PRACE GEOGRAFICZNE, zeszyt 104
Instytut Geografii UJ
Kraków 1999

Ludwik Kaszowski, Kazimierz Krzemień

CLASSIFICATION SYSTEMS OF MOUNTAIN RIVER CHANNELS

Abstract: The authors have compared several river channel classification systems and typology methods, and constructed a diagram comparing river channel classifications.

Key words: channel typology, methods of river channel typology.

1. Introduction

River channel typology is one of subjects less frequently written about or dealt with in the vast body of fluvial geomorphology literature. While many of the works do conclude with a channel and channel reach classification, they are rarely very specific about the methods employed. Being research goal oriented the existing classifications are fragmentary. Indeed it is worth pointing out that there are very few large-region or countrywide river channel classifications. What is more, the two basic terms used in fluvial studies, i.e. a river and a channel, are frequently used either interchangeably or some aspects, e.g. planform, are only attributed to rivers and others to channels; a tendency reflected in the actual river and channel typologies (Matthes 1956; Falkowski 1971, 1991).

The methods of river channel classification seem to require certain systematisation. This paper, based on the authors' experience and considerations from their research in the Tatra Mts. (Kaszowski 1979; Kaszowski, Krzemień 1979; Krzemień 1981), aims to systematise the river channel typologies and compare typological procedures.

2. Overview of Channel Classifications

The description and classification of a river channel is normally based on aerial photographs, topographic and geological maps, and hydrological materials (Popov 1969).

However, in the view of some researchers this laboratory approach must be supported with fieldwork (Rudberg, Sundborg 1975; Kellerhals, Church, Bray 1976). Another approach is presented by those researchers who use code-and-form survey systems during mapping as the basis of channel description (Tille 1970; Witt 1976; Kaszowski 1980; Krzemień 1980, 1984; Rączkowska 1983, Kamykowska et al. 1999). They normally divide channels into homogenous reaches (in terms of their morphodynamics and morphostatic) and then work on detailed characterisation. Dividing channels into homogenous reaches is also recommended by J.W. Popov (1969), K.J. Gregory and D.J. Walling (1973), S. Rudberg and A. Sundborg (1975), R. Kellerhals, M. Church and D.J. Bray (1976). Although not always precisely specified, this procedure may be regarded as a typological procedure.

Most classification systems are based on up to a dozen or so, criteria (Tab. 1). The most frequently used criteria are: pattern (Russel 1954; Leopold, Wolman 1957; Dury 1969), stability (Vielikanov 1955; Schumm 1963b), bed and bedload material, and dominating processes (Popov 1969; Krzemień 1976; Kaszowski, Krzemień 1977). The variety of existing approaches to typology begs the question whether a comprehensive classification is feasible.

Tab. 1. Examples of the river channel classifications

No.	Author (year)	Criteria	Types of river channels
1	2	3	4
1	Russel R.J. (1954)	channel pattern	1) straight. 2) meandering, 3) braided
2	Vielikanov M.A. (1956)	channel stability	River types: 1) with rocky channels, weakly eroded; low rate of bed-load transportation, 2) with channels alternately eroded and upbuilt; size and shape of riffles and pools are constant, 3) with tendency to deepen the channels; no change of channel pattern, annual changes of riffle and pool location, 4) with changing channel depth and pattern during the floods, mountain rivers, weak bank erosion, 5) of debris-mud flows during the floods
3	Matthes G.H. (1956)	different	1) primary channel types, 2) hard-bed streams, 3) erodible-bed steams, 4) alluvial meandering rivers, 5) braided rivers, 6) delta channels, 7) estuaries, 8) bay-channels, 9) salt-marsh channels, 10) lake outlets

Tab. 1.

