METHODOLOGICAL TEMPLATE FOR ASSESSMENT OF RIVER MORPHOLOGY CONDITIONS

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River ecosystems remain enigmatic to many people, and are often seen as offering fewer benefits to society compared with lakes or terrestrial habitats. Fluvial geomorphology has established in the world as a modern dynamically developing discipline that was able to deepen and itemize its theoretical and methodological basis thanks to the most recent knowledge obtained by a detailed field research. The methodology of river morphology assessment consisting of comparison between the properties of river reach and reference reach conditions and based on ideas of the holistic understanding of river systems are designed. The proposed template includes guidance on sample site selection, field procedures and the scoring system for the assessment. The assessment is based on the principle that the highest quality is obtained when the morphological conditions are as close to the reference situation as possible and when the spatial variation is as large as possible.

Key words: river morphology, assesment, template

INTRODUCTION

River ecosystems remain enigmatic to many people, and are often seen as offering fewer benefits to society compared with lakes or terrestrial habitats. This may soon change, however, because of a developing trend in environmental sciences to emphasize the benefits and services provided by aquatic and terrestrial ecosystems. Benefits are frequently separated into *supporting services* (e.g., biogeochemical cycling, production, habitat or refugia, and biodiversity), *regulating services* (e.g., regulation of water quality, climate, floods and erosion, and biological processes such as pollination, pests, and diseases), *provisioning services* (direct or indirect food for humans, fresh water, wood and fiber, and fuel), and *cultural services* (e.g., aesthetic, spiritual, educational, and recreational). Monetary values are assigned to a subset of these services. The levels of ecosystem services provided by riverine landscapes are an increasing function of the hydrogeomorphic complexity of the local functional process zones. This hypothesis should prove valid for most of the ecosystem services listed in **Tab. 1**. (THORP et al. 2010).

Fluvial geomorphology has established in the world as a modern dynamically developing discipline that was able to deepen and itemize its theoretical and methodological basis thanks to the most recent knowledge obtained by a detailed field research. In connection with the holistic and hierarchised interpretation and *geo-graphisation* of the river landscape, research, assessment and monitoring of its morphological basis has become an indivisible part of the management and protection of this landscape type. Integrated research of river landscape also became topical in connection with the global climatic change. Cognition of processes taking place during floods and in dry spells and their effect on fluvial geosystems has revealed new dimensions in research of not only fluvial geomorphology but it also opens space for collaboration with the related sciences and practices. The reached results facilitate closer collaboration between fluvial geomorphologists and other engineering, biological and environmental scientific disciplines. The basic prerequisite for successful development of fluvial geomorphology and its contribution to the planning is first of all the cognition of the water bodies and basin structures, as well as the processes that take place there in different time horizons. However, assessment of the actual state i.e. assessment of these structures and processes is equally important. In accord with PETTS (1995), these ideas might be as well summarized in the form of a challenge for future fluvial geography which relies on three areas: a) assessment of the health condition of rivers in collaboration with ecologists and hydrobiologists; b) in research of flood threat and the response to it; and c) in the area of river

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Geomorphic structure, ecosystem services and benefits	River type					
	Confined	Meandering	Braided	Anastomosing	Leveed	Reser-voir
Geomorphic structure - selected hydrogeomorphic attributes						
Bank line complexity (ratio of bank line length to downstream length)	L	LM	H	H	L	M
Relative number of channels	L	L	H	HM	L	L
Functional habitats within channels	L	LM	M	H	M	H
Channel/island permanence	M	M	L	H	M	H
Floodplain size and connec-tivity with main channel	L	MH	M	H	L	L
Natural ecosystem benefits						
Biodiversity (species richness and tropic diversity)	L	M	L	H	L	M
Proportion of native biota (prior to any change in river)	H	H	H	H	L	L
Primary and secondary productivity	L	M	M	H	L	H
Nutrient cycling and carbon sequestration	L	LM	LM	H	L	H
Water storage	L	LM	L	H	L	H
Sediment storage	L	M	M	H	L	H
Anthropocentric services						
Food and fiber production (agricultural production excluded)	L	M	L	H	L	M
Water withdrawal potential	MH	M	L	M	H	H
Recreation	LM	LM	L	H	L	H
Disturbance and natural hazard mitigation	L	M	L	H	H	H
Maintenance and catastrophic risk of failure	N/A	N/A	N/A	N/A	M	H
Transportation	M	M	L	M	H	H

