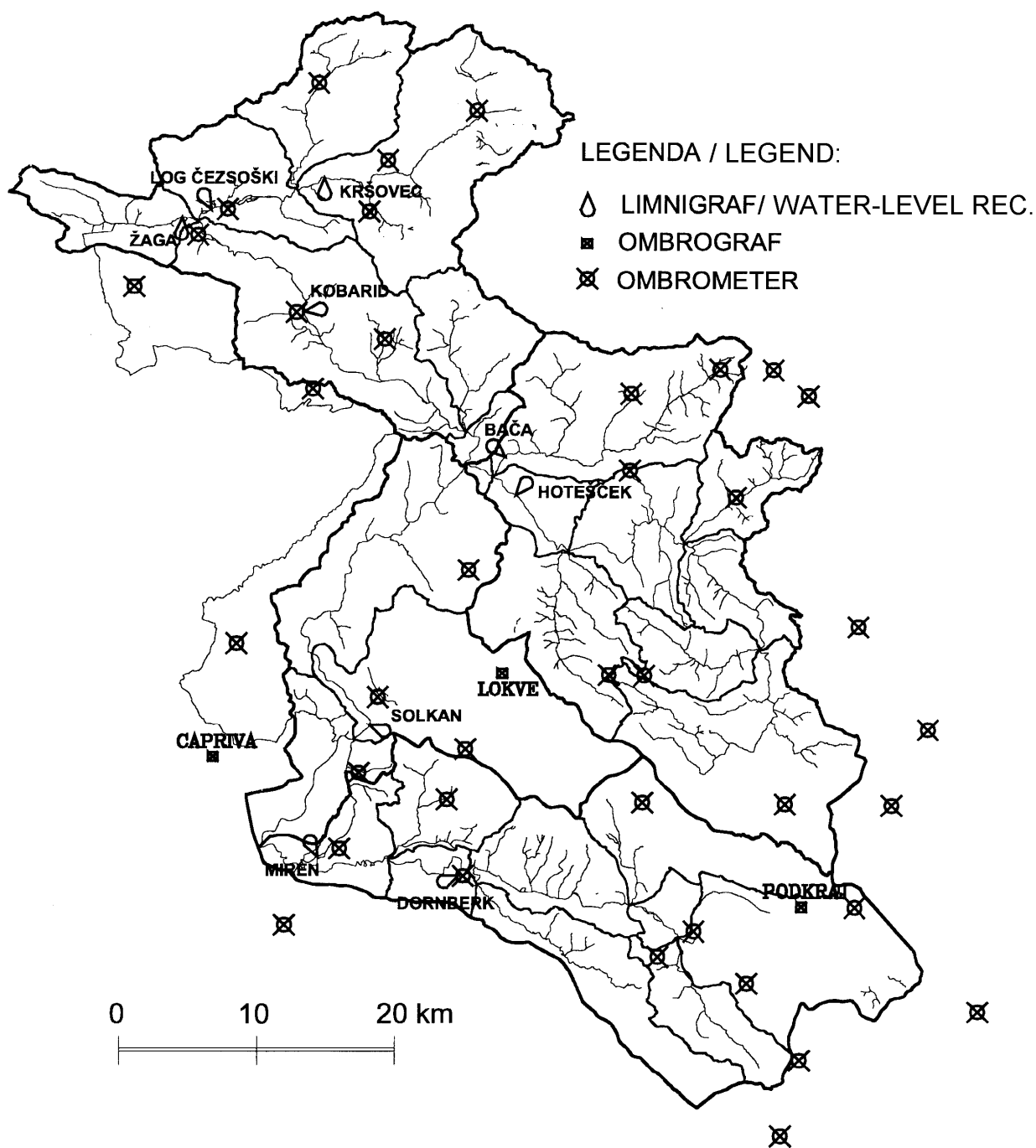
Preglednica 1. Računska shema porečja Soče.

| KO- RAK | ŠT. NA KUPU | OPERACIJA | RAČUNSKA SHEMA POREČJA SOČE |
|------------|----------------|-------------|---|
| 1 | 1 | izračun | izračuna hidrogram površinskega odtoka s padavinskega območja 1 – Trentarska Soča (611) |
| 2 | 2 | izračun | izračuna hidrogram površinskega odtoka s padavinskega območja 2 – Koritnica (612) |
| 3 | 1 | seštevanje | sešteje dva hidrograma iz korakov 1 in 2 v sotočju Soče in Koritnice |
| 4 | 1 | propagacija | propagira val iz koraka 3 do sotočja Soče in Učje |
| 5 | 2 | izračun | izračuna hidrogram površinskega odtoka s padavinskega območja 3 – Bovška Soča (613) |
| 6 | 3 | izračun | izračuna hidrogram površinskega odtoka s padavinskega območja 4 – Učja (614) |
| 7 | 1 | seštevanje | sešteje tri hidrograme iz korakov 4, 5 in 6 v sotočju Soče in Učje |
| 8 | 1 | propagacija | propagira val iz koraka 7 do sotočja Soče in Tolminke |
| 9 | 2 | izračun | izračuna hidrogram površinskega odtoka s padavinskega območja 5 – Tolminska Soča (615) |
| 10 | 3 | izračun | izračuna hidrogram površinskega odtoka s padavinskega območja 6 – Tolminka (616) |
| 11 | 1 | seštevanje | sešteje tri hidrograme iz korakov 8, 9 in 10 v sotočju Soče in Tolminke |
| 12 | 1 | propagacija | propagira val iz koraka 11 do sotočja Soče in Idrijce |
| 13 | 2 | izračun | izračuna hidrogram površinskega odtoka s padavinskega območja 7 – Soča-Modrej (617) |
| 14 | 1 | seštevanje | sešteje dva hidrograma iz korakov 12 in 13 v sotočju Soče in Idrijce |
| 15 | 2 | izračun | izračuna hidrogram površinskega odtoka s padavinskega območja 8 – Idrijska Idrija (621) |
| 16 | 3 | izračun | izračuna hidrogram površinskega odtoka s padavinskega območja 9 – Kanomljica (622) |
| 17 | 2 | seštevanje | sešteje dva hidrograma iz korakov 15 in 16 v sotočju Idrijce in Kanomljice |
| 18 | 2 | propagacija | propagira val iz koraka 17 do sotočja Idrijce in Cerknice |
| 19 | 3 | izračun | izračuna hidrogram površinskega odtoka s padavinskega območja 10 – Masorska Idrija (623) |
| 20 | 4 | izračun | izračuna hidrogram površinskega odtoka s padavinskega območja 11 – Cerknica (624) |
| 21 | 2 | seštevanje | sešteje tri hidrograme iz korakov 18, 19 in 20 v sotočju Idrijce in Cerknice |
| 22 | 2 | propagacija | propagira val iz koraka 21 do sotočja Idrijce in Trebušnice |
| 23 | 3 | izračun | izračuna hidrogram površinskega odtoka s padavinskega območja 12 – Stopniška Idrija (625) |
| . | . | . | . |
| . | . | . | . |
| . | . | . | . |
| 50 | 3 | izračun | izračuna hidrogram površinskega odtoka s padavinskega območja 24 – Dobravska Vipava (645) |
| 51 | 4 | izračun | izračuna hidrogram površinskega odtoka s padavinskega območja 25 – Branica (646) |
| 52 | 2 | seštevanje | sešteje tri hidrograme iz korakov 49, 50 in 51 v sotočju Vipave in Branice |
| 53 | 2 | propagacija | propagira val iz koraka 52 do sotočja Vipave in Lijaka |
| 54 | 3 | izračun | izračuna hidrogram površinskega odtoka s padavinskega območja 26 – Prvaška Vipava (647) |
| 55 | 4 | izračun | izračuna hidrogram površinskega odtoka s padavinskega območja 27 – Lijak (648) |
| 56 | 2 | seštevanje | sešteje tri hidrograme iz korakov 53, 54 in 55 v sotočju Vipave in Lijaka |
| 57 | 2 | propagacija | propagira val iz koraka 56 do sotočja Soče in Vipave |
| 58 | 3 | izračun | izračuna hidrogram površinskega odtoka s padavinskega območja 28 – Mirenska Vipava (649) |
| 59 | 1 | seštevanje | sešteje tri hidrograme iz korakov 41, 57 in 58 v sotočju Soče in Vipave |