1	2	3	4
4	Leopold L.B. Wolman M.G. (1957)	channel pattern	1) straight, 2) meandering, 3) braided
5	Schumm S.A. (1963 a)	sinuosity	1) straight, 2) transitional, 3) regular, 4) irregular, 5) tortuous
6	Schumm S.A. (1963 b)	mode of sediment transportation	1) suspended-load channels, 2) mixed-load channels, 3) bedload channels
7	Popov J.W. (1969)	dominant channel process, channel pattern	1) channels with transported band bars, 2) channels with alternate bars, 3) channels modelled by restricted meandering, 4) channels modelled by free meandering, 5) channels modelled by interrupted meandering, 6) channels with mid-bars
8	Dury G.H. (1969)	channel pattern	1) straight, 2) straight-simulating channels, 3) meandering, 4) braided, 5) deltoid distribution pattern, 6) anabranching, 7) reticulate channels, 8) irregular
9	Falkowski E. (1971)	valley genesis, channel pattern, dominant process	I a: juvenile river with a valley modelled by erosion, I b: juvenile river with a valley modelled by sedimentation; II: mature free rivers - free meandering or braided channel pattern; III: mature restricted rivers - limited horizontal as well as vertical displacements of the channel
10	Galay V.J., Kellerhals R., Bray D.J. (1973) Kallerhals R., Church M., Bray D. J. (1976)	channel pattern	Classification system 1) straight, 2) sinuous, 3) irregular, 4) irregular meanders, 5) regular meanders, 6) tortuous meanders
		islands	1) none, 2) occasional, 3) frequent, 4) split, 5) braided
		bars	1) none, 2) side bars, 3) point bars, 4) channel junction bars, 5) mid-channel bars, 6) diamond bars, 7) diagonal bars, 8) sand waves, large dunes
		lateral migration	1) none, 2) downstream progression, 3) progression and cut-offs, 5) entrenched loop development, 6) irregular lateral activity, 7) avulsion

Tab. 1.

1	2	3	4
11	Brice J.C. (1975) vide Thorne C.R. (1977)	character of sinuosity character of braiding character of anabranching	1) single phase, equiwidth channel, deep 2) single phase, equiwidth channel, 3) single phase, wider at bends, chutes rare, 4) single phase, wider at bends, chutes common, 5) single phase, irregular width variation, 6) two phase underfit, low-water sinuosity, 7) two phase, bimodal bankfull sinuosity 1) mostly bars, 2)bars and islands, 3) mostly islands, diverse shape, 4) mostly islands, long and narrow 1) sinuous side channels mainly, 2) cut-off loops mainly, 3) split channels, sinuous anabranches, 4) split channel, sub-parallel anabranches, 5) composite
12	Krzemień K. (1976)	lithology, morphostatics dominant processes	1) rocky, 2) rocky-alluvial, 3) alluvial 1) erosional, 2) transportational, 3) depositional
13	Kaszowski L. Krzemień K. (1977)	lithology channel-bottom channel pattern dominant process or morphodynamic function channel structure	1) rocky (R), 2) alluvial (A) 1) rocky with rocky bottom (Rr), 2) rocky with debris bottom (Rd), 3) alluvial with rocky bottom (Ar), 4) alluvial without accumulation forms (Ao), 5) alluvial with accumulation forms in the bottom (Ad) 1) straight (S), 2) crooked (C), 3) braided (B) 1) modelled by erosion (E), 2) trasportational (T), 3) modelled by deposition (D) Examples of channel structures: (B-S), (C-B), (S-C-B), 2(C-B)-C, (Rd-Ad), 2(Rd-Rr)-Ad, E, (E-D-T), (E-T-D), (E-T)-(E-D)
14	Klimaszewski M. (1978)	lithology	1) rocky, 2) rocky-alluvial, 3) alluvial
15	Rust B.R. (1978)	Sinuosity and degree of channel division	1) straight, 2) braided, 3) meandering, 4) anastomosed
16	Baumgart-Kotarba M., Kotarba A. (1979)	channel morphology, valley bottom morphology, actual river activity	1) stable channels, cut in moraine and coarse scree sediments, 2) temperate stable channels with slight tendency to erosion or accumulation, 3) channels strongly modelled by lateral erosion, 4) channels modelled by depth erosion

Tab. 1.

