



ZADANIE 6a

Hydromorphological Index for Rivers (HIR)

Hydromorphological assessment and classification method for running waters in Poland

fulfilling standards of PN-EN 14614: 2008

Authors

Krzysztof Szoszkiewicz, Szymon Jusik, Daniel Gebler, Krzysztof Achtenberg, Marta Szostak, Joanna Chmist

Poznan University of Life Sciences

Mariusz Adynkiewicz-Piragas, Jan Błachuta

Institute of Meteorology and Water Management - National Research Institute

Tomasz Okruszko, Paweł Marcinkowski, Marek Giełczewski

Warsaw University of Life Sciences (SGGW)

Artur Radecki-Pawlik

University of Agriculture in Krakow

Karol Pietruczuk

The Provincial Inspectorate of Environmental Protection in Poznan

Marcin Przesmycki

The Provincial Inspectorate of Environmental Protection in Wroclaw, Delegation in Walbrzych

Katarzyna Pędziwiatr

Adam Mickiewicz University in Poznan

Przemysław Nawrocki

WWF Poland

Illustrations: Justyna Urbaniak, *Poznan University of Life Sciences*



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I. INTRODUCTION

The proposed method is based on original metric called **Hydromorphological Index for Rivers (HIR)** and can be used in the hydromorphological assessment of all types of flowing waters in Poland. It allows assessment of both lowland rivers as well as mid-altitude and highland streams. The proposed system can be used to assess the natural and heavily modified rivers as well as artificial channels, and in principle was created as precise, easy to implement and relatively inexpensive.

In addition to a comprehensive description of the fluvial habitat, the studies allow to present a hydromorphological status of surveyed rivers in the numerical form, which allows the calculation of the synthetic indices adapted to the specificities of flowing waters in Poland. The developed indicators are a tool allowing the **assessment and classification of the hydromorphological quality status** of the surveyed river section and the entire surface water bodies.

Description of the river environment in the system is characterized by **objectivity and is well suited for statistical analysis**. The method gives **repeatable results** and is highly resistant to error due to personal factors, so that research carried out by different people have low level of volatility. The studies are based on recording of elements of river environment that can be clearly identified on the basis of the manual and after completion of the several-days training. It is assumed that a person familiar with the method, equipped with the necessary field equipment, is able to perform a survey of the river section in the field in **less than two hours**.

The proposed method has been prepared for the purpose of the **monitoring of the hydromorphological status** of flowing waters in Poland. It fulfils requirements of the EU Water Framework Directive (WFD). The method can also be used for other purposes, such as **environmental impact assessments** of investments on the river environment and predicting the hydromorphological effect of restoration. Moreover, the proposed system can be used in scientific research as a various **ecological studies** of different groups of aquatic organisms.

The basis of the proposed system is a field survey, which is supplemented by analysis of Geographic Information Systems data and remote sensing materials:

- Field surveys carried out by the proposed system allows to collect large number of parameters describing various hydromorphological attributes of the surveyed river section.
- Studies based on Geographic Information Systems and remote sensing materials delivers tens of variables gathered from various databases such as Hydrographic Map of Poland MPHP,



Geoportal, Topographical Data Base, Geomelio, National Council of Water Management (KZGW) Geoportal, General Directorate for Environmental Protection (GDEP) Geoservice, et al.

Basing on the field survey supplemented by analysis of the GIS data and remote sensing materials the **complex evaluation** of the hydromorphological conditions is gathered, including the **principal classification** of the hydromorphological status meeting WFD criteria. Analysis of the GIS data and remote sensing materials already enable to estimate the hydromorphological conditions of a river site. This approach enable for **preliminary classification of hydromorphological status** of non-surveyed water bodies.

Basing on the field survey, the HIR value can be estimated for the considered river site and comparing with the reference conditions the hydromorphological quality status in the five-class system can be calculated. Properly selected, representative survey sites (one or more depending on the heterogeneity of the environment), enable classification and evaluation of entire surface water bodies in the framework of the national environmental monitoring.

Presented system is fully compliant with the requirements of the European Committee for Standardization CEN (Comité Européen de Normalisation) related to WFD. The prototype of this method is the River Habitat Survey system (RHS, Environment Agency 2003), which from the beginning has been largely used at work on the European standard in the field of hydromorphology of rivers. It was the fundamental method used in a variety of studies carried out for the needs of CEN, on the development of indicators of the flowing waters hydromorphological status valorization and identification of rivers reference conditions. In addition, prepared methodology of hydromorphological observations is consistent with the standard EN 14614: 2004 (*Water quality – Guidance standard on determining the degree of modification of river hydromorphology*) and its Polish counterpart, i.e. PN-EN-14614: 2008 (*Jakość wody - Wytyczne do oceny hydromorfologicznych cech rzek*).

The proposed method of hydromorphological assessment of rivers is an original system, which was prepared utilising range of elements of other methods developed in Poland and other countries. In the greatest extent it has been used River Habitat Survey (RHS) system, which was developed in Britain (Environment Agency 2003, Raven et al. 1998, Szoszkiewicz et al. 2012, Jusik et al. 2014). Moreover, a range of Polish systems were utilised, including proposals of Adynkiewicz-Piragas (2009), Radecki-Pawlik (2014), Szoszkiewicz et al. (2015).

For the purposes of implementing the rivers assessment method based on Hydromorphological



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Index for Rivers the **HIR Information Centre** was established. It conducts information activities, mainly through various publications, the Internet (online portal and email consultation) and telephone consultations. It also organizes training courses and verifies the qualifications of researchers certifying acquired skills with accreditation.



II. BASIS OF THE HIR SYSTEM

SURVEY SITE SELECTION

The HIR method base on the field surveys, which are conducted along a 500 m river section (smaller watercourses - channel width ≤ 30 m) or 1000 m long (larger watercourses with a channel width > 30 m). The HIR method is not suitable for surveying dam reservoirs or other kinds of standing water bodies.

SURVEY SITE STRUCTURE

The survey site according to the HIR method include an evaluation of three zones: river channel bank zone and river valley:

River channel

River channel zone is the lowest part of the river valley formed by water flow, permanently or partially located under water. In the hydromorphological description river channel is between the right and left bank.