Table 1. The sequence of computations for the Soča watershed.

| STEP | NO. ON THE STACK | OPERATION | SEQUENCE OF COMPUTATIONS FOR THE SOČA WATERSHED |
|------|------------------|-----------|---|
| 1 | 1 | compute | compute runoff hydrograph from watershed 1 – Trentarska Soča (611) |
| 2 | 2 | compute | compute runoff hydrograph from watershed 2 – Koritnica (612) |
| 3 | 1 | combine | combine two hydrographs from steps 1 and 2 in the confluence of the Soča and Koritnica streams |
| 4 | 1 | route | route hydrograph from step 3 to the confluence of the Soča and Učja streams |
| 5 | 2 | compute | compute runoff hydrograph from watershed 3 – Bovška Soča (613) |
| 6 | 3 | compute | compute runoff hydrograph from watershed 4 – Učja (614) |
| 7 | 1 | combine | combine three hydrographs from steps 4, 5 and 6 in the confluence of the Soča and Učja streams |
| 8 | 1 | route | route hydrograph from step 7 to the confluence of the Soča and Tolminka streams |
| 9 | 2 | compute | compute runoff hydrograph from watershed 5 – Tolminska Soča (615) |
| 10 | 3 | compute | compute runoff hydrograph from watershed 6 – Tolminka (616) |
| 11 | 1 | combine | combine three hydrographs from steps 8, 9 and 10 in the confluence of the Soča and Tolminka streams |
| 12 | 1 | route | route hydrograph from step 11 to the confluence of the Soča and Idrijca streams |
| 13 | 2 | compute | compute runoff hydrograph from watershed 7 – Soča-Modrej (617) |
| 14 | 1 | combine | combine two hydrographs from steps 12 in 13 in the confluence of the Soča and Idrijca streams |
| 15 | 2 | compute | compute runoff hydrograph from watershed 8 – Idrijska Idrijca (621) |
| 16 | 3 | compute | compute runoff hydrograph from watershed 9 – Kanomljica (622) |
| 17 | 2 | combine | combine two hydrographs from steps 15 and 16 in the confluence of the Idrijca in Kanomljica streams |
| 18 | 2 | route | route hydrograph from step 17 to the confluence of the Idrijca and Cerknica streams |
| 19 | 3 | compute | compute runoff hydrograph from watershed 10 – Masorska Idrijca (623) |
| 20 | 4 | compute | compute runoff hydrograph from watershed 11 – Cerknica (624) |
| 21 | 2 | combine | combine three hydrographs from steps 18, 19 in 20 in the confluence of the Idrijca and Cerknica streams |
| 22 | 2 | route | route hydrograph from step 21 to the confluence of the Idrijca and Trebuščica streams |
| 23 | 3 | compute | compute runoff hydrograph from watershed 12 – Stopniška Idrijca (625) |
| . | . | . | . |
| . | . | . | . |
| . | . | . | . |
| 50 | 3 | compute | compute runoff hydrograph from watershed 24 – Dobravska Vipava (645) |
| 51 | 4 | compute | compute runoff hydrograph from watershed 25 – Branica (646) |
| 52 | 2 | combine | combine three hydrographs from steps 49, 50 in 51 in the confluence of the Vipava and Branica streams |
| 53 | 2 | route | route hydrograph from step 52 to the confluence of the Vipava and Lijak streams |
| 54 | 3 | compute | compute runoff hydrograph from watershed 26 – Prvaška Vipava (647) |
| 55 | 4 | compute | compute runoff hydrograph from watershed 27 – Lijak (648) |
| 56 | 2 | combine | combine three hydrographs from steps 53, 54 in 55 in the confluence of the Vipava and Lijak streams |
| 57 | 2 | route | route hydrograph from step 56 to the confluence of the Soča and Vipava streams |
| 58 | 3 | compute | compute runoff hydrograph from watershed 28 – Mirenska Vipava (649) |
| 59 | 1 | combine | combine three hydrographs from steps 41, 57 in 58 in the confluence of the Soča and Vipava streams |

RAZPOREDITEV MERSKIH POSTAJ / LOCATIONS OF THE GAUGING STATIONS



Slika 4. Razporeditev padavinskih in limnigrafskih postaj na padavinskem območju Soče.
Figure 4. Locations of the rainfall and water level gauging stations in the Soča watershed.