1	2	3	4
17	Klimek K. (1979)	morphology and geology of catchment basin, river morphodynamics	Channels of the Polish Carpathian Mts.: 1) simple type (Ps) of middle elevation mountains, 2) simple type of middle elevation mountains and foothills (Psw), 3) composite type of high and middle elevation mountains (Zws)
18	Kaszowski L., Krzemień K. (1979), Krzemień K. (1981, 1984)	dominant process or morphodynamic function	1) modelled by deep erosion, 2) modelled by lateral erosion, 3) modelled by deposition, 4) modelled by redeposition, 5) transportational
19	Richards K. (1982)	channel pattern	1) single thread channels, 2) multi-thread channels
20	Rączkowska Z. (1983)	lithology, morphostatics, morphodynamics (on the base of 25 features of the valley and channel)	1) rocky channel, fashioned by bed scour in the unglaciated valley, 2) channel cut into alluvial valley-fills shoving tendency toward either erosion or accumulation in the unglaciated valley, 3) moderately stable channel cut into glacifluvial deposits occurring in the unglaciated valley, 4) stable channel cut into morainic deposits which are found in the formerly glaciated valley, 5) moderately stable channel cut into morainic deposits which were reworked by rivers in the formerly glaciated valley.
21	Chalov S.R. (1984)	channel gradient, bedload size, Froude number	1) mountain-type: a) with developed alluvial features, gradient 5-80‰, F=0.3-0.8, b) with undeveloped alluvial features, gradient 15-125‰, F= 0.8-1.2, c) with multiple thresholds, gradient 23-125‰, F>1.2, 2) foothill, and mid mountain and intermountain basin type, gradient 0.2-50 ‰ F<0.3, 3) flatland type, gradient 0.2-15 ‰, F<0.3
		morphological shape and horizontal deformation of the channel	1) meandering, 2) braided: a) simple – single braiding, b) complex - single braiding, c) simple – coupled braiding, d) complex - coupled braiding, e) dispersed – multi-arm channel, f) one-sided braiding, 3) non-braided or relatively straight

Tab. 1.

1	2	3	4
22	Chalov S.R. (1991)	type of bedrock and stream kinetics (Froude number) size of downcut and channel development	1) mountain type: a) rocky, b) with thresholds and waterfalls, c) with non-developed alluvial features, d) with developed alluvial features, 2) foothill, 3) flatland 1) cleaved: a) relatively straight, b) tortuous, c) accumulative, 2) transitional – with forced and adapted meanders, 3) with broad floodplains: a) relatively straight with single braiding, b) freely meandering: - with meanders moving along the river; - with meanders moving laterally, c) braided (multi-arm): - one-sided; - one-sided braiding; - coupled, - parallel braided and dispersed, d) passively adapted: - marshy; - overgrowing (flooded)

3. Methods of Typology

Although only few works specify methods of channel type or subtype determination in a clear and consequent manner, the author's typological procedures can be traced and identified. For the purposes of this paper methods found in the fluvial literature have been classified as follows:
1. one-criterion method;
2. dominant characteristic method;
3. equivalent criteria method;
4. method of indicative characteristic analysis;
5. method of reach boundary analysis;
6. method of channel structure analysis;
7. method of catchment environment analysis;
8. method of numerical taxonomy.

3.1. One Criterion Method

Procedure:
– selection of a channel characteristic – the sole criterion for typology;
– identification of channel types.

In this method planform is the most frequently used criterion and input data comes almost exclusively from maps and aerial photographs. Channel types are identified either on the basis of qualitative characteristics (qualitative typology), e.g.

channel pattern (straight, meandering, braided; Leopold, Wolman 1957), or quantitative characteristics (quantitative typology), e.g. coefficient of sinuosity (Schumm 1963a), coefficient of braiding or development. M. Klimaszewski (1978), determined channel types on the basis of the bed material (Tab. 1). Various factors can be used to explain the origin of the channel types determined with the one criterion method: type of hydrological regime, channel-building deposits or channel transported deposits and human influence.

3.2. Dominant Characteristic Method

Procedure:

– selection of the main characteristics characterising the channel;
– selection of the dominant characteristic and optionally, ranking the remaining characteristics according to their significance;
– identification of channel types.

Research of river channel systems should not be limited to the investigation of just one characteristic. A complete survey of a river channel environment may only be achieved through the examination of a number of characteristics (variables). Characteristics are ranked for significance and, for the purposes of taxonomy, one that covers all the remaining attributes is selected as the „leading", „primary", or „dominant" characteristic. The secondary characteristics can be used to characterise channel types identified according to the dominant characteristic or as secondary criteria for the identification of subtypes. The typical dominant characteristics are pattern (Leopold, Wolman 1957), channel stability, and the dominating process.

3.3. Equivalent Criteria Method

Procedure:

– selection of criteria for typology (dominant characteristics);
– selection of equivalent criteria;
– drawing-up the typological table;
– verification of the types identified.