Bank zone

Part of the river between water line and bank-top, usually covered in different proportions by bryophytes, trees, bushes, grasses and perennials plants.

River valley

The riverside plain, adjacent to the bank-top.

WATER BODY ASSESSMENT

Data based on single survey site allow for the assessment and classification of hydromorphological status of the homogenous river section. Surveys on a single site is sufficient for the purpose of Environmental Impact Assessment (EIA) of the investments influencing watercourses. Single site survey can also be carried out as a supporting to biological survey (eg. ichthyofauna, benthic macroinvertebrates, macrophytes et al.). Evaluation of the hydromorphological multi-kilometer stretches (e.g. entire surface water bodies) requires data of 1-3 survey sites. The number of survey sites depend on the heterogeneity of land use in the area adjacent to the river bank.

Assessment of entire surface water bodies, which can vary in length, reaching even tens of



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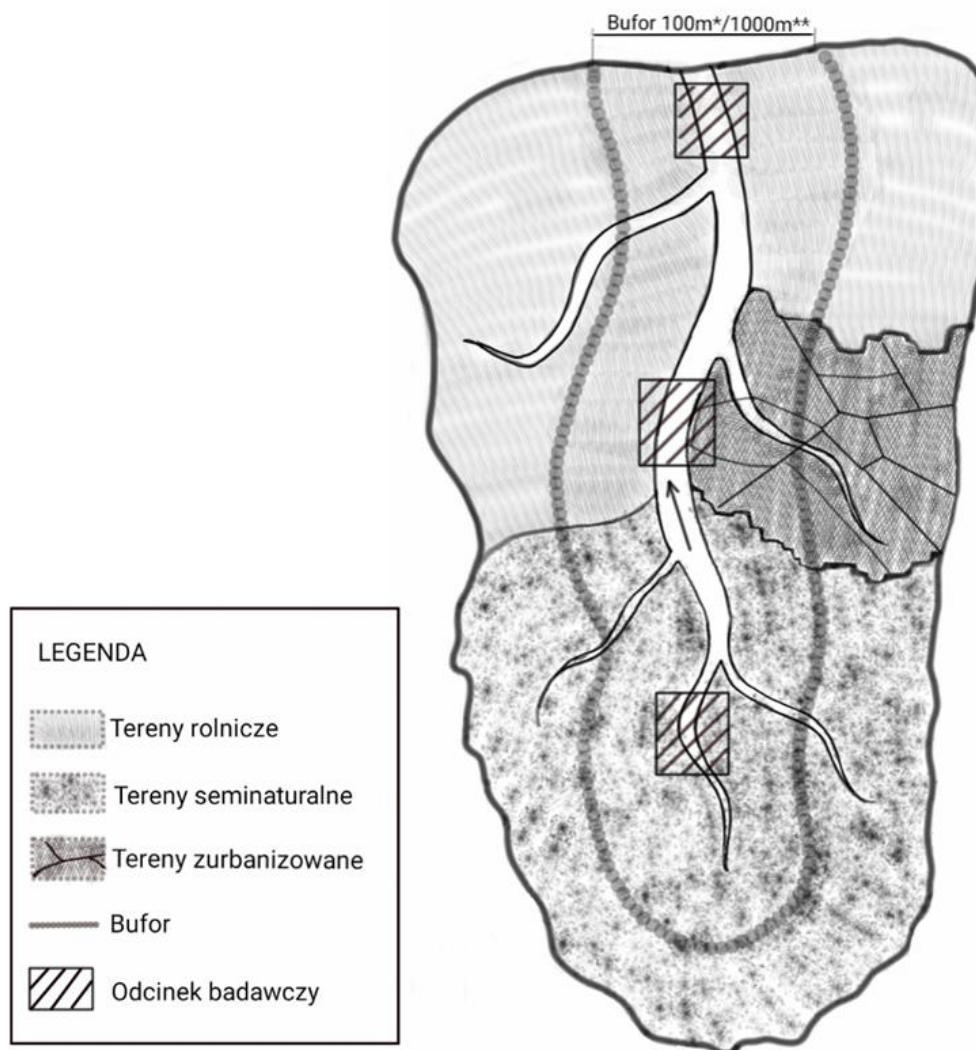
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kilometers, requires analysis of orthophotomaps and GIS resources (e.g. digital maps and databases) to evaluate heterogeneity of the land use in the area adjacent to the river bank. According to the detected land use diversification number of required survey sites is determined, which can vary between one (homogenous land use of the channel buffer in the entire water body) to three representative survey sites (heterogeneous land use of the channel buffer in the entire water body). The land use categories identified are: (1) urban, (2) agricultural, and (3) natural/semi-natural areas. The buffers width is 100 m from watercourse banks (small and mid-sized rivers) or 1000 m (large rivers). The assessment should be made with an accuracy of at least 10%. The land use category is represented by survey site when it covers at least 25% of the buffer zone. (Fig. 1).

Hydromorphological status of entire water body is calculated as an average of the status of partial survey sites. It is a weighted average that takes into account the share of different types of land use in the buffer of 100 meters from the watercourse bank along the entire surface water body.

It is recommended to combine one of the HIR survey sites with the biological sampling stretch when the water body evaluation assessment is carried out within the national monitoring system. The HIR assessment can replace standard habitat assessment supplementing biological sampling (macrophytes, macroinvertebrate and phytobenthos).



Explanations:

Tereny rolnicze – agricultural areas

Tereny seminaturalne – semi natural areas

Tereny zurbanizowane – urban areas

Bufor – buffer

Odcinek badawczy – survey site

Fig. 1. Water body survey scheme - survey site distribution depends from the land use in the buffer zones. The buffer zones are 10 and 100 meters from watercourse banks (small and mid-sized rivers, width ≤ 30 m) or 100 and 1000 m (large rivers river channel, width > 30 m)

III. ANALYSIS OF GIS RESOURCES AND REMOTE SENSING MATERIALS

Principles of the approach

The preliminary assessment of hydromorphological quality of the entire water body based on widely available, mainly public, spatial data. It aims to deliver introductory data for the field survey stage. Moreover, it also provide preliminary assessment for those water bodies that are not included

in the field survey scheme.