Lastnosti padavinskih območij so določene na podlagi hidrografskih, geometrijskih, geoloških in pedoloških kriterijev (Šraj, 1995). Geometrijske lastnosti padavinskih območij (preglednica 2) so bile določene s pomočjo programa AutoCAD Map na podlagi digitaliziranih topografskih kart v merilu 1:25000. Hidrografski in geološki kriteriji (preglednica 3) pa so bili določeni s pomočjo karte talnih značilnosti in karte hidrogeologije, ki sta bili podigitalizirani v merilu 1:250 000. Vsako padavinsko območje je vezano na svoj enotni hidrogram, ki ni odvisen od naliva. HEC-1 omogoča sintetiziranje enotnega hidrograma po treh metodah. Najboljše rezultate je dala SCS metoda. Pravilna oblika enotnega hidrograma je poleg pravilne padavinske situacije najpomembnejša pri analizi površinskega odtoka.

Hidrološki model je bil umerjen za štiri dogodke s pomočjo merjenih hidrogramov na devetih postajah vzdolž Soče in njenih pritokov (Šraj, 1995). Pri merjenih hidrogramih je bil določen delež baznega odtoka in odštet od celotne vrednosti pretoka. Problem predstavlja položaj limnigrafov, ki se vedno ne ujema z mejami padavinskih območij (slika 4) in je umerjanje lahko samo približno. Model je bil umerjen tako, da odstopanja v volumnih odtoka niso bila večja od 10% in da so se konice merjenih in izračunanih hidrogramov čim boljše ujemale, tako po višini kot po času (slika 5, preglednica 4).

Model je dal, glede na pomankljive padavinske podatke, dobre rezultate. Razlike v volumnih poplavnih valov so minimalne. Konice so se časovno dobro ujele. Malo slabši so rezultati na padavinskih območjih Bače in Vipave. Kot je razvidno iz rezultatov, večji del pretoka prispeva padavinsko območje Idrijce.

Characteristics of the watersheds were defined, based on hydrographic, geometric, geological and pedological properties (Šraj, 1995). Geometric characteristics of the watersheds (Table 2) were defined with computer program AutoCAD Map, based on digitised topographic maps 1:25 000. Maps of soil characteristics and hydrogeology digitised in scale 1:250 000 have been the base for defining hydrographic and geological characteristics (Table 3). Each watershed has its own unit hydrograph, independent from the storm. HEC-1 enables a syntetization of the unit hydrograph with three methods. SCS method has given the best results in our example. The right shape of the unit hydrograph is beside the right precipitation situation the most important thing by the runoff analyses.

Hydrological model was moderated for four events with measured hydrographs on nine stations along the Soča river and its tributaries (Šraj, 1995). The base runoff was defined from measured hydrographs and subtracted from the whole one. There was another problem because the location of the gauging stations wasn't always in accordance with the watershed boundaries (Figure 4), so the moderating has been approximate. The model was moderated thus that deviation of the volumes wasn't exceeded 10% and that the peaks of the measured and calculated hydrographs overlaid the best by high and time (Figure 5, Table 4).

Model has given good results according to insufficiency of the data. The differences in volumes of hydrographs have been minimal and peaks have been good time corresponded. Only the results for Bača and Vipava watersheds were a little bit worse. The major part of the runoff was contributed by Idrijca watershed, as can be seen from the results.

Preglednica 2. Geometrijski podatki za posamezna padavinska območja Soče (Šraj, 2000).
 Table 2. Geometric data for individual Soča sub-watersheds (Šraj, 2000).

| Šifra / Code | Št. HEC/ HEC No. | Površina / Area | Dolžina / Length | Težišče / Centre of gravity | Padec / Slope |
|-----------------|---------------------|----------------------|---------------------|-----------------------------------|------------------|
| | | A [km ²] | L [km] | Lca [km] | I [%] |
| 611 | 1 | 178,6 | 21,5 | 10,8 | 1,8 |
| 612 | 2 | 86,7 | 14,0 | 7,6 | 1,8 |
| 613 | 3 | 75,8 | 8,5 | 4,2 | 0,7 |
| 614* | 4 | 51,0 | 13,8 | 6,7 | 1,8 |
| 615 | 5 | 176,9 | 28,4 | 15,1 | 1,0 |
| 616 | 6 | 63,6 | 11,0 | 8,0 | 0,5 |
| 617 | 7 | 13,0 | 3,6 | 2,5 | 0,4 |
| 621 | 8 | 160,8 | 22,2 | 9,8 | 0,5 |
| 622 | 9 | 45,4 | 11,7 | 5,2 | 0,65 |
| 623 | 10 | 42,2 | 11,8 | 5,7 | 0,5 |
| 624 | 11 | 45,2 | 13,2 | 6,9 | 0,5 |
| 625 | 12 | 70,3 | 13,6 | 8,5 | 0,5 |
| 626 | 13 | 101,5 | 14,4 | 6,5 | 0,2 |
| 627 | 14 | 30,8 | 8,5 | 4,2 | 0,55 |
| 628 | 15 | 144,5 | 21,8 | 10,3 | 0,55 |
| 629 | 16 | 3,1 | 2,3 | 1,4 | 0,55 |
| 631 | 17 | 149,1 | 22,6 | 14,1 | 0,3 |
| 633 | 18 | 176,3 | 8,9 | 1,8 | 0,2 |
| 635* | 19 | 64,2 | 12,5 | 8,5 | 0,08 |
| 641 | 20 | 131,3 | 1,5 | 1,5 | 0,2 |
| 642 | 21 | 50,4 | 12,6 | 6,9 | 0,2 |
| 643 | 22 | 16,8 | 4,9 | 3,2 | 0,2 |
| 644 | 23 | 88,5 | 9,3 | 5,0 | 0,2 |
| 645 | 24 | 70,4 | 14,0 | 5,8 | 0,15 |
| 646 | 25 | 80,3 | 29,6 | 13,6 | 0,2 |
| 647 | 26 | 23,8 | 10,5 | 4,4 | 0,09 |
| 648 | 27 | 57,9 | 9,0 | 6,2 | 0,1 |
| 649* | 28 | 46,8 | 17,0 | 7,9 | 0,09 |