Selection of just one characteristic as the dominant characteristic is not always justifiable, particularly in the mountains. The addition of more „dominant" characteristics improves the precision of channel type identification and characterisation.

Initially a pair of equivalent characteristics is selected from the dominant characteristics and ranked accordingly (Kamykowska et al. 1999). Next a typological table is drawn-up and the equivalent characteristics are compared on several axis of the table (Kamykowska et al. 1999). The resulting types and subtypes are labelled with numbers and letters. This type of typology must be verified in the field. The equivalent criteria method is used for determination of homogenous channel reaches which are to be characterised in a given way. Among the pairs of leading equivalent characteristics are: type of material in which the channel is formed (bedrock or cover) and the channel pattern (straight, meandering or braided), or pattern and stability.

This method allows the *a priori* type identification and its usefulness depends on the confrontation of the chosen types with the actual channel systems in the field.

3.4. Method of Indicative Characteristic Analysis

Procedure:
- selection of the primary typological criterion;
- selection and comparison of the indicative characteristics;
- qualitative, according to the group division adopted;
- quantitative, according to the characteristic intensity classification;
- transposition of the indicative attributes onto one characteristic corresponding to the primary criterion;
- identification of channel types according to the primary criterion.

A classification of a river channel system which takes into account the intensity and character of the modelling process, requires a comparison and analysis of characteristics related to morphodynamics (Kaszowski 1980; Krzemień 1981, 1984; Tab. 1.). Such indicative characteristics, grouped together, are easily transposed onto one dominant characteristic. If a channel is to be classified according to its modelling process with the use of the coefficient of channel bars, it is quite clear that the reaches with the highest values of that coefficient also display a tendency to intensive deposition and re-deposition of bedload material. Similarly, it is easy to divide channels into „deep" with the tendency to depth erosion, and „wide" with a tendency to lateral erosion on the basis of the shape factor. Thus, the transposition of various indicative characteristics like the coefficient of bars or shape factor onto the dominant fluvial process leads to the identification of channels or channel reaches modelled by a given set of processes.

3.5. Method of Reach Boundary Analysis

Procedure:
- selection of features characterising the channel;
- comparison of the indicative characteristics by the group division adopted;
- comparison of quantitative characteristics by intensity;
- drawing-up a comparison scheme of the qualitative and quantitative characteristics for all channel reaches;
- comparison of the number of borders in every channel reach;
- boundary significance assessment, boundary verification, and selection of channel type boundaries;
- channel type labelling and description.

The boundary analysis method can be applied to those channel systems which have been divided into reaches and where every reach has been characterised (Rączkowska 1983; Chełmicki et al. 1993). All the quantitative and qualitative characteristics, are the basis for joining of adjacent reaches. This leads to a number of divisions of a given channel system into reaches according to the characteristic intensity or character. Where boundaries between reaches established according to different characteristics do not coincide their significance is determined by a quantitative comparison; the most frequent boundaries will normally separate channel types, the less frequent ones subtypes, etc. This method involves a risk of analysing characteristics which correlate with other characteristics, so the importance of some boundaries may be overestimated.

3.6. Method of Channel Structure Analysis

Procedure:
– selection of the indicative characteristic (typological criterion);
– selection of the indicative characteristic (typological criterion);
– attribution of the indicative characteristic to the homogenous channel reaches;
– establishing the reach sequence (structures for each channel);
– identification of channel types according to the reach sequence type (structures).

Channel systems may be compared through a comparison of their structures i.e. sequences of morphostatic or morphodynamic reaches. Hence the determination of channel structure may be regarded as a typological procedure.

3.7. Method of Catchment Environment Analysis

Procedure:
– selection of the typologically significant environmental characteristics;
– classification of catchment geomorphology types based on the geomorphologic and geologic similarity/dissimilarity analysis;
– similarity/dissimilarity analysis of the remaining environmental characteristics and their effect on fluvial processes;
– identification and naming of morphodynamic types of channel in relation to the catchment types determined.

In contrast to the aforementioned methods which normally require a division of channels into reaches, the catchment environment analysis method results in the determination of entire channel system types (Klimek 1979; Chalov 1984). Inevitably this involves a certain degree of generalisation, but it highlights differences between fluvial systems on a regional scale, leading to the identification of their function in the modelling of geomorphology of these regions.