A river is characterized by the lowest stream order, according to MPHP 2010, is assessed in each water body. If there is more than one river characterized by the same (lowest) stream order in a particular water body, then all such rivers shall be considered. The survey is performed for the entire river. To avoid a risk of omitting some elements, it is recommended to divide river into two- (rivers with channel width ≤ 30 m) or four-kilometres (rivers with channel width > 30) reaches. Information on hydrological regime, river longitudinal profile, hydraulic structures, land use and river valley characteristics is collected in the stage of preliminary assessment.

Equipment requirements and resource availability

A PC or laptop working station with an efficient web connection is necessary for the preliminary assessment based on GIS resources and remote sensing materials. Specialised software is required, that enables to analyse and visualize vector and raster data, as well as to work with databases. These requirements are fulfilled, among others, by such software as: ArcGIS, QGIS and MapInfo.

The most basic data required for preliminary hydromorphological assessment are orthophotos. They can be obtained from several widely available, mainly public, sources such as:

- Geoportal WMS server – WMS is a standard protocol for serving georeferenced map images over Internet (<http://www.geoportal.gov.pl/uslugi/usluga-przegladania-wms>),
- Google Earth platform – possible to be directly downloaded by QGIS,
- ArcMap (ESRI) basemaps,
- Google Maps resources - possible to be directly downloaded by QGIS.

An important data source, that may significantly advance and improve quality of the assessment is Topographic Objects Data Base (BDOT 10k) available as:

- Geoportal WMS service - (<http://www.geoportal.gov.pl/uslugi/usluga-przegladania-wms>),
- File data base to be acquired from the Central Office of Survey and Cartographic Documentation (CODGiK) upon a written request.

Data of the BDOT 10k are conformed to 1:10 000 scale topographic map by degree of accuracy. This database contains information on topographical objects, including:

- Objects spatial localization,
- Objects characteristics,
- Cartographic codes,
- Objects metadata.



Objects available in this database are divided into 9 classes:

- Water network,
- Communication network,
- Utility infrastructure network,
- Land cover,
- Buildings and installations,
- Land use complexes,
- Protected areas,
- Administrative units,
- Other objects.

Other data source allowing for particularization of the desktop survey is the data base of hydraulic structures created by National Authority for Water Management (KZGW), available as:

- Geoportal KZGW WMS service - (<http://geoportal.kzgw.gov.pl/imap/>),
- File data base to be acquired from the National Authority for Water Management (KZGW) upon a written request.

Desktop protocol - assessment based on GIS and remote sensing materials

Protocol based on GIS data and remote sensing materials consists two-page form (Part A). The first page of the form includes seven sections (river with channel width <30 m) or five sections (river with channel width >30 m), related to synthetic assessment of the entire water body. The second page contains two sections (rivers with channel width <30 m) or four sections (rivers with channel width >30). Sections A6-A8 are complementing synthetic assessment of water body. Section A9 is a table, where detailed analysis of the water body divided into two kilometres reaches takes place. A task for the surveyor is to assess different elements related to river naturalness and its modification based on widely available, mainly public, data sources (orthophotos, spatial databases). The assessment is done by assessing percentage of various elements along the entire river reach or by summarizing the number of features.

Section A1 contains general information on the surveyed water body, including water body name, code, stream order and river length. Additionally, data on the surveyor and the used for assessment data sources is entered.

Section A2 contains information on hydrological regime gathered from the water gauge stations available on a web-page. Additionally, water discharge for the given water level is calculated.



Section A3 contains information on river sinuosity. A sinuosity ratio is calculated in 5 class-scale. This analysis base on orthophotos or by applying GIS tools on MPHP 2010 data. Additionally, for rivers with channel width >30 , an information on channel width variability and a number of river reaches selected for the field survey due to channel width is noted.

Section A4-is used for assessment of river morphological activity for rives with channel width >30 m. A total number of side bars as well as islands and mid-channel bars is recorded.

Section 5-contains information on engineering structures. They are divided into 4 categories: water management objects, damming structures, spillways and regulating structures, and spanning structures and bridges. Data obtained from the National Authority of Water Management, either as thematic layer containing hydraulic structures data or as Geoportal WMS service, is necessary for a proper fulfilment of this section. Alternatively, the Topographical Objects Data Base (BDOT 10k) can be used for this purpose. These data sources contain information on the type of damming structures, including damming height and presence/absence of operational fish ladder. Type and number of damming structures are noted in three categories depended on the damming height and operational fish ladder presence. In case of water management objects, spillways and regulating structures, a type of structure is noted and classified into one of three categories dependent on percent of water body length being influenced by these structures. In case of spanning structures and bridges a type and a total number of such objects within surveyed water body shall be noted.

Section A6—contains information on land use structure. This structure is divided into three categories: urban, agricultural and semi-natural areas. A type of land use is assessed within two buffers for each group of rivers. The width of the buffer is 100 m (for rivers with channel width <30 m) and 1000 m (for rivers with channel width >30 m). This assessment is performed either in visual way using orthophotos, topographic maps, and/or Google Earth, or by using GIS-tools and spatial data bases (BDOT 10k).

Section A7-is used for collecting information on trees in the valley along the surveyed river reach. It is noted as a percent share of surveyed river reach covered by trees in entire water body length. This assessment shall be performed in a visual manner using orthophotos, because these elements are too narrow to be accurately presented on topographic maps and/or in spatial data bases.

Section A8 refers to lateral connectivity of river with its valley, and takes into account such elements as: embankments, inter-embankment zones, ox-bow lakes and wetlands. These elements can be assessed using orthophotos, but BDOT database might be very useful too, because it contains the embankments thematic layers, that are difficult to be verified just using orthpohotos.