Tab. 1 Relationship between the geomorphic structure of rivers and some ecosystem benefits and services they provide. Six types of natural and artificial river systems are used as examples. Relative benefits and services are given as low – L, medium – M, and high – H (Modified after THORP et al. 2010)

and basin management. The ambition of the article is to present the methodological platform for the assessment of changes in river morphology.

APPROACHES TO RIVER MORPHOLOGY ASSESSMENT

Recent key books dealing with the fluvial-geomorphologic issues (GURNELL an PETTS 1995, THORNE et al. 1997, THORNE 1998, BROWN and QUINE 1999, DOWNS and GREGORY 2004, BRIERLEY and, FRYIRS 2005, FRYIRS and BRIERLEY 2013) and ecological (GORDON et al. 2004 THORP et al. 2008) point to the fact that assessment of morphology is an integral step in research of channel-floodplain geosystems as the basis of the river landscape. Other publications,, manuals and studies present particular assessments or monitoring procedures relying on morphological classification schemes of rivers ROSGEN (1994 and 1996), MONTGOMERY and BAFFINGTON (1997), or their modifications. The examples of such works is the assessment of rivers of Vermont (KLINE et al. 2003), British Columbia (Channel Assessment Procedure Guidebook 1996), banks in the state of Washington (CRAMER and BATES eds., 2003), manual for basin and river assessment in the state of Oregon (SALMINEN et al., 1999), manuals of river rehabilitation and management (KOEHN et al. 2001, Bennett et al. 2000) and those of the riparial zone (LOVETT and PRINCE eds. 1999) in Australia. Survey of river morphology constitutes a part of the methodology concerning the survey of river habitats (River habitat survey, version 2003) in Great Britain. The methodology of the eco-morphological survey significantly enriched by its modification for great rivers has been developed in Germany (FLEISCHHACKER and KERN 2002). Methodology for the assessment of what is referred to as the geomorphologic index of rivers has been elaborated in the South African Republic (ROWNTREE and ZIRVOGEL 1999). As far as the EU is concerned, a complex of activities with the aim to improve the state of all surface waters concentrates in the Water Framework Directive 2000/60/EÚ (WFD). Apart from the above quoted studies, which helped us to orientate in the methodology concerning the river morphology assessment there is a great number of studies that more or less only apply or modify the basic ideas contained in the quoted studies.

At the moment of selection of particular methods applicable to river morphology assessment though, it is necessary to realize that no assessment can embrace the total complexity and moreover that the relationships, processes or responses must be considered in the context of anthropic effects. In spite of it, many assessing approaches have been developed which try to bridge this gap by search for simpler causal relationships and an adequate set of indicators, which relatively sufficiently explain the natural range of variability and behavioural mechanisms attributable to streams.

THEORETICAL BACKGROUND

In terms of procedure, assessment of morphological properties of rivers always leans on comparisons of a delimited (naturally or artificially) river reach with the referential one which is reconstructed or little affected by anthropic activities and which reflects the developmental trajectory of the geosystem (**Fig. 1**). Delimitation of the assessed reach is done:

a) As purpose-bound – i.e. river is simply divided into reaches with equal length, which comply with the aim and exhaustiveness of assessment.

b) Intentionally – if it is only a local issue, and

c) Stipulating a channel-floodplain unit selected on the basis of properties quoted in the river morphology hierarchic classification (RMHC) (LEHOTSKÝ 2004) and by knowing its invariant as a referential sample. Invariant is identified from a detailed cognition of the functioning of the channel-floodplain units (cha-racter of plan form, channel setting in the floodplain, possibilities of lateral and vertical erosion and migration, type of the channel as a taxon, character of development of morphological units, and the like), comprehension of its functioning in the river segment determined by longitudinal profile inclination, size of discharge and basic types of valleys, character of the river zone (LEHOTSKÝ and NOVOTNÝ 2004) and finally by basin properties. The assessed river reach is in a good condition if its morphological conditions are close to referential.