* padavinsko območje sega tudi izven meja Slovenije

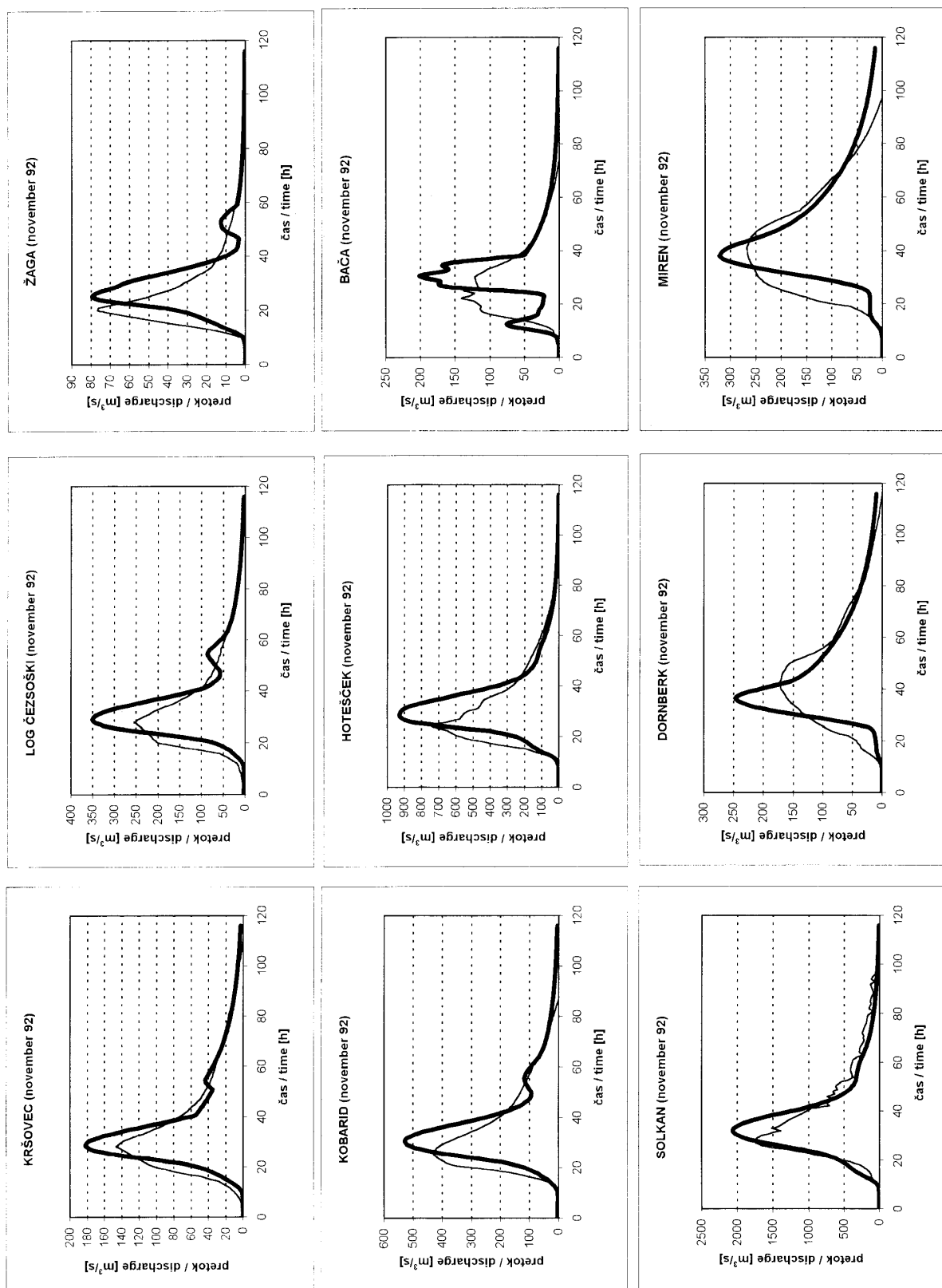
* watershed outside of the Slovenia national border

Preglednica 3. Parametri posameznih padavinskih območij Soče
 za dogodek November 1992 (Šraj, 2000).

Table 3. Model parameters for individual Soča sub-watersheds
 for november 1992 event (Šraj, 2000).

| Padavinsko območje / Watershed | T _p [h] | IA [mm] | CN | K [h] | X |
|--------------------------------|--------------------|---------|----|-------|------|
| 1 | 7 | 15 | 29 | | |
| 2 | 6 | 35 | 29 | | |
| 3 | 6 | 35 | 29 | 0,8 | 0,15 |
| 4 | 5 | 21 | 48 | | |
| 5 | 6 | 24 | 30 | 2,6 | 0,15 |
| 6 | 6 | 21 | 40 | | |
| 7 | 5 | 25 | 36 | 0,3 | 0,3 |
| 8 | 4 | 15 | 55 | | |
| 9 | 2 | 20 | 68 | | |
| 10 | 4 | 9 | 60 | 1,1 | 0,1 |
| 11 | 5 | 10 | 75 | | |
| 12 | 7 | 25 | 40 | 1,3 | 0,09 |
| 13 | 6 | 29 | 68 | | |
| 14 | 6 | 25 | 40 | 0,8 | 0,15 |
| 15 | 3 | 10 | 37 | | |
| 16 | 3 | 12 | 70 | 0,2 | 0,5 |
| 17 | 5 | 8 | 80 | 2,1 | 0,05 |
| 18 | 8 | 25 | 40 | 0,8 | 0,15 |
| 19 | 9 | 22 | 50 | 1,7 | 0,06 |
| 20 | 3 | 10 | 40 | | |
| 21 | 7 | 10 | 65 | | |
| 22 | 3 | 15 | 70 | 0,7 | 0,15 |
| 23 | 8 | 15 | 40 | | |
| 24 | 7 | 10 | 75 | 1,9 | 0,06 |
| 25 | 8 | 10 | 70 | | |
| 26 | 7 | 7 | 70 | 1,4 | 0,08 |
| 27 | 5 | 2 | 70 | | |
| 28 | 5 | 2 | 60 | 2,4 | 0,05 |

- T_p čas zakasnitve povodja v urah / watershed lag value in hours
 IA začetne izgube na nezasneženi površini v mm / initial rainfall abstraction in mm for snow free-ground
 CN SCS koeficient za določanje padavinskih izgub / SCS curve number for rainfall losses on snow-free ground
 K Muskingumov koeficient propagacije v urah / Muskingum coefficient for routing
 X Muskingumov utežni koeficient propagacije / Muskingum weighted coefficient for routing



Slika 5. Primerjava merjenih (tanka črta) in izračunanih (poudarjena črta) hidrogramov (Šraj, 2000).