3.8. Method of Numerical Taxonomy

One of the following methods can be used for investigation:
– the furthest neighbour;
– the median;
– the centroid;
– the mean;
– the nearest neighbour.

Procedure:
– selection of characteristic features;
– calculation of taxonomic distances for channel reaches and selected characteristics;

– determination of similarity between reaches;
– drawing-up of group dendrites;
– setting levels at which units of typology are well described for each method in the dendrite;
– transfer of typological units onto the channel long profile;
– reach grouping;
– naming of the grouped units (channel types).

Channel systems to which methods of taxonomy may be applied, must first be divided into reaches and given detailed description. Taxonomy offers a higher degree of objectivity in grouping reaches of the same type and an easier determination of channel type boundaries in the final stages of the procedure (Chełmicki et al. 1993). These methods may also be applied to the large-scale fluvial system typology.

This paper attempts to provide various approaches to channel type identification in the form of „methods", although the original authors were not always conscious they were using them, nor had they given them names. Each of the presented methods has several unrefined elements, the presentation and analysis of which, however, is beyond the limited scope of this paper.

For the general purposes the single criterion or equivalent characteristic methods are the most useful and most frequently applied, while the remaining methods are used for channel classification in regional units of various size.

4. Channel Classification Schema

The variety of research approaches in fluvial geomorphology may be explained in the subject's inherent connections with geomorphology, geology and hydrology (Fig. 1.). There is no consensus even among geomorphologists who tend to emphasise different factors. In view of this variety of approaches and the number of criteria applied the authors conclude that the development of one ultimate channel type classification may be impossible. What is possible however, are fragmentary typologies that are useful so far, as they fulfil a given research objective or practical goal. Hence only a more or less complex classification schema indicating the typology criteria can be developed. This standpoint is represented by V.J. Galay, R. Kellerhals and D.I. Bray (1973) as well as by a channel mapping instruction (Kamykowska et al. 1999).

The morphostatic, morphodynamic, hydrologic, and sedimentologic approaches are related to the four fundamental characteristics of the river channel environment: forms, processes, water and sediments, whereas the fifth approach, physiographic, is related to the environment surrounding the river channel system, i.e. the geographical environment of the catchment area. Corresponding approaches in river channel classification imply the following principal criteria: morphostatics, morphodynamics, hydrology, sedimentology, and physiogeography (Fig. 2.), all of which are indispensable in order to establish a complete characteristic of a channel system and its origin. Other basic criteria in the classification schema serve to increase not only the degree of detail but also the comprehensive appraisal of the river channels and their classification. The paper gives only some examples from a multitude of potential detailed criteria (Tab.