For verification of wetlands a database from GIS-mokradła web service (<http://www.gis-mokradla.info/html/index.php?page=mokradla>) is necessary. This database can be obtained upon a written request. For information on inter-embankment zone is necessary to measure river width and a distance between embankments, and then to select a proper option dependent on a ratio of inter-embankment zone width and river width (assessment categories differ for rivers with channel width below and above 30 m). In this section, it should be also noted if embankments are present on one river bank or on both banks. In case of rivers with channel width >30 m both river banks are assessed separately.

Section A9 informs about presence of protected areas in the river valley. Assessment is performed by providing a type of the protected area and percent share of such areas within the water body in buffer, which width depends on the river size, 100m in case of rivers with channel width <30 m, and 1000 m for rivers with channel width >30 m.

Section A10 gives possibility to note (as table) the elements of above described sections for two and four kilometres long rivers reaches. First column (reach number) contains ordinal numbers of subsequent reaches starting from the outlet/end of water body. The table is organized in such a way that the elements most problematic for the assessment, such as land use, trees cover, bridges, oxbow lakes, can be noted. All these elements are assessed using orthophotos, and their spatial variability may appear problematic for assessment. Remaining empty columns are for noting remarks and commentaries

IV. FIELD SURVEY

Principles of the approach

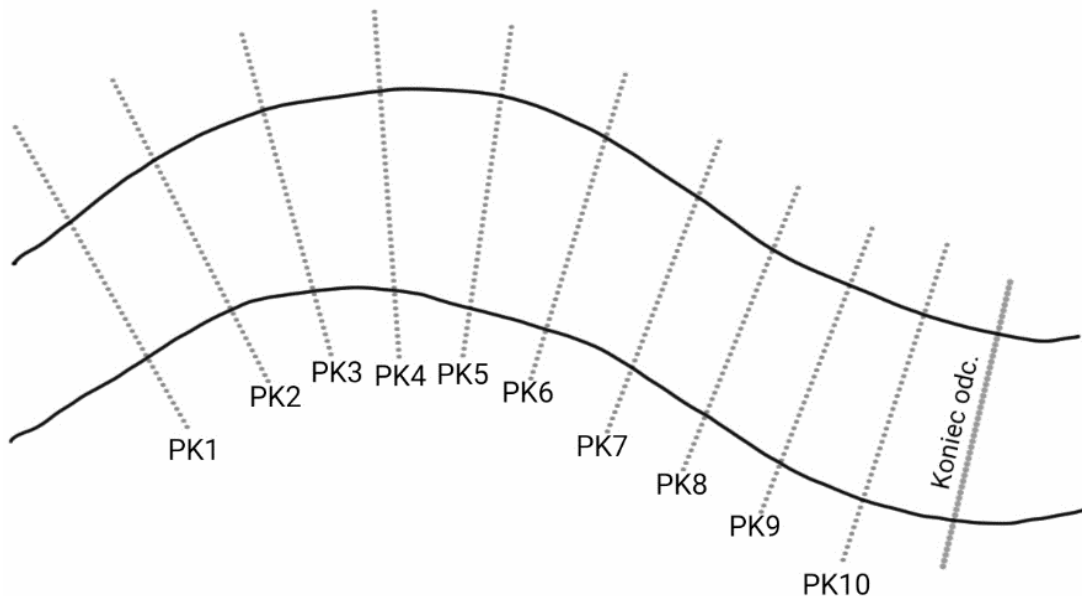
The river evaluation and classification is principally based on field survey, which is carried out along a standard 500 m or 1000 m long watercourse site, depending on the river width. Observations are conducted in **two stages**: first on 10 uniformly distributed spot-check profiles (spot-checks, transects), and later within the sweep-up stage when the entire survey site is considered.

The first stage survey is carried out on at ten control spot-checks (profiles), spaced equally every 50 m (rivers with channel width ≤ 30 m) or 100 m (rivers with channel width >30 m) (Fig. 2). Each spot-check is designed to record physical parameters of river channel, bank and adjacent buffer of the river valley. Among recorded attributes are: river bed and bank material, dominant flow type, erosion features, river material accumulation as well as types of modifications. These elements are



recorded over a 1 m wide transect (rivers with channel width ≤ 30 m) or 10 m (rivers with channel width >30 m). In the case of very big rivers the bottom substrate is assessed jointly for the entire survey site, reporting only one type of material dominant in the bottom. Moreover These elements are recorded over a 1 m wide transect (rivers with channel width ≤ 30 m) or 10 m (rivers with channel width >30 m). Additionally, information on structure of aquatic and bank vegetation and land use of a bank zone is recorded in transects of 10 m in width (all river types).

The second stage, called seep-up stage, is designed for a synthetic description of the entire 500- or 1000-m length of survey site. Among recorded attributes are various natural features and modifications, which were not recorded in the previous stage. Moreover information on a predominant valley form, channel dimensions and description of hydroengineering structures is delivered.