Figure 5. Comparison of the measured (thin line) and calculated (bold line) hydrographs (Šraj, 2000).

Preglednica 4. Analiza rezultatov hidrološkega modela Soče (Šraj, 2000).
 Table 4. Analyses of the Soča hydrological model results (Šraj, 2000).

| <i>model november 92</i> | VOLUMEN / VOLUME | razlika / difference | Qmax | razlika / difference | Tp | razlika / difference |
|--------------------------|-----------------------------------|-------------------------|---------------------|-------------------------|-----------|-------------------------|
| | [10 ⁶ m ³] | [%] | [m ³ /s] | [%] | [h] | [h] |
| KRŠOVEC | | 1,2 | | 24,10 | | 0,5 |
| računani / computed | 15,98 | | 182 | | 28,5 | |
| merjeni / measured | 16,18 | | 146 | | 28 | |
| LOG ČEZSOŠKI | | 6,8 | | 38,00 | | 1 |
| računani / computed | 27,44 | | 350 | | 29 | |
| merjeni / measured | 25,70 | | 254 | | 28 | |
| ŽAGA | | 0,0 | | 3,50 | | 5,5 |
| računani / computed | 4,98 | | 79 | | 25,5 | |
| merjeni | 4,98 | | 77 | | 20 | |
| KOBARID | | 3,0 | | 23,20 | | 5,5 |
| računani / computed | 43,75 | | 528 | | 30,5 | |
| merjeni / measured | 42,48 | | 428 | | 25 | |
| HOTEŠČEK | | 8,6 | | 25,50 | | 4,5 |
| računani / computed | 68,81 | | 929 | | 28,5 | |
| merjeni / measured | 63,33 | | 740 | | 24 | |
| BAČA | | 0,7 | | 42,90 | | 8,5 |
| računani / computed | 12,69 | | 201 | | 30,5 | |
| merjeni / measured | 12,77 | | 141 | | 22 | |
| SOLKAN | | 3,6 | | 18,80 | | 5 |
| računani / computed | 174,90 | | 2066 | | 32 | |
| merjeni / measured | 168,78 | | 1740 | | 27 | |
| DORNBERK | | 3,2 | | 42,20 | | 5,5 |
| računani / computed | 25,14 | | 247 | | 36,5 | |
| merjeni / measured | 25,97 | | 174 | | 42 | |
| MIREN | | 8,8 | | 19,90 | | 3 |
| računani / computed | 36,97 | | 322 | | 38 | |
| merjeni / measured | 40,52 | | 268 | | 41 | |

2.5 AVTOMATSKA IZDELAVA VHODNE STRUKTURE HIDROLOŠKEGA MODELA S POMOČJO ŠIFRANTA

Ker se šifrant popolnoma ujema z vhodnimi strukturami hidroloških modelov in je prilagojen računalniški obdelavi, ga lahko s pomočjo GIS-ov uporabimo tudi za avtomatsko izdelavo vhodne strukture hidrološkega modela.

V bazi šifer padavinskih območij poiščemo na želeni ravni vse šifre oziroma padavinska območja, ki sestavljajo porečje našega hidrološkega modela (slika 6). To storimo tako, da definiramo najmanjšo in največjo iskano šifro. Pri tem uporabimo tekstovni način razvrščanja, ki nam pravilno razvrsti šifre, tudi če kombiniramo več ravni hkrati. Razvrščenim šifram avtomatsko dodelimo števila od ena naprej in jih preko GIS-ov (Autodesk, 1998) vnesemo še v grafični del baze. Tako s pomočjo šifrant padavinskih območij in GIS-ov avtomatsko izdelamo vhodno strukturo hidrološkega modela.

3. DRUGI PRIMERI UPORABE ŠIFRANTA

Ker je sistem šifriranja prilagojen računalniški obdelavi, je njegova uporabnost v GIS-ih (slika 7) zelo velika. Šifrant lahko prekrivamo z drugimi digitalnimi bazami, npr. s karto pokrovnosti, s karto hidrogeoloških značilnosti, z digitalnim modelom reliefa itd., delamo statistične analize, izdelujemo poljubne tematske karte (slika 8) itd. Na podlagi šifrant se določijo tudi administrativne meje območnih vodnih skupnosti.