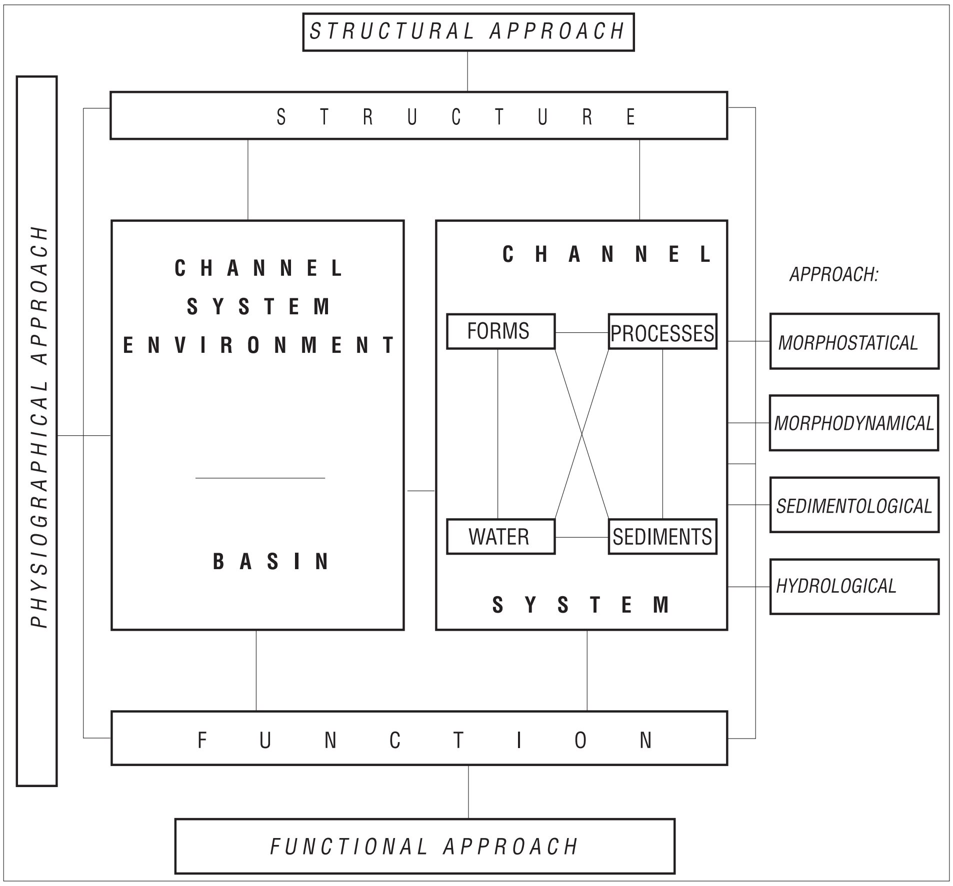

Fig. 1.

1.), and it remains a topic for scientific and academic discussion which of them are more useful for a typological procedure.

Conclusion

River channels, as an element of geomorphologic systems of all climatic zones and a focus of matter circulation, serve as a synthetic indicator of system dynamics and development trends. Thus, the channel types determined, may give some indication as to the evolutionary state of a geomorphological system, providing information of vital practical significance. In view of the above, there is a need for further studies on the spatial differences and functions of various channel types in geomorphological systems.

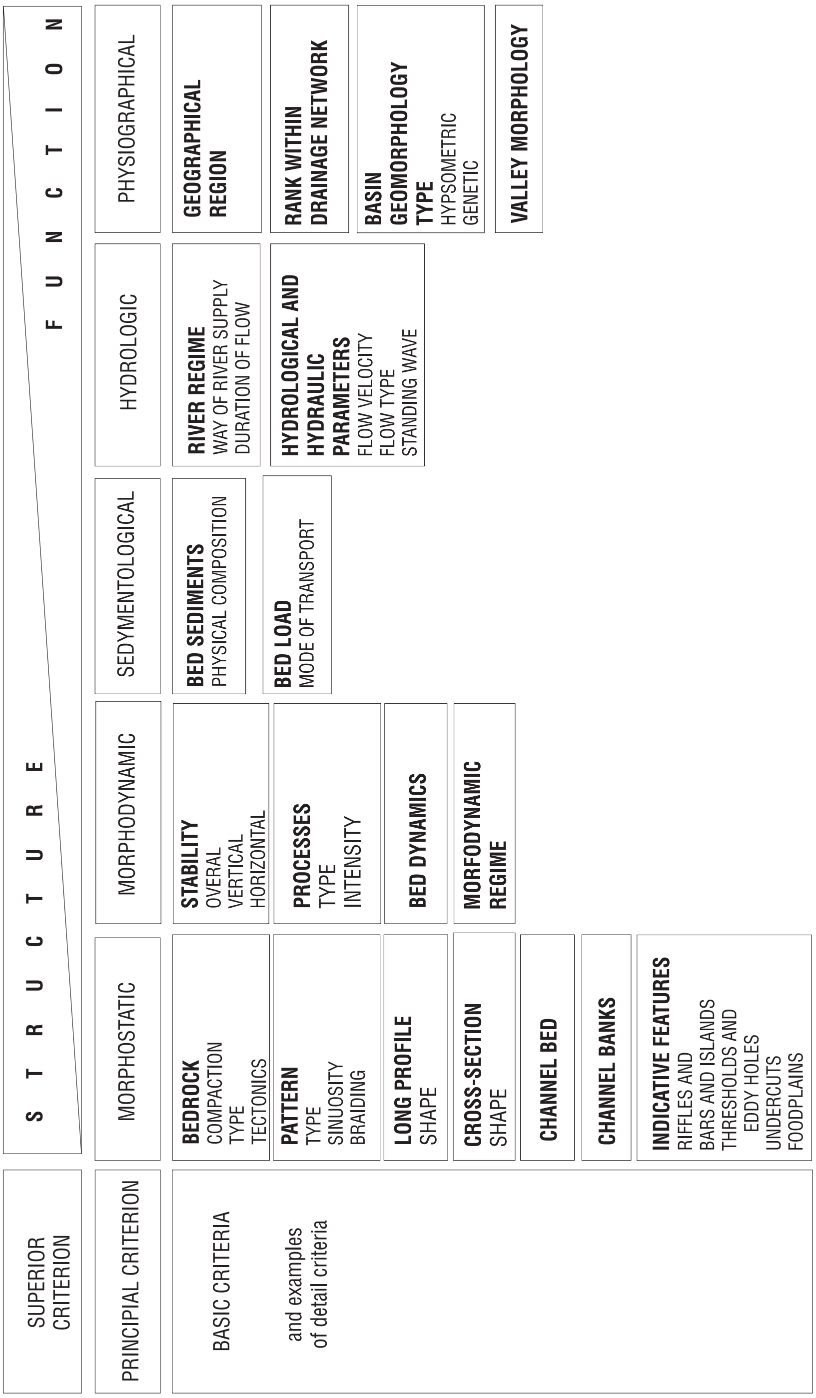
SUPERIOR CRITERION
S T R U C T U R E
F U N C T I O N
PRINCIPIAL CRITERION
MORPHOSTATIC
MORPHODYNAMIC
SEDYMENTOLOGICAL
HYDROLOGIC
PHYSIOGRAPHICAL
BASIC CRITERIA
and examples of detail criteria
BEDROCK COMPACTION TYPE TECTONICS
PATTERN TYPE SINUOSITY BRAIDING
LONG PROFILE SHAPE
CROSS-SECTION SHAPE
CHANNEL BED
CHANNEL BANKS
INDICATIVE FEATURES RIFFLES AND BARS AND ISLANDS THRESHOLDS AND EDDY HOLES UNDERCUTS FOODPLAINS
STABILITY OVERAL VERTICAL HORIZONTAL
PROCESSES TYPE INTENSITY
BED DYNAMICS
MORFODYNAMIC REGIME
BED SEDIMENTS PHYSICAL COMPOSITION
BED LOAD MODE OF TRANSPORT
RIVER REGIME WAY OF RIVER SUPPLY DURATION OF FLOW
HYDROLOGICAL AND HYDRAULIC PARAMETERS FLOW VELOCITY FLOW TYPE STANDING WAVE
GEOGRAPHICAL REGION
RANK WITHIN DRAINAGE NETWORK
BASIN GEOMORPHOLOGY TYPE HYPSOMETRIC GENETIC
VALLEY MORPHOLOGY