Apart from the above said, there exist a number of other important assumptions that must be respected in assessment of river morphology:

1. It is a fact that the *good morphological condition* of a stream in artificially or naturally delimited assessed reach is not the reflection of its maximum spatial diversity as it is, for instance, postulated in landscape ecology. It is because some types of stream reaches are more homogeneous by nature and other in turn, vary more in their essence.

2. The model of hierarchic classification shows that as far as morphological properties of rivers concern, there is a set of certain similar taxons, types of assessed reaches. They are entities with specific properties and composition of morphological elements while every type can be characterized by means of a specific set of attributes that do not agree with those in other types of river reaches, i.e. assessment can be only carried out by comparison of values corresponding to attributes of referential reach of certain type with values of attributes of other reach but only of the same type. If we know them, we can also decide about the relevance of the particular attribute. Otherwise it is not possible to compare, evaluate and monitor the reaches. It means that only the related types of river reaches can be compared and assessed.

3. Assessment must respect the principles of vertical, lateral and longitudinal linkages. In other words, it is not possible to examine and assess the river bed without its flood plain and on the contrary, it is not possible to disrespect the state of morphology in downstream and upstream reaches or disrespect the position of the reach in the framework of superior taxons, etc.

4. If assumption 2 is accepted along with the fact that the aim of the assessment is to identify changes in the state of those morphological properties of the river that were affected by humans but also those that were caused by other natural phenomena (climate, tectonics) and their effects are identifiable as consequences of the natural development of the stream whether it was under the effect of sudden events or in time of an average regime in

Fig. 1 Examples of morphological conditions of river reaches reflecting different evolution trajectories. Pristine natural river reaches without human impact could be use as reference sites (1-3). Deriving reference conditions of river morphology need to take into account long-term evolution of river morphology such as different effects of channel incision (4, 5) or natural disaster – windblown forest (6). Human impact influences morphology of river reaches and results in channel narrowing (7), decreasing in river bed diversity due to large woody debris extracting (8) and introducing new artificial bank structure (9). River channel connectivity is modified by gravel extraction (10), water abstraction (11), or check-dam construction (12)

time horizon of 100-200 years, it seems logical that the taxon which complies with the conditions of appropriateness as the subject of assessment is the channel-floodplain units of RMHC (LE-HOTSKÝ, GREŠKOVÁ 2003, LEHOTSKÝ 2004). Subject of assessment defined in a similar way but under a different name (what is referred to as the River Style), also interpreted as the taxon of the hierarchic structure of water steam can be found in BRIERLEY et al. (2002) and FRYIRS (2003). Other authors call these river units used as assessment subjects simply river reaches. Inclusion and comprehension of the development of the channel-floodplain unit at the level of superior taxons (segment, zone and basin with river network) already sufficiently traces the evolutionary trajectory. On the other hand, cognition of lower taxons it is composed facilitates cognition and assessment of change symptoms and identification of the morphological *health* condition of river.

5. The present development of a river must be always seen as the continuation of its development in time while this aspect of evolution provides possibilities to explain mainly the causes of changes in structure and processes and less symptoms of these changes.

6. It is necessary to discern the morphocentric assessment of morphological properties of streams. Morphocentric assessment captures the character of changes in terms of aggradation or degradation. Results can be then used in eco-morphocentric assessment. Monitoring is only a survey done in regular intervals in mostly artificially, metrically and non-genetically set river reaches. Morphocentric assessment should be part of monitoring that is in its preparative phase, it means during selection and definition of referential conditions, identification of the reach to be monitored and interpretation of obtained results.

7. The key point of assessment is identification of thresholds and setting of threshold values of channel-floodplain geosystem properties. If they are exceeded, the character and type of river morphology changes. For instance, type of river reach changes in 50 – 100 years. They are detectable only in the field. Threshold values are detected by looking for changes in character and composition of morphological units, symptoms of changes in channel planform, and the like. Engineering interventions such as bridges, weirs or dams often fulfil the role of thresholds.