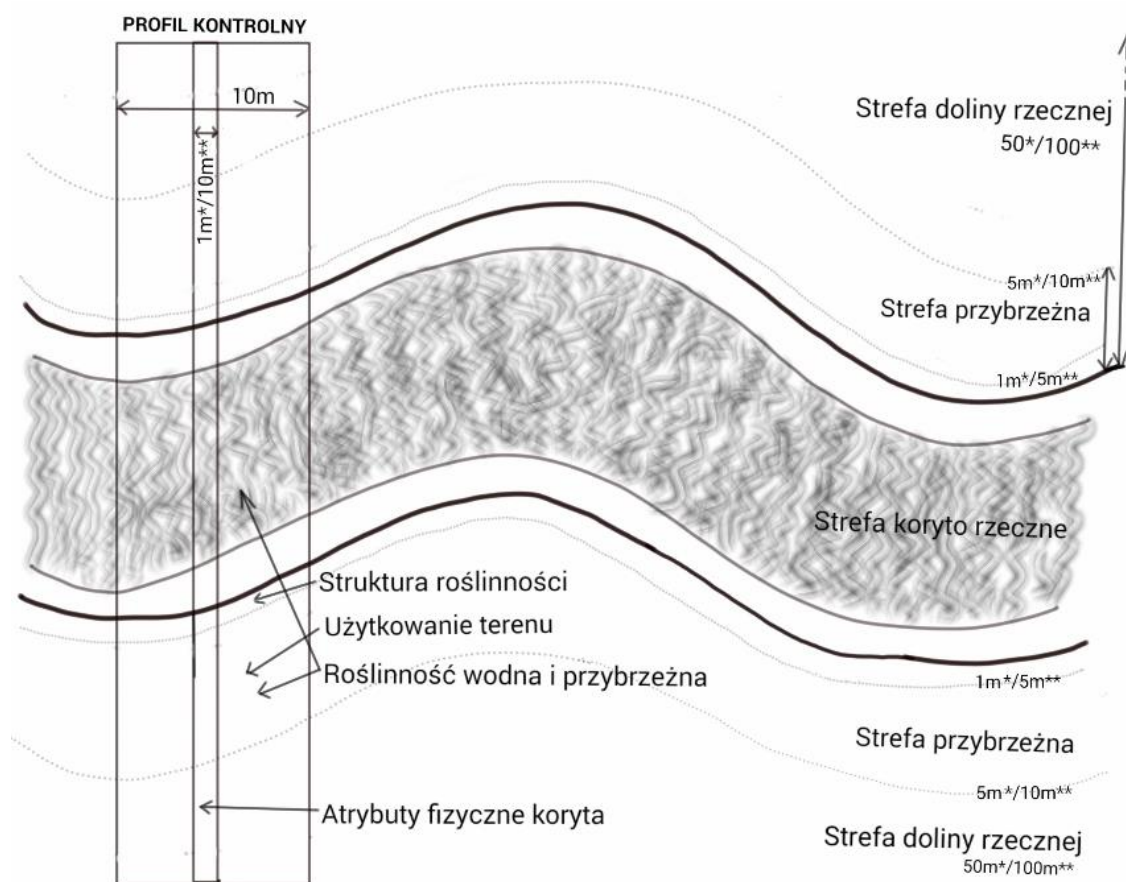


Explanation:

PK – Spot-check

Koniec odc. – End of survey site

Fig. 2. Example of the survey site with ten spot-checks (PK). Distance between spot-checks is 50m in small and medium rivers (channel width <30 m) and 100m in large rivers (channel width >30 m)



Explanation:

Profil kontrolny – Spot-check

Strefa doliny rzecznej – River valley zone

Strefa przybrzeżna – River valley adjacent to the banktop

Strefa koryto rzeczne – River channel

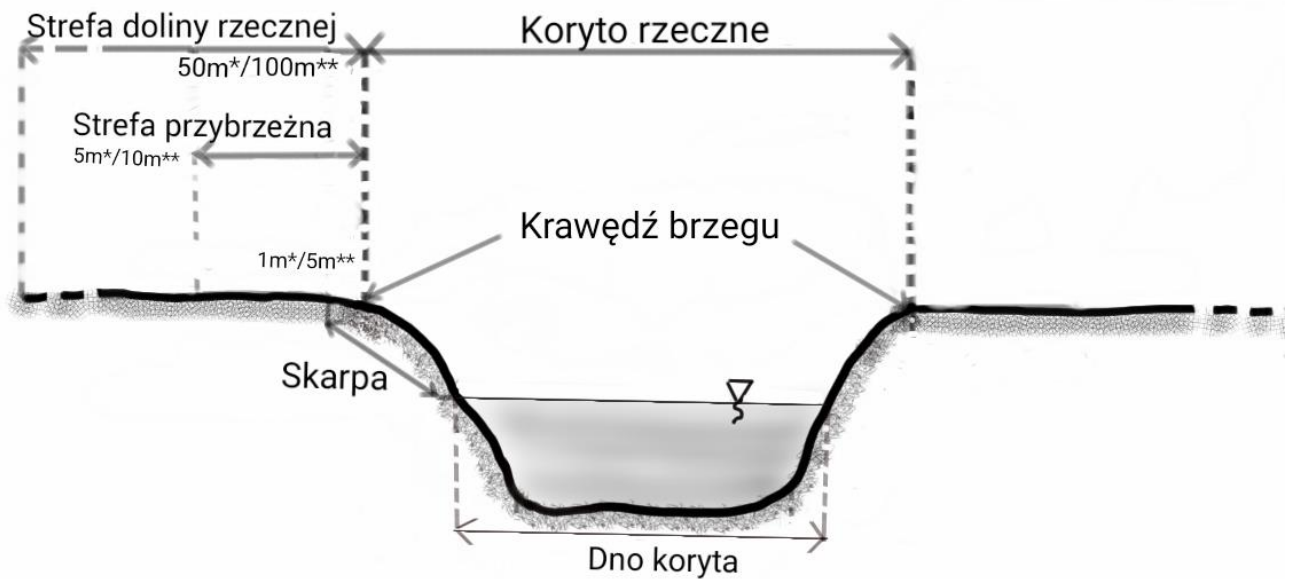
Struktura roślinności – Vegetation structure

Użytkowanie terenu – Land-use

Roślinność wodna i przybrzeżna – Aquatic and marginal vegetation

Atrybuty fizyczne koryta – Physical attributes of riverbed

Fig. 3. River channel dimensions
*River width <30m; ** River width >30m



Explanation:

Dno koryta – Riverbed

Krawędź brzegu – Banktop

Skarpa – Bank-face

Struktura roślinności – Vegetation structure

Strefa doliny rzecznej – River valley zone

Strefa przybrzeżna – River valley adjacent to the banktop

Fig. 4. River channel dimensions
*River width $<30\text{m}$; ** River width $>30\text{m}$

Staff requirements

Conducting hydromorphological surveys with HIR method requires providing a properly trained staff. Specialists conducting surveys and evaluating river hydromorphological status should be trained on the four-day course. The program should include analysis of the GIS resources and remote sensing data as well as the field surveys. Achieving competences during the course should be verified by examination. The quality of the course should be certified by the HIR Information Centre.