Fig. 2.

References

Baumgart-Kotarba M., Kotarba A., 1979, *Wpływ rzeźby dna doliny na wykształcenie koryta Białej Wody w Tatrach*, Folia Geogr., ser. Geogr.-Phys. 12, Kraków.

Brice J.C., 1975, *Air photo interpretation of the form and behavior of alluvial rivers*, Final report to the US Army Research Office.

Chełmicki W., Krzemień K., Sobański M., 1993, *Próba typologii koryta rzecznego Feshie River (Szkocja)*. Streszcz. referatów i przew. wycieczkowy, II Zjazd Geomorf. Polskich. Lądek Zdrój 4-7.10. 1993.

Chalov R.S., 1984, *Morfologija i dinamika recznykh rusel* [in:], N.I. Makkavev, R.S. Chalov (eds), *Erozionnye procesy*, Mysl, Moscou.

Chalov R.S., 1991, *Ruslovye protsessy na rekakh Altaiskogo Kraya*, Karta 1:1000000, Minsk.

Dury G.H., 1969, *Relation of morphometry to runoff frequency* [in:] R.J. Chorley (ed), *Water Earth and Moon*, Methuen, London, England.

Falkowski E., 1971, *Historia i prognozy rozwoju układu koryta wybranych odcinków rzek nizinnych Polski*, Biul. Geolog., 12, Warszawa.

Falkowski E., 1991, *Inżynieryjno-geologiczne problemy ochrony środowiska przyrodniczego na obrzeżach den dolinnych Niżu Polskiego*, Gospodarka Wodna, 1.

Galay V.J., Kellerhals R., Bray D.I., 1973, *Diversity of River Types in Canada*, *Ninth Canadian Hydrology Symposium Fluvial Processes and Sedimentation*, Univ. of Alberta, Edmonton, May 8 and 9.

Gregory K.J., Walling D.E., 1973, *Drainage Basin*. [in:] E. Arnold (ed), *Form and process a geomorphological approach*, (publishers) Ltd.