8. It is necessary to bear in mind that assessment can be accomplished for various purposes. Then the rate of details of river research and scale of the geomorphologic map have to correspond. If it is the case of streams below 30 metres wide, the map should be at scale 1:500. But it requires adequate technical (GPS, distance meter, GIS, compass, inclinometer, wading rod) or material (fishing boots, raincoat) equipment, a very concrete work plan with specified steps. Map le-gend uses a specific terminology of fluvial geomorphology and apart from its scale it does not differ substantially from other geomorphologic maps.

9. Taking into account that the deviation of contemporary environmental conditions in Carpathian catchments from historical ones and the varied trends of channel evolution recorded during the twentieth century emphasize the need to base the reference state for assessment and restoration of Carpathian rivers in their human-modified sections on contemporary conditions (WYŻGA et al. 2012). Thus the assessment of Slovak rivers is based on the principle that the highest quality is obtained when the morphological conditions are as close to such reference situation as possible and when the spatial variation is as large as possible. When a comparison with ***the reference situation*** is possible, this is given priority. For example with plan form, a good score is given to rivers where the plan form is the same as in the reference condition and not to a specific plan form (e.g., a straight stream is given a good score if it is also straight in the reference condition). Old maps are a key source of information for setting the reference condition for some morphological parameters. Field surveys on reference sites may be needed to identify the reference conditions for other parameters. Parameter values may differ between streams even though they are in a reference condition. This simply reflects the natural variation in parameters values found in natural systems or contemporary modified water bodies by human activity which could not naturally or artificially return to pristine natural state.

UNITS AND STAGES OF ASSESSMENT

The basis unit for the assessment and hydromorphological survey is a river reach. Guidance of how to define river types and reference reaches is given in Harrelson (1994). The river reach could be sub-divided into 3 – 5 survey units (SU) of equal length. Some parameters, such as the channel plan form of the river bed (e.g., degree of sinuosity) might be assessed for several reaches. The survey strategy is thus hierarchical. The size of morphological forms and features changes as river size increases and therefore the length of the reach and SUs is scaled according to the size of rivers (CHURCH 2002). In Slovak conditions channel width is used as the basis for size definitions rather than discharge because it is easily measured in the field or it can be interpreted from a map or aerial photograph. ***Three channel size groups*** are proposed (1. less than 10 m; 2. 10 – 30 m; 3. more than 30 m). The length of the reaches defined will vary from river system to river system and from upland to lowland streams. The exact location of the survey within the reach will depend on the environmental variation along the reaches defined. The selected survey unit (SU) should therefore be representative of the river reach in question with respect to channel morphology, land use, geology and geomorphology. The floodplain parameters, that are included in the survey, are based on the whole floodplain. Riparian vegetation is assessed in a 20-meter wide zone along both sides of the river. All other parameters are based on the stream channel. ***Surveys***

should be carried out during low flow periods when the riverbed structure and substrate is visible. In addition, the field survey should be carried out in the vegetation period from June to September, as several parameters rely on assessing the vegetation structure. The vegetation period may differ throughout Slovakia due to climatic and topographic differences, and the survey period should be adjusted to the climatic conditions.

The assessment procedure consists of ***five stages***:

1. Collection of data

2. Defining the reaches and survey units

3. Assessing map based parameters

4. Field survey

5. Assessment and presentation.

Stage 1. Collection of data

Data sources are maps, aerial photographs and GIS layers, as well as maps showing the water body delineation within catchments. The following material can be used for the survey:

− Topographic maps 1:10,000 or 1:25,000 for the definition of the current plan form,

− Historical maps for comparison of sinuosity,

− GIS databases layers or maps for land use analysis on the floodplain and in the catchment

− Geological maps (1:50,000),

− Aerial photographs and / or vegetation maps for estimation of the land use and the vegetation on the floodplain and riparian areas,

− Other material regarding water abstraction, reservoir management etc.