Field survey equipment

The hydromorphological survey requires following equipment: survey form, clipboard, field field key, range pole, digital camera and GPS. It is recommended to carry binoculars on a wide rivers. In the case rainfall, the Weather Writer and a laminated field key is useful.

Staff should wear waders during the survey. For safety reasons it is strictly recommended to work in two-person teams and to carry a mobile phone, which range needs to be verified prior to the field



studies.

Study methods in different river types

In the case of small and medium-sized watercourses with a stable bottom a survey may be conducted wading in the river channel. Analyses need to be performed at low and medium water levels and in sections not subjected to permanent damming, including particularly confluence sections of rivers and areas of damming structures. In the case of larger rivers and deep watercourses with an unstable substrate field surveys need to be conducted on both river banks, while in the spot-checks a range pole is used to assess physical features of the river channel. In the case of large rivers, with no ford access, analyses are conducted on one river bank. Morphological elements of the opposite river bank may be evaluated using binoculars. Moreover, it is admissible to conduct analyses from a boat, dinghy or kayak at such locations as e.g.:

- Those with a considerably overgrown river bank zone and the littoral zone overgrown e.g. by shrubs, common rush, reed mace, etc.;
- Those with wetlands in river banks, e.g. peatbogs;
- In large rivers, where the river bank zone is considerably overgrown with vegetation,
- When passage through the river bank zone is hindered, e.g. by drainage ditches or other structures.

Photographic documentation

We need to take at least 2 photographs of each experimental HIR section, presenting its general character, and if any objectionable elements are found, an adequate number of additional photographs needs to be taken. Picture taking against the sun should be avoided.

Modification of river channels and all important morphological elements should be documented in photographs. **It is particularly important to photograph all hydroengineering structures with a considerable environmental impact, which would facilitate assessment of their actual impact on the river environment.**

Field survey form

The surveyor records presence (and in certain cases the number of occurrence) or the absence of natural morphological features of the river channel and river bank areas observed on site and hydromorphological transformations. There are four basic recording options:

- Entering numbers of individual morphological forms found in relation to e.g. rapids, natural stepped falls, pools, potholes, point bars, waterfalls and hydrological structures;



- Marking the presence of a given form with a tick: ✓. In some categories it is optional to show a high intensity of a given form: D (i.e. incidence over >33 % length of the analysed section);
- Introduction of a two-letter acronym for attributes recorded in the spot-checks;
- Measurements of the river channel, such as the width of the river channel and water table, depth of the river channel and mean water depth.

The heading of the field report (section B1) is used to record basic information on the survey site, such as the name and the water body code, the name of the river and the experimental station, date and time of the observation, personal data of the person performing the observations and geographical coordinates. On site the first page of the field report is filled in first (sections B2-B4), where data on spot-checks are collected. At the end sections B5-B19 are filled in (pages 2-4 of the form), which are used to record information concerning the entire survey site. Experience shows that it is most convenient to fill in this part of the report when returning to the starting point, after describing all the spot-checks. The synthetic part of the field report refers to the entire 500-m section (or 1000 m in the case of large rivers), as then e.g. elements of the river environment are included, which were omitted when describing the spot-checks.

Section B1 contains basic information on the investigated water body containing the name and code number of the water body. In this part the basic information on the survey site is given, including the GPS coordinates of the beginning, centre and end of that section. Information on the person performed the field studies as well as the date and time of the survey is also recorded here.

Sections B2, B3, B4 are prepared for recording information in 10 transects (spot-checks). Spot-checks are regularly distributed (every 50 m in small and medium-sized rivers and at every 100 m in the largest rivers with river channel width of over 30 m). Each surveyor should test personal number of steps over a distance of 50 and 100 m.

In each spot-check information is entered concerning the bank and bottom of the river channel as well as the littoral zone. They include dominant materials of the bank and the bottom of the river channel, type of current, anthropogenic modifications and natural morphological elements in relation to the bank and the bottom of the river channel, groups of aquatic plants, the structure of vegetation and land use of the littoral zone. Abiotic elements (section B2) are evaluated in rivers with river channel width <30 m within the belt of 1m in width, whereas other elements (sections B3 and B4) refer to the belt of 10 m wide (Fig. 1). In the case of rivers with the river channel width >30 m all parameters in sections B2-B4 are evaluated in identical profiles of 10 m in width. An



exception is provided for the bottom substrate evaluated jointly as dominants over the entire 1000 m survey site.

Filling in sections B2 and B4 consists in entering acronyms for attributes identified in the spot-checks. For each record respective 2-letter acronyms are applied (e.g. GL = boulders; PR - profiled). All acronyms are listed in the report, while they are also explained in the field key. Most acronyms are easy to learn by surveyors, but having a copy of the field key will facilitate an on-going verification of potential doubts.

Some fields in the field form in sections B2 and B4 are outlined with a bold line, which indicates a limitation of the number of categories given for a respective attribute in the spot-check. Only the dominant form of a given attribute is recorded, even if more than one are observed.

In fields not outlined in bold it is admissible to enter more than one (max. two) categories of a given attribute. For example, when describing bank modifications, we need to take into consideration both profiling and reinforcement.

Section B3 provides a list of channel vegetation types. In the proposed method plant species are not identified, but they are classified to one out of eight morphological types such as algae, bryophytes, emergent, submerged with floating leaves, completely submerged, floating, creeping amphiphytes or detritus. In this report these types are recorded, which cover at least 1% river channel area in the 10 m belt of the spot-check in small and medium-sized rivers or which cover $>1\text{ m}^2$ area in large rivers. Those present are recorded as a '✓' or as 'D' if more than 1/3 of the channel within 10m wide transects covered.

Section B5 informs on the occurrence of various physical attributes of the river channel. Occurrence of individual hydromorphological forms is recorded in three categories: not found, found or abundantly found. In order to record the presence of a given attribute, it has to be found in a minimum 1% length of the survey site.

Section B6 contains the number of natural morphological elements in an survey site, such as rapids and stepped falls, pools and potholes, waterfalls and point bars, either strengthened or not strengthened by vegetation. When they are not found, the entry is zero. The best method is to systematically calculate these attributes when moving between the spot-checks. Due to the considerable depth of the largest rivers with river channel width $>30\text{ m}$ in that section natural elements are recorded, which are located over the water surface, i.e. various types of point bars.