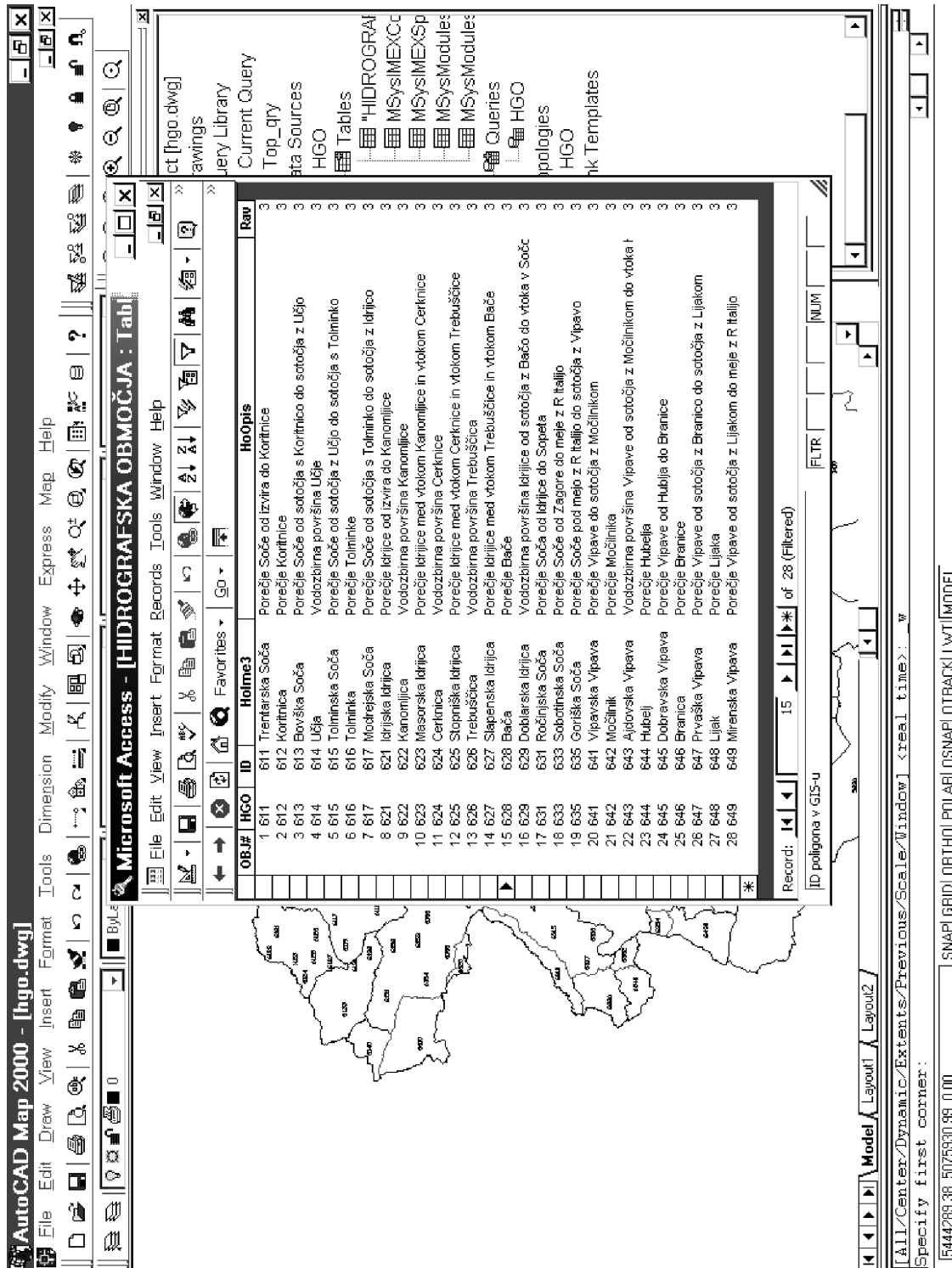
2.5 THE APPLICATION OF THE WATERSHED CODING SYSTEM FOR AUTOMATIC MAKING THE HYDROLOGICAL MODEL INPUT STRUCTURE

Because the coding system completely tallies with the model input structure and it is computer adapted, it can be used for automatic construction of the hydrological model input structure with GIS.

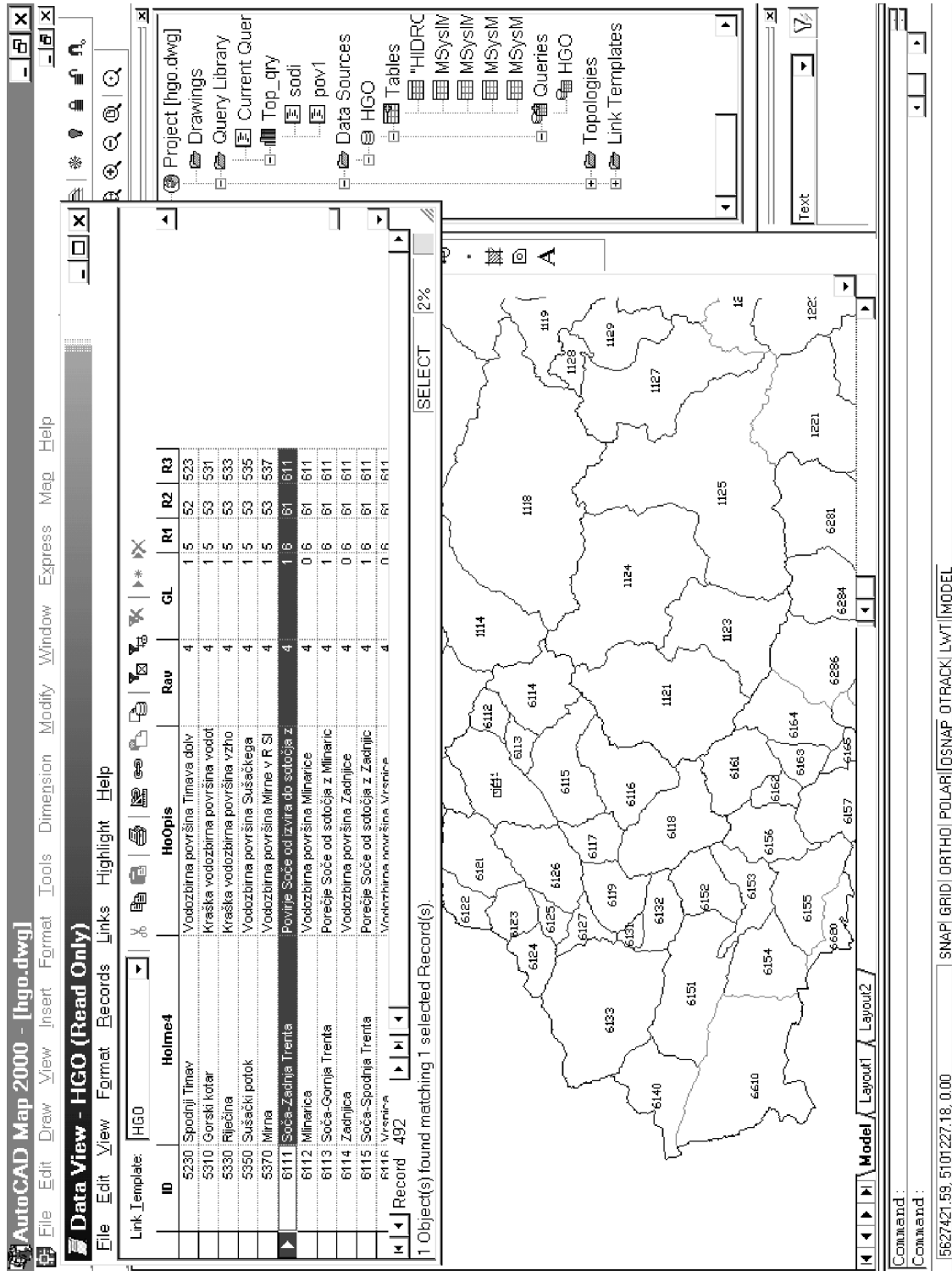
All codes composed our hydrological model watershed on the desired level had been searched in the watershed's code database (Figure 6). We do that with defining the maximum and minimum code using text type of arrangement. So we can get the correct arrangement also by combining more levels at the same time. Numbers from one up were automatically assigned to arrange codes and entered also in the graphical part of the base by GIS (Autodesk, 1998). So hydrological model input structure was made automatically with help of the watershed coding system and GIS.