Stage 2. Defining the reaches

River reach and representative sites should be selected based on the methodology given above and the exact location of the survey units should be determined from a map, orthophoto maps and field survey. The basis for this work is the delineation of the rivers into water bodies (reaches), carried out prior to the assessment described in this protocol. The locations of the units to be surveyed are marked on a topographic map or in the GIS environment.

Stage 3. Assessing map based parameters

Map based parameters include catchment parameters and parameters related to channel modifications. Furthermore, parameters related to river valley form and maps and aerial photographs can also assist in the assessment of land use and floodplain structure. The results can then be checked in the field afterwards. The results are entered in the survey forms. Many site protocol parameters can also be obtained from maps. This should also be carried out prior to the field survey. In some cases the assessment of the map-based parameters will be substituted by expert judgements. This will be case where map data are unavailable. Expert judgements will typically involve transfer of data or knowledge from similar sites in other catchments or nearby sites up- or downstream from the reach under survey (THORNE et al., 1997).

Stage 4. Field survey

The field survey should be carried out in the reach as defined from maps. Any changes to the location of reach decided in the field should be mapped and documented for future use. The exact location of reach should be altered only where field surveying is impossible due to restrictions on access to the river. Parameter descriptions (and pictures showing the different features) should be taken to the field in order to enhance the quality of the assessment. The field survey forms should be completed in the field and any map survey parameters should be checked whenever possible. The field survey should be carried out by walking along the watercourse, and by wading the stream. For large rivers and waterways, that are too deep for wading, inspections are carried out by boat and occasional landings.

Stage 5. Assessment

The site protocol parameters are collected to characterise the overall landscape features at the sites and in the catchment. The assessment parameters are divided into two main groups, the morphology parameters and the hydrology parameters. The morphology parameters can be separated into four categories: 1. Channel form; 2. Instream features; 3. Bank / riparian zone and 4. Floodplain parameters. Each parameter is assigned a score from 1 to 5, with 1 indicating the ‘best’ state and 5 indicating the ‘worst’ state. The score for each parameter is averaged for the reach if the assessment is carried out on the SU level, and the SU parameter values within each of the four categories are averaged to give a SU category score. The final reach morphology score is the average of the category values. The hydrology category includes four parameters. The final hydrology score is the average of the four parameter scores. This score is not combined with the morphology score. The final morphology and hydrology scores are used to determine the morphological and the hydrological quality classes.

ASSESSED PARAMETERS

Survey forms of the reach are to be completed as *the site protocol and assessment form for the structural features* for each survey unit (SU). The site protocol holds the general descriptions of the reach, including identification, site attributes and catchment attributes. The site protocol describes the present state of the river, whereas many of the assessment parameters describe the present state compared to the reference situation. The site protocol includes a number of parameters used to characterise the river and the surroundings. It is also used to identify the survey site and includes many relevant parameters that will enable a variety of analyses. Most parameters can be used to group streams with identical features thereby enabling comparison of hydromorphological and biological parameters among identical streams. *The site protocol consists of 5 separate parts: identification, channel parameters, riparian and floodplain features, catchment features and hydrological parameters.* The first parameters are used to identify the site and the exact location within the catchment. Many of the parameters can be assessed from maps; the remaining should be assessed from other relevant sources. Individual map parameters should preferably be derived from maps having identical scales to ensure consistent parameter estimation. The surveyor, date of survey, and a photo or a sketch of the site is also included in the identification part of the protocol. The survey unit should be situated within slope assessment length. If there are any significant tributaries entering the river or other significant changes to the river plan form (e.g. dam) within the defined length, the assessment length should be reduced to exclude these changes in plan form. Each parameter affecting the natural conditions at the site is marked with "X" in the protocol. *The assessment protocol is divided into five categories or groups of parameters. Four parameters are each targeting different aspects of the hydromorphological structure of the river/stream and the fifth target the hydrological aspects of the hydromorphological quality.* All parameters are described below and procedure of scoring is described in Pedersen et al. (2004).