Section B7 evaluates profiles of bank banks. If the profile type is rarely represented we mark it with



a tick (✓). In turn, if it is so common that it exceeds 1/3 length of the analysed section, a large share (D) is marked in the form.

Section B8 concerns dimensions of the river channel. Measurements are taken in one representative cross-section. An optimal location for the measurements is provided by a possibly symmetrical, straight and uniform reach. Channel measurements do not have to be taken at a spot-checks. Guidance on how to measure the channel is included in the survey form. Measurements are to be taken using a range pole.

Section B9 requires the number of different types and extent of artificial structures to be recorded. As in section B6, a cumulative record is made during the spot-check survey. Zero must be recorded if non hydroengineering structure are present.

Section B10 concerns forms connected with tree plantings. The occurrence of individual hydromorphological forms is recorded in the system of three quantitative categories (not found, found or found in abundance). Some attributes marked with an asterisk (*), e.g. drooping branches, which means that they may be recorded in the form even when they are found over <1% length of the survey site.

Section B11 contains information concerning the width of the littoral zone with no land use, i.e. forests, tree and shrub plantings, tall herbs, wetlands, surface waters except for fishing ponds and natural open spaces. They are evaluated in five categories depending on the width of this zone.

Section B12 records a valley type dominant in the survey site. It may be selected from among four characteristic types.

Section B13 is used to survey land use in the river valley. In this section 10 categories of land use may be selected from. Evaluations are made separately for each of the banks.

Section B14 is used to evaluate the connection of the river with its valley. Elements found in the valley indicating its natural character (oxbow lakes, peatbogs) and anthropogenic elements are recorded here. Evaluation is done within three categories (none, found or abundant).

Section B15 includes supplementary field information on the survey site, such as water level during the field survey, hydrological type of watercourse, etc.

Section B16 records human impact affecting the river site, which may be present, but have not been included in other parts of the field report.

Section B18 provides additional information, which may be significant for the investigated river



section and which could not be entered in other sections of the field report.

Survey requirements

Precipitation and high water level

A high water level and enhanced turbulence hinder identification of many morphological elements. Some of them may be then completely invisible (e.g. point bars and submerged vegetation). Studies conducted at high water stages frequently should not be conducted for safety reasons.

In the case of longer periods of heavy rains field surveys should be postponed until the water level and its transparency return to normal (medium or low). Field surveys should also be avoided in the backwater zone of river mouths.

Survey season

It is best to conduct field surveys during the plant vegetation period. In Poland it is a period from May to October.

Field surveys may be performed in other seasons of the year, on condition there is no snow cover. However, it needs to be remembered that in winter not all vegetation groups are well-visible, particularly floating species, which do not root in the substrate (e.g. duckweed), as well as rooted plants with floating leaves (e.g. yellow waterlily, white waterlily) and emerged dicotyledonous plants (e.g. water parsnip, great yellowcress). Vegetation cover by other groups of plants is possible to estimate in the winter season, since plants submerged in the limnetic zone are typically evergreen, while emerged monocotyledonous species are well-visible until spring as dried rushes. Determination of the littoral vegetation structure also poses no major problems after the completion of vegetation - species variation of trees, shrubs and bryophytes may be easily determined throughout the year, while the structure of herbaceous plants may also be determined based on dried shoots.

Conditions required for precision of results

In the proposed method the precision of field surveys is crucial. An accurate description of elements of the river environment, conducted by competent and adequately trained specialists, is necessary. Data collected on site are verified during the process of data entry in the computer data base. Each report has to be verified in terms of completeness of data while still being on site.



V. EVALUATION AND CLASSIFICATION OF THE HYDROMORPHOLOGICAL STATUS OF RIVERS

PRELIMINARY ASSESSMENT BASED ON GIS RESOURCES AND REMOTE SENSING MATERIALS

The desktop method is entirely based on the analysis of the remote sensing data and available spatial databases. It is necessary that the utilized data is standardised in terms of the detail level for the entire country, which allows to compare the results between different water bodies analysed by various Voivodship Inspectorates of Environmental Protection..

In order to assess river naturalness and the degree of their modification basing on GIS resources and remote sensing materials, two numerical metrics are calculated: GIS Hydromorphological Diversity Score (GIS-WRH) and GIS Hydromorphological Modification Score (GIS-WPH). The range of the evaluated parameters are presented in tables below (Table 1 and 2). Number of considered attributes depends on river size and their number is greater for large rivers.



Table 1. Attributes included in the GIS Hydromorphological Diversity Score

Attribute symbol	Attribute name	Scale	Scoring
PRH1	Sinuosity index	Multi-thread channels	5
		Meandering channels ($S_i > 1,3$)	4
		Sinuuous channels ($1,05 < S_i \leq 1,3$)	3
		Polygonal channels(?) koryta łamane	2
		Straight channels ($1 < S_i \leq 1,05$)	1
In case of assessing the entire water body weighted average is calculated for the stretches with particular planform type.			
PRH2	Mid-channel bars and islands	>75% of the area under low pressure land use type	5
		25-75% of the area under low pressure land use type	3
		<25% of the area under low pressure land use type	1
PRH3	Side bars	>75% of the area under low pressure land use type	5
		25-75% of the area under low pressure land use type	3
		<25% of the area under low pressure land use type	1
PRH4	Floodplain land use structure	Semi-natural area	10
		Agricultural area	5
		Urbanized area	
		Final scoring is calculated as weighted average of particular land use class in each buffer zone	
PRH5	Potential wood delivery	>75% of the length of water body	5
		50-75% of the length of water body	3
		25-50% of the length of water body	2
		<25% of the length of water body	1
		Absence	0
PRH6	Ox-bow lakes	>75% of the length of water body	5
		50-75% of the length of water body	3
		25-50% of the length of water body	2
		<25% of the length of water body	1
		Absence	0
PRH7	Wetlands	>75% of the length of water body	5
		50-75% of the length of water body	3
		25-50% of the length of water body	2
		<25% of the length of water body	1
		Absence	