3. OTHER EXAMPLES OF THE CODING SYSTEM APPLICATION

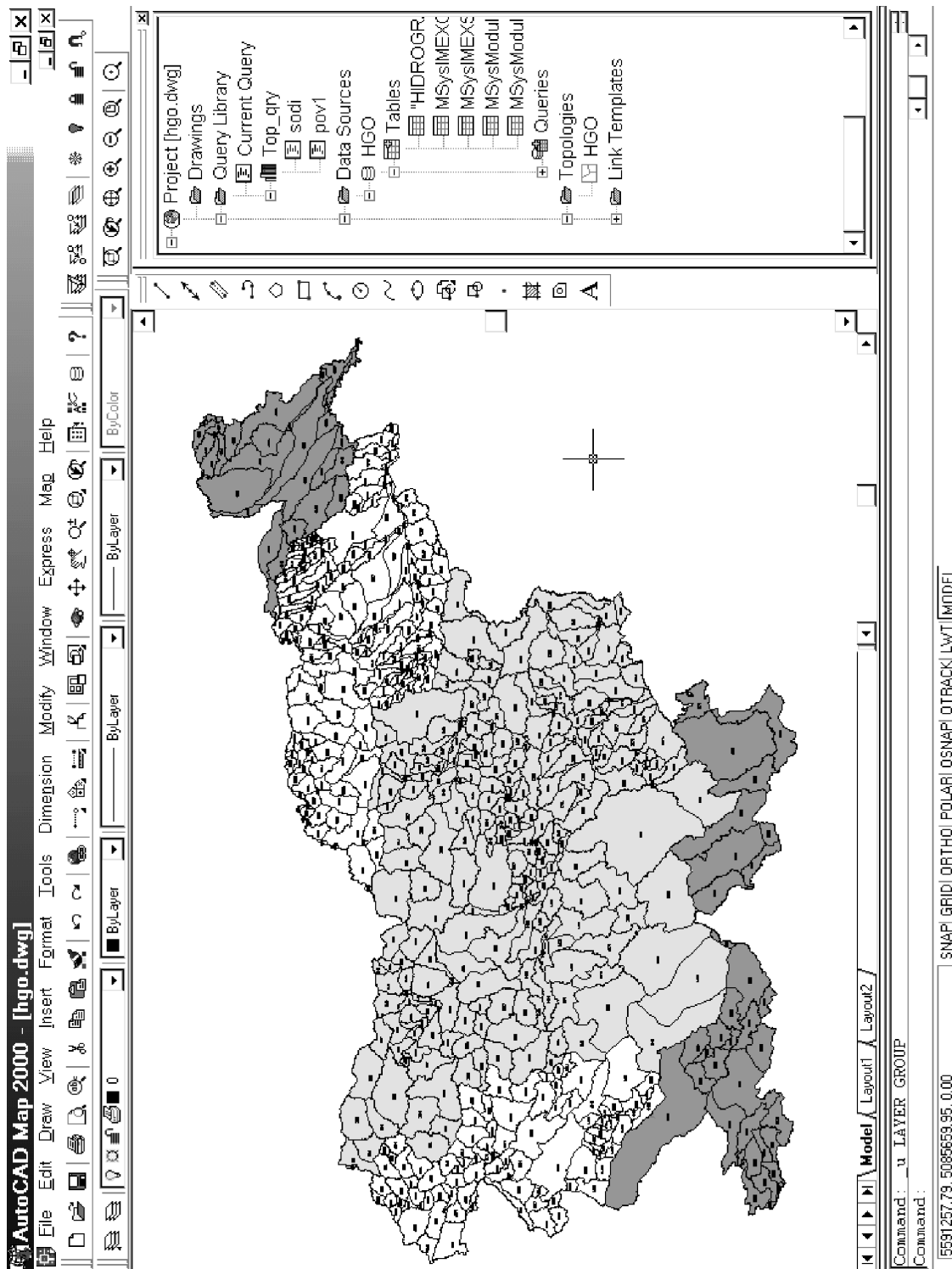
Because the coding system is computer adapted its applicability in GIS (Figure 7) is great. The coding system could be overlaid with other digital maps such as map of land cover, hydrogeological map, digital model of relief and so on. We can do statistical analyses, make optional thematic maps (Figure 8) etc. Administrative boundaries of regional water communities could also be defined on base of the coding system.