CHANNEL PLANFORM PARAMETERS

The parameters are assessed according to their current state relative to the historical and non-degraded state. They are found by comparing present day features from the 1:10,000 maps with features from historical maps. These parameters should be assessed over longer river channel length than the length of survey units for the following multiples of SU length: small river – 3 x survey unit length (3 x 200 m, for medium river - 6x survey unit length (6 x 500 m), for large river – 6 x survey unit length (6 x 1000 m). If there are any significant tributaries entering the river or other significant changes to the river plan form (e.g. dam) within the defined length the assessment length should be reduced to exclude these changes in plan form. If no old maps exists or the channel on the old maps shows sign of modification, the three channel parameters have to be assessed by expert judgement. This should include an analysis of the land use, river valley slope, geology and geomorphology, from which the natural type can be interpreted with help from the literature (e.g., ROSGEN 1994, THORNE et al., 1997 and THORNE 1998). Another possibility is that the historic type and channel pattern can be inferred from a similar site with similar characteristics and data available. Alternatively, remnants of the old channels in the flood plain can potentially be identified on aerial photos, from which the historic channel type, length and sinuosity can be estimated. The Channel planform score (CPS) is calculated as the average of the scores given for channel sinuosity, channel type and channel shortening:

$$CPS = (1.1 + 1.2 + 1.3)/3$$

Channel sinuosity (1.1). Sinuosity will be obtained by standard procedure measuring the real length of river channel and dividing it by the length of the valley.

Channel type (1.2). The channel type according to branching at the present time is detectable from the 1:10 000 maps, historical maps provide its past shape.

Channel shortening (1.3). The channel shortening value will be obtained by comparison of the present state (length of the river channel in survey unit from the 1:10 000 maps) and the state in the past (from historical maps).

IN-STREAM FEATURES

The in stream parameters are assessed in field and comprise several parameters related to the current conditions in the stream and on the stream bed. The in-stream parameters should be surveyed from within the stream. The in-stream features are all evaluated at the scale of the SSU. After the in-stream features have been assessed, the scores of all SSUs are first averaged and then the in-stream feature score (IFS) is calculated as the average of the scores given for the SU, i.e.:

IFS = (2.1 + 2.2 + 2.3 + 2.4 + 2.5 + 2.6)/6

Bed elements (2.1). This parameter gives the number of individual bed elements such as islands, various bar forms and rapids (bedrock bars). If the river is too large for bed elements to be identified, this parameter is excluded from the assessment. The minimum size (either width or length) of the individual structure must reach 1/3 of the channel width (which is defined here as the distance between the left bank and the right bank at the time of the survey at the location of the structure).

Bed substrates (2.2). The assessment is carried out while standing in the river. The natural bed substrate is assessed by counting the number of different types that cover more than 5 % of the bed in the SSU. The abbreviations for the substrates that cover more than 5 % of the bed are circled in the assessment form as follows:

Bedrock *(BE)* exposed solid rock,

Boulder *(BO)* loose rocks > 256 mm diameter,

Cobble *(CO)* loose material 64 – 256 mm diameter,

Gravel/pebble *(GR)* loose material 2 – 64 mm diameter,

Sand *(SA)* particles 0.06 – 2 mm diameter,

Coarse debris *(CD)* Organic matter > 1 mm (leaves, twigs, small pieces of wood etc.),

Silt/mud *(MU)* very fine deposits < 1 mm,

Clay *(CL)* solid surface comprising sticky material,

Peat *(PE)* predominantly or totally peat, organic origin.

If all coarse substrate types (boulder, cobble and gravel/pebble) are present, the SSU automatically scores 1. If the inorganic substrates are estimated to be covered by more than 25 % silt/mud or more than 75 % bio-film (e.g. filamentous algae) scores below 5 should be added +1. If silt/mud cover is estimated to cover more than 50 %, scores below 4 should be added +2 and the score 4 should be added +1. If the riverbed is completely covered by artificial substrate the score is 5.