Table 2. Attributes included in the GIS Hydromorphological Modification Score

Attribute symbol	Attribute name	Scale	Scoring
PPH1	Water course realignment	no realignment (natural watercourse)	0
		≤25 % of a water body	1
		25-50 of a water body	3
		50-75 of a water body	5
		>75 of a water body	7
PPH2	Damming structures	nodamming	0
		≤0,2 points/ km of a water body	3
		0,2-0,5 of a water body	5
PPH3	Spanning structures, bridges	>0,5/km of the length of water body	3
		0,2-0,5/km of the length of water body	2
		<0,2/km of the length of water body	1
PPH4	Water management objects	>33% of the length of water body	3
		5-33% of the length of water body	2
		<5% of the length of water body	1
PPH5	Spillways and regulating objects	>33% of the length of water body	3
		5-33% of the length of water body	2
		<5% of the length of water body	1
PPH6	Embankments	>75% of the length of water body	5
		50-75% of the length of water body	3
		25-50% of the length of water body	2
		<25% of the length of water body	1
		Absence	0
PPH7	Inter-embankment zone	Absence	3
		<5 channel width	2
		>5 channel width	1
		In case of assessing the entire water body weighted average is calculated for the stretches with particular inter-embankment zone width	

A river is characterized by the lowest stream order, according to MPHP 2010, is assessed in each water body. If there is more than one river characterized by the same (lowest) stream order in a particular water body, then all such rivers shall be considered. The survey is performed for the entire river. To avoid a risk of omitting some elements, it is recommended to divide river into two-kilometres (rivers with channel width ≤30 m) or four-kilometres (rivers with channel width >30) reaches. Information on hydrological regime, river longitudinal profile, hydraulic structures, land use and river valley characteristics is collected in the stage of preliminary assessment.

In case of conducting the assessment for the entire water body, GIS-WRH and GIS-WMH are evaluated as a summarized scoring based on the protocol. The final score is calculated as follows:

$$GIS\ WRH = \frac{\sum GIS - WRH_i}{n}$$



where:

GIS-WRH – GIS Hydromorphological Diversity Score

GIS-WRH_i –GIS Hydromorphological Diversity Score of *i* section

n – number of sections per water body

$$GIS\ WPH = \frac{\sum WPH_i}{n}$$

where:

GIS-WPH – GIS Hydromorphological Modification Score;

GIS-WPH_i – GIS Hydromorphological Modification Score of *i* section

n – number of sections per water body

ASSESSMENT BASED ON FIELD SURVEY DATA

The hydromorphological classification of watercourses is based on **Hydromorphological Index for Rivers (HIR)**. Index HIR is a matrix combining two indices: Hydromorphological Diversity Score (WRH) and for the Habitat Modification Score (WPH).

Hydromorphological Diversity Score (WRH)

WRH informs on diversity of natural morphological elements of the watercourse and the river valley. It combines natural features of three zones of the river, i.e. the river channel, the bank-top zone and the river valley buffer adjacent to the bank.

1. The river channel zone

- 1.1. Variation of the river line
- 1.2. Variation in the river bed slope
- 1.3. Heterogeneity of water flow
- 1.4. Heterogeneity of river bottom material
- 1.5. Natural morphological features of river channel bottom
- 1.6. Natural morphological elements of banks
- 1.7. Variation of vegetation types in the river channel



- 1.8. Structure of bank vegetation
- 1.9. Variation in elements accompanying trees
2. The bank-top zone
 - 2.1. Structure of bank-top vegetation
 - 2.2. Not-managed bank-top zone
3. The river valley zone
 - 3.1. Natural land use of the valley
 - 3.2. Connection between the river and the valley

Hydromorphological Modification Score (WPH)

WPH informs on the total degree of modifications of the hydromorphology of the watercourse and the river valley. It takes into consideration all forms of transformations recorded in the HIR method, such as reinforcements and transformations of the channel profile and presence and abundance of engineering structures. The value of this index is calculated as a sum of categories presented below:

1. Transformed transverse section of the river channel
2. Hydroengineering structures
3. Transformations observed in spot-checks
4. Disturbance of the connectivity with the river valley
5. Other types of human degradation

River evaluation and classification based on field survey

The final field assessment takes into account both the Hydromorphological Diversity Score (WRH) and the Hydromorphological Modification Score (WPH). Basing on these two indices a multimetric HIR can be calculated ranging from 1 (reference value) to 0 (extreme degradation):

$$HIR = \frac{\left(\frac{WRH - WPH}{100}\right) + 0,85}{1,8}$$

The river classification is considered in five river type system:

- H1 - small and mid-sized, mid-altitude and highland rivers, including all watercourses with



a channel width ≤ 30 m.

- H2 - small and mid-sized lowland rivers in the non peat-bog valleys, with a channel width ≤ 30 m.
- H3 - small and mid-sized lowland rivers in the peat-bog valleys, with a channel width ≤ 30 m.
- H4 - large rivers, including all the watercourses wider than 30 m,
- H5 - artificial canals.

Tab. 3 Classification system of Polish rivers based on HIR index

River type	Status water body	Channel width	Altitude	Valley peat-bog	HIR multimetrix				
					I	II	III	IV	V
H1	natural and heavily modified	≤ 30 m	upland and mountains	-	$\geq 0,824$	$\geq 0,715$	$\geq 0,600$	$\geq 0,485$	$< 0,485$
H2			lowland	no	$\geq 0,761$	$\geq 0,639$	$\geq 0,500$	$\geq 0,375$	$< 0,375$
H3			lowland	yes	$\geq 0,725$	$\geq 0,592$	$\geq 0,459$	$\geq 0,326$	$< 0,326$
H4	natural	> 30 m	lowland	-	$\geq 0,728$	$\geq 0,629$	$\geq 0,530$	$\geq 0,431$	$< 0,431$
H5	artificial	-	-	-	$\geq 0,513$	$\geq 0,420$	$\geq 0,342$	$\geq 0,253$	$< 0,253$

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