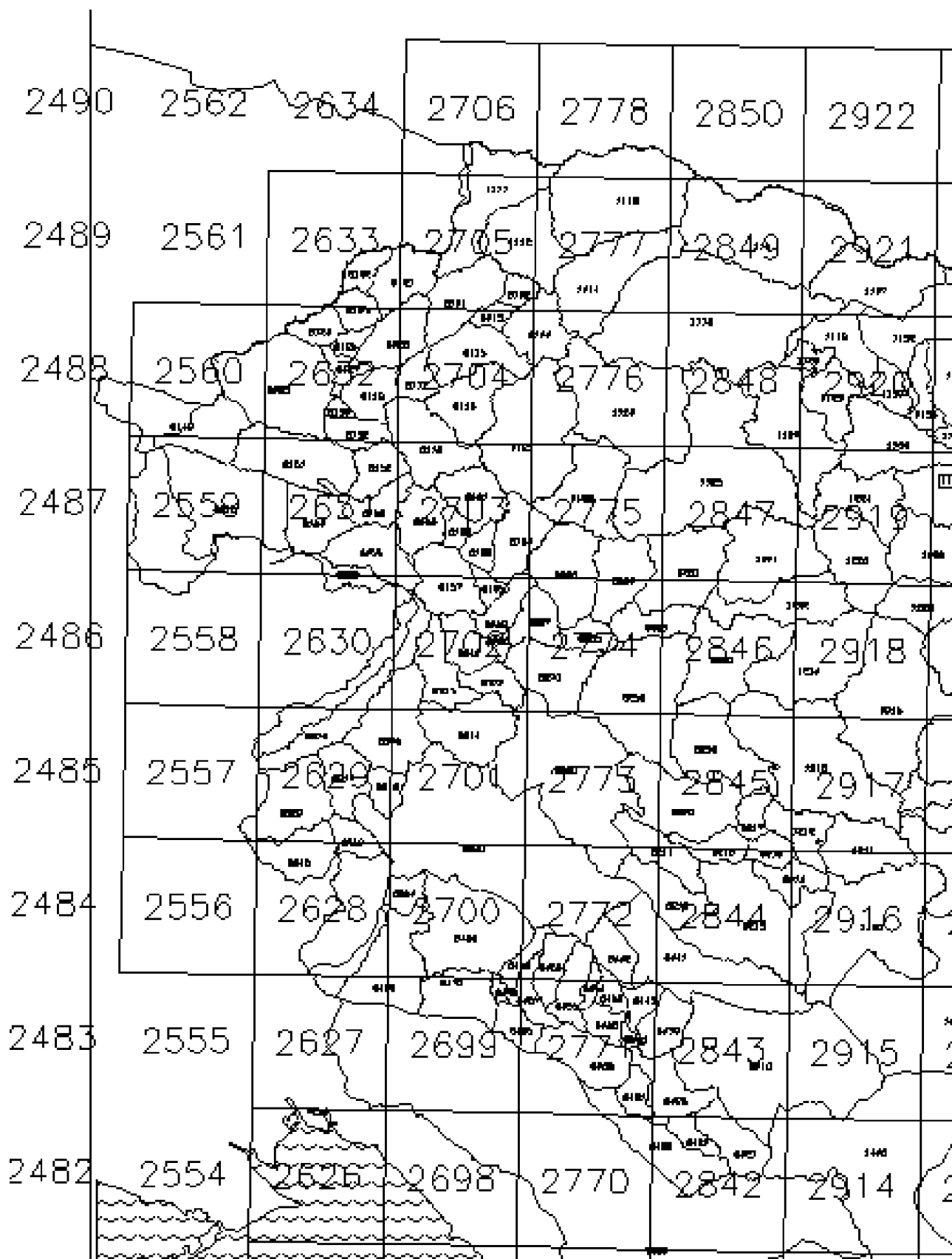
Slika 6. Avtomatska izdelava vhodne strukture hidrološkega modela Soče v GIS-ih.
 Figure 6. Automatic making of the hydrological model input structure with GIS.



Slika 7. Šifrant padavinskih območij Republike Slovenije v GIS-ih.
 Figure 7. The coding system of the Republic of Slovenia in GIS.



Slika 8. Prikaz glavnih padavinskih območij R Slovenije s šifrantom na četrti ravni.
Figure 8. Review of the main watersheds of the Republic of Slovenia with the coding system on the fourth level.



Slika 9. Padavinsko območje Soče, prekrito z mrežo modela ALADIN-SI.
 Figure 9. The Soča river watershed overlaid with the ALADIN-SI model net.

Še en primer uporabe šifranta padavinskih območij: padavinska območja, prekrita z mrežo modela ALADIN-SI, ki nam daje napoved padavin za 48 ur vnaprej. Napovedane padavine, ki pripadajo posameznemu kvadratu mreže, se procentualno porazdelijo na posamezno padavinsko območje. Tako dobimo vhodne podatke za hidrološke modele pri napovedovanju poplavnih valov (slika 9) (Brilly in ostali, 2000).

Naslednji korak je določitev karakteristik posameznih padavinskih območij in njihova vključitev v GIS. Tak sistem je bistvenega pomena za sodoben razvoj vodnega gospodarstva, učinkovito zaščito okolja, napovedovanje poplav itd.

4. ZAKLJUČKI

Pomen šifranta padavinskih območij R Slovenije je izjemen, saj si je tudi Evropska agencija za okolje za eno od prvih nalog zadala izdelavo katastra in šifranta vodotokov držav Evropske unije (Morris, 1994).

Sistem šifriranja padavinskih območij je strukturiran tako, da omogoča preprosto programiranje in neposreden vnos v hidrološke modele. Tudi kombiniranje različnih ravni šifranta se popolnoma ujema z vhodno strukturo modela.

Šifrant padavinskih območij predstavlja temelj sodobnega informacijskega sistema za potrebe varstva okolja, urejanje podatkov o okolju, njihovo obdelavo in statistično analizo, za izdelavo vodnogospodarskih načrtov, programov, strokovnih podlag, katastra vodnogospodarskih objektov in ostalih prostorsko določenih podatkov.

One another example of the application of the coding system: watersheds overlaid with ALADIN-SI model net. The model ALDADIN-SI gives us precipitation forecast for 48 hours beforehand. Forecasted precipitation within individual square of the model net had been distributed to the individual watershed by percentage. Thus we get input data for hydrological models by flood forecasting (Figure 9) (Brilly et al., 2000).

The next step is defining the characteristics of the individual watersheds and their incorporating in GIS. Such as system is significant for contemporary development of the water management, effectively environment protection, flood forecasting etc.

4. CONCLUSIONS

Making the river coding system of the European Union was one of the first tasks of European Environmental Agency also (Morris, 1994). The coding system of the Republic of Slovenia is therefore significant.

The structure of the watershed coding system enables simple computer programming and direct hydrological modelling. Also combining different levels of the coding system completely tallies with model input structure.

The coding system of the Republic of Slovenia represents the basis of contemporary information system for environment protection, environmental data management, data handling and statistical analyses, water management plans and programmes, cadastre of hydraulic structures and other space related data.

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