Kamykowska M., Kaszowski L., Krzemień K., 1999, *River-channel mapping insruction, Key of the river-bed description*, Prace Geogr., IG UJ, 104.

Kaszowski L., 1979, *Dynamiczna typologia koryt rzecznych na obszarze Karpat i ich przedgórza*, Spraw. z Posiedz. Kom. Nauk., PAN, Oddz. w Krakowie, 21/1(1977), Kraków.

Kaszowski L., 1980, *Struktura i typy koryt rzecznych w dorzeczu Raby*, Spraw. z Posiedz. Kom. Nauk., PAN, Oddz. w Krakowie, 22/1 (1978), Kraków.

Kaszowski L., Krzemień K., 1977, *Structure of mountain channel systems as examplified by chosen Carpathian streams*, Studia Geomorph., Carp.-Balc., 11, Kraków.

Kaszowski L., Krzemień K., 1979, *Channel subsystems in the Polish Tatra Mts.*, Studia Geomorph., Carp.-Balc. 13, Kraków.

Kellerhals R., Church M., Bray D., 1976, *Classification and analysis of river processes*, Journal of the Hydraulics Division, ASCE. 102, HY 7.

Klimaszewski M., 1978, *Geomorfologia*, PWN, Warszawa.

Klimek K., 1979, *Geomorfologiczne zróżnicowanie koryt karpackich dopływów Wisły*, Folia Geogr., ser. Geogr.-Phys., 12, Kraków.

Krzemień K., 1976, *Współczesna dynamika koryta potoku Konina w Gorcach*, Folia Geogr., ser. Geogr.-Phys., 10, Kraków.

Krzemień K., 1981, *Zmienność subsystemu korytowego Czarnego Dunajca*, Zesz. Nauk. UJ, Prace Geogr., 53.

Krzemień K., 1984, *Współczesne zmiany modelowania koryt potoków w Gorcach,* Zesz. Nauk. UJ, Prace Geogr., 58.

Leopold L.B., Wolman M.G., 1957, *River channel patterns: braided, meandering, and straight*, Prof. Paper 282-B, U.S. Geological Survey.

Matthes G.H., 1956, *River engineering, American Civil Engineering Practice*, R. W. Abbett (ed), 2. John Wiley and Sonc Inc. New York, N.Y.

Popov J.V., 1969, *Deformatsyi rechnykh rusel i gidrotekhnicheskoye stroitelstvo*, Gidrometeoizdat, Leningrad.

Rączkowska Z., 1983, *Types of stream channels in the Chochołowska Drainage Basin (The Polish Western Tatra Mts.),* Studia Geomorph., Carp.-Balc., 16, Kraków.

Richards K., 1982, *Rivers, form and process in alluvial channels,* Methuen, London and New York.

Rudberg S., Sundborg A., 1975, *Vattendragen i Norra, Norrland*, Geovetenskapliga naturvärden Uppsala Universitet Naturgeografi.

Russel R. J., 1954, *Alluvial morphology of Anatolian rivers*, Ann. Amer. Geogr. 44.

Rust B. R., 1978, *A classification of alluvial channel systems* [in:] A.D. Miall (ed.), *Fluvial Sedimentology,* Canadian Soc. of Petroleum Geologists, Calgary, Memoir, 5.

Schumm S. A., 1963a, *Sinuosity of alluvial rivers on the Great Plains.*, Geol. Soc. Amer. Bull. 74.

Schumm S. A., 1963b, *A tentative classification of alluvial river channels*, Circular 477, United States Geol. Survey.

Thorne C. R., 1997, *Channel types and morphological classification* [in:] C.R. Thorne, R.D. Hey, M.D. Newson (eds.), *Applied fluvial geomorphology for river engineering and management*, John Wiley & Sons Ltd.

Tille W., 1970, *Kartowanie brzegów rzek*, Przegl. Zagr. Lit. Geogr. 4, Warszawa.

Vielikanov M. A., 1955, *Dinamika ruslowyh potokov, nanosy i ruslo*, II, Moscou.

Witt A., 1976, *Modyfikacja metody Tillego dotyczącej kartowania brzegów rzek,* Spraw. Pozn. Tow. Przyj. Nauk, Wydz. Mat.-Przyr., 91 za 1973, Poznań.