Variation in width (2.3). Variation in width is defined as the largest channel wetted width divided by the smallest channel wetted width in the SU at the time of the survey. The width is the distance from the right bank to the left bank perpendicular to the current, independent of whether islands occur in the cross-section. For large rivers, the value is found from topographic maps (scale 1:10,000 or 1:25,000) or on aerial photographs. Man-made structures such as port entries, etc., and small-scale protrusions are not taken into account. For smaller rivers the variation of width is measured in the field. The smallest and largest river widths are measured in each SSU and added to the assessment form. The ratio between the largest and the smallest width considering all measurements within all the SSUs is calculated.

Flow types (2.4). This parameter is the number of different flow types in the SU. The flow types included in the assessment are based on the flow types defined in the River Habitat Survey as well in Lehotský and Grešková (2005).

Large woody debris (2.5). The parameter is the density of large woody debris (LWD) per 1 km. LWD is defined here as trees or substantial parts of trees that are either at least 3 metres long or have a diameter of more than 30 cm for medium sized and large rivers, and for small rivers the dimensions are half of these values. LWD is found in the channel and must be partly under water at the time of the survey. Forty pieces of LWD per km are considered to represent the potential natural state. If aggregations of LWD are present each individual LWD is counted. This value is based on results obtained in navigable rivers in North America and has been verified during the mapping of the lower course of the Mulde in Germany (KERN et al., 2002) and proved by field surveys of small Slovak rivers.

Artificial bed features (2.6). This covers constructions such as fairway, bed reinforcement, parallel structures, groynes, ground sills, pipeline crossing and colmatage. Artificial bed features are always made of artificial materials that are not endemic to the stream / river.

BANK / RIPARIAN ZONE PARAMETERS

Bank and riparian parameters are assessed separately for the left and the right side of the stream in each SSU. The scores for each parameter are first averaged for all SSU and then bank and riparian score (BRS) is calculated as the average of the three bank and riparian parameters.

BRS = (3.1 + 3.2 + 3.3)/3

Natural riparian vegetation (3.1). This includes vegetation in the riparian zone along both channel banks. The riparian zone is here defined as a 20-metre strip with the lower boundary at bankfull stage. Islands are not included in the survey. Note that in the case of trees it is the projected area of the canopy that is used for the coverage and not the stem of the tree. Scores are given according to the extent of the different groups:

Natural: >90 % natural vegetation. Rest: other vegetation types. No artificial structures or managed land.

Near natural: 25 % – 90 % natural vegetation. Rest: other vegetation types. No artificial structures or managed land.

Semi-natural: <25 % artificial structures or <50% managed land

Modified: 25 – 50 % artificial structures or 50-75% managed land

Heavily modified: >50 % artificial structures or >75 % managed land.

Bank stabilisation (3.2). This parameter is used to assess the restriction of natural lateral dynamics due to stabilised banks and a separate assessment for the left and right bank is carried out. The survey is field based and is carried out in each of the 5 sub-units. The percentage length of the river bank affected by stabilisation structures is assessed in the field.

Bank profile (3.3). The assessment focuses on the length of natural riverbanks in the SSU. The habitat quality of profiled and stabilised banks is considered additionally. The survey is carried out for both left and right bank. The determination of the share of natural banks in a unit requires a field survey for all river sizes. In order to distinguish between natural and artificial banks short descriptions of the characteristic features for each type are given.

FLOODPLAIN PARAMETERS

Subject of the assessment is the extent of the current floodplain exposed to frequent flooding compared with the extent of the natural (historic) floodplain and the natural vegetation/land use in the current floodplain. The assessment considers the extent of natural alluvial habitats (i.e. alluvial forest including abandoned channels such as oxbows, side-arm systems and cut-off meanders) and the type of land use in cultivated areas. Undisturbed floodplains are characterised by wetland vegetation, natural forests and/or natural water bodies. These water bodies must be in contact with surface water channel. The floodplain is identified based on geological/soil/morphological criteria (map and field). The assessment is carried out in each of the survey sub-units and on the both sides of the river. Results are averaged for all SSUs and sides and then the floodplain score (FPS) is calculated as:

$$FPS = (4.1 + 4.2)/2$$

Flooded area (4.1). The flooded area is here defined as that part of the floodplain that has the potential of being flooded. Subject of the assessment are the retention function of the floodplain and its function as a meander corridor (morphodynamic channel migration). Therefore the actually flooded area must be estimated in relation to the old alluvial floodplain. Flood controlling structures such as guide dykes must be taken into account. The survey and assessment are carried out separately for each section of the floodplain and the L and R bank. This parameter is only relevant in alluvial valleys. The survey is fully based on maps and existing information (no field survey) and is concentrated in the survey unit. In case of multiple discrete sub-units the entire length from the upstream to the downstream sub survey unit is considered.

Natural vegetation / land use on floodplain (4.2). Natural floodplain (floodplain forest, wetland and abandoned channels). The area covered by natural or secondary forest, wetlands and abandoned channels in relation to the total survey section area must be estimated for each side of the river. The share of non-indigenous species may not exceed 10 %. Abandoned channels must be connected to the flow regime of the river (surface connection to the river or connection by groundwater), in order to be part of the natural floodplain area. Land use in remaining area: Subject to the assessment score is only the relation between natural/not natural land use. Registration of the types of not natural land use on each side of the river is to be registered in the site protocol.

HYDROLOGICAL REGIME PARAMATERS

This group of parameters is used to evaluate the effect of artificial impacts on the hydrological regime in the SU. Artificial impacts include changes caused by hydropower dams and operation, abstractions (for irrigation, water supply, etc.) and industrial outlets to the stream. The hydrological quality is assessed by 4 parameters, one describing the change in mean flow, one describing the change in low flow, one describing the change in water level range and one describing the impact of artificial frequent flow fluctuations, all compared to the reference state. Preferably the estimates are based on hydrological records. If records are not available, the parameters are estimated from available data of abstraction rates, outlet rates from power stations, industrial discharges, etc. Another option is to obtain estimates of mean flow, low flow and high flow from before and after the artificial impact from other sources (recorded observations, general knowledge). The hydrological regime score (HRS) is calculated as the average of the scores given for mean flow, low flow, water level range and frequent flow fluctuations:

$$HRS = (5.1 + 5.2 + 5.3 + 5.4)/4$$

Mean flow (5.1). The score is based on the reduction in mean flow from the mean flow in the reference state

Low flow (5.2). The score is evaluated based on the reduction in low flow from the low flow in the reference state. If hydrological records are available, Q_{355} can be used. Otherwise the low flow is the typical flow during low flow periods.

Water level range (5.3). The range in water level is defined as (Hc / Hr) x 100, where Hc is the current difference between the mean annual maximum water level and the mean annual minimum water level, and Hr is the difference between the mean annual maximum water level and the mean annual minimum water level in the reference condition.

Frequent flow fluctuations (5.4). Frequent flow fluctuations occur typically below hydropower plants where the operation of the turbines changes on a short-term (often daily) basis. The score is based on the magnitude of the frequent flow fluctuations, which is assessed as minor, moderate or major.

Results of assessment will be presented in five quality classes of hydromorphological state of river channels. The final score of classes of hydromorphological state quality (Tab. 4) of river channels is identical with the final score of classes of ecological state defined in WFD. The resulting quality of hydromorphological state represents the degree of deviation of the observed value from the reference state: high state (no or very minor deviation from undisturbed conditions), good state (slight deviation from reference conditions), moderate state (moderate deviation from reference conditions), poor state (high deviation from reference conditions) and bad state (full deviation from reference conditions).

CONCLUSION

In sense, river can be viewed as barometers of landscape conditions, or carchment health. Assessments and improvments to river conditions are contingent on researchers, managers, and the community working together to establish sustainable, long-term management strategies that *work with nature*. The use of geomorphologists in the planning phase of engineering will hopefully become established with hazard identification and interpretation. Of increasing importance will also be an understanding of the control that morphological diversity and fluvial dynamics have in supporting biotic populations and ecosystem resilience. The presented geomorphological approach should promote proactive planning and management of rivers, their morphological variability in maintaining channel dynamic metastable equilibrium.

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