HYDROMORPHOLOGICAL PRESSURES UNDER CLIMATE CHANGE: FROM ASSESMENT TO NATURE-BASED SOLUTIONS WITH A CATCHMENT SCALE PERSPECTIV

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ABOUT ME

- **Assistant Professor at the National Research Institute of Meteorology and Water Management (IMGW-PIB)** since 2001.
- Since 2007 – **Head of the Environmental Research Department** in Wrocław.
- Specialist in **hydrology, river hydromorphology**, water management, environmental engineering and climate change adaptation.
- Currently working on descriptors of hydromorphological changes in rivers, implementation of new observation technologies and machine learning for monitoring riverbed cover and morphological changes.
- Co-author of the **Polish standard methodology** for assessing the hydromorphological status of rivers.
- Experienced in designing and implementing special monitoring programmes, including hydrological measurements, in anthropogenically modified areas.
- **Author of** adaptation plans for selected cities in Poland and implementer of local climate adaptation measures in the German–Polish border region.
- Active in **transboundary water cooperation** and water diplomacy with Germany and the Czech Republic within the framework of the Border Water Commission.
- **Leader** and **responsible partner** in numerous national and international research and implementation projects on climate change adaptation, extreme weather events and development of climate resilience platforms.
- Cooperates with state and local authorities, research institutions and NGOs. Active member of the International Network of River Basin Organisations (INBO).

KEY AREAS OF EXPERTISE

- Hydrology & Water Management
- River Hydromorphology & Monitoring
- Climate Change Adaptation & Resilience
- Urban Adaptation Planning & Nature-based Solutions
- Transboundary Cooperation & Water Diplomacy
- Data, Monitoring & Decision Support Tools

SELECTED ACHIEVEMENTS

- **25+ years of experience** in research and practical projects in water and environmental management
- Author of urban climate adaptation plans for Polish cities
- Implementation of local adaptation measures in the German–Polish border region
- Leader and partner in numerous national and international projects
- Strong cooperation with national authorities, municipalities, research institutions and NGOs

Institute of Meteorology and Water Management
National Research Institute (IMGW-PIB)
Poland, Warsaw

METEO
IMGW-PIB
meteo.imgw.pl

IMGW-PIB is a public organisation
under the supervision of the Ministry of Infrastructure.
It fulfils **governmental tasks** in forecasting and warning of hazardous meteorological and hydrological phenomena and performs statutory tasks of the National Hydrological and Meteorological Service, including the supervision of regular meteorological and hydrological measurements and observations.

IMGW-PIB IN NUMBERS

- **~1,400** specialists and experts
- **63** synoptic stations
- **900+** climatological and precipitation stations
- **900+** hydrological stations

OBSERVATION NETWORK ACROSS POLAND

- Hydrological stations
- Climatological and precipitation stations
- Synoptic stations

ENVIRONMENTAL RESEARCH DEPARTMENT

My department currently employs **10 people**, including **5 researchers** specialising in:

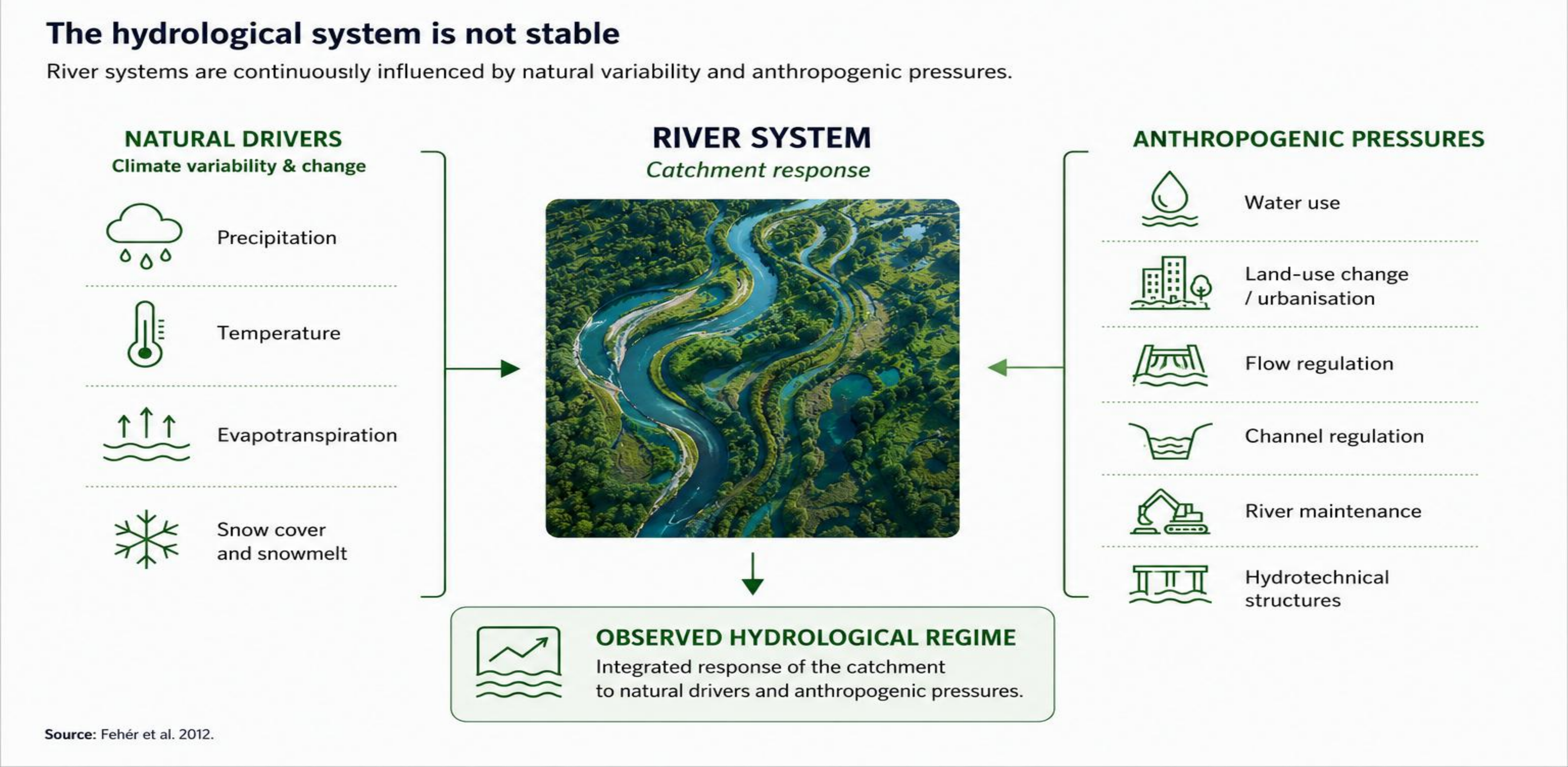
Hydrology | Hydromorphology | Environmental protection | Biology | Hydrogeology | Climatology | Meteorology

- Developtment of measures and strategies for **adaptation to climate change**
- Assessment of the **hydromorphological status** of watercourses and the natural retention of river valleys
- Implementation of **special monitoring** in anthropogenically modified areas
- Application of **GIS tools** in water management and environmental protection

MAIN ACTIVITIES

- Forecasting and warning of hazardous meteorological and hydrological phenomena
- Regulàr metéorologicai and hydrological measurements and observations
- Research and development in hydrology, climatology, oceanography, and environmental sciences
- Support for water management, safety and climate adaptation

River System



Hydromorphology as an interdisciplinary field

River form and function cannot be interpreted from morphology alone

WFD hydromorphological quality elements

Hydrological regime
quantity and dynamics of flow
groundwater connection

River continuity
barriers and regulation
organism migration

Morphological conditions
channel geometry
bed, substrate, riparian zone

Hydromorphology integrates disciplines

to explain river-system response

Why does it matter?

Hydromorphology links:

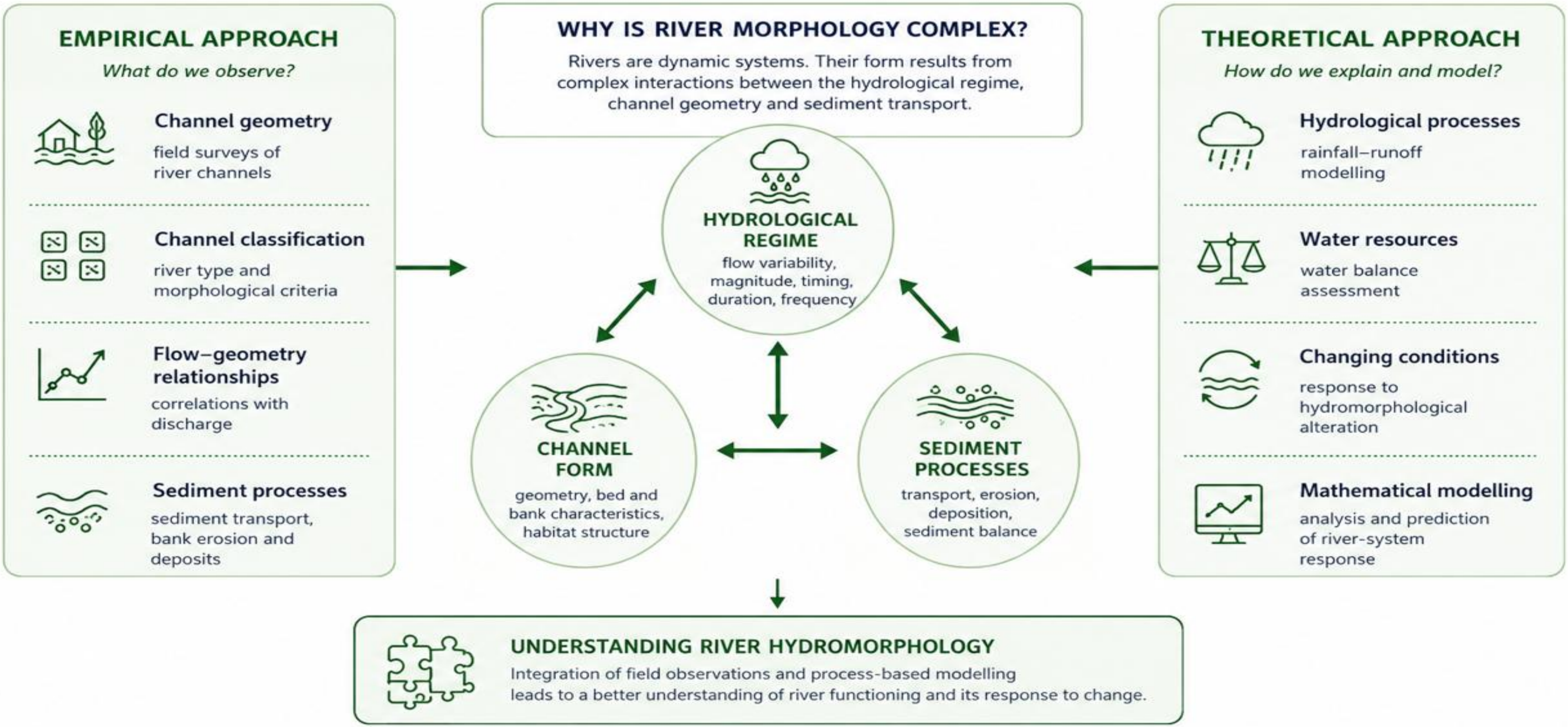
- **river form**
  morphological conditions
- **flow**
  hydrological regime
- **connectivity**
  river continuity
- **ecological status**
  river-system functioning

KEY POINT

Hydromorphological assessment requires an integrated view of flow, form and continuity — not morphology alone.
This justifies linking field-based hydromorphological monitoring with long-term hydrological observations.

Hydromorphology: understanding river processes

A relatively new scientific field in Poland, closely linked to the implementation of the Water Framework Directive and river morphology assessment.



Sources: Ackers, 1982; Przedwojski, 1998.

From River Morphology to Hydromorphological Assessment

Not a review of methods, but the evolution of the assessment perspective

Hydromorphology links river form, flow and continuity in ecological status assessment.

1 River morphology
channel form • sediment • erosion

→

2 Hydromorphological assessment
hydrological regime • continuity • morphology

→

3 WFD requirements
supporting quality elements for ecological status

→

4 National monitoring
field assessment + hydrological observations

Three components introduced into assessment practice

- Hydrological regime
- River continuity
- Morphological conditions

KEY POINT

Many assessment methods describe observable river features very well, but long-term hydrological regime alteration requires additional temporal analysis.

This is why field-based hydromorphological monitoring should be interpreted together with long hydrological records.

Conceptual slide based on presentation storyline; WFD = Water Framework Directive.

Hydrological regime – the weakest component of hydromorphological assessment

Review of assessment methods shows a strong focus on observable morphological features

MORPHOLOGY IS WELL REPRESENTED

Substrate & longitudinal continuity	**15 methods**
Channel geometry	**14 methods**
Vegetation	**12 methods**
Flow type	**11 methods**
Erosion processes	**5 methods**
Bank structure & vegetation	**82% of methods**
Valley: vegetation, land use & continuity	**~65% of methods**

HYDROLOGICAL REGIME IS POORLY REPRESENTED

1	**Water level + Qmin**	**6 methods**
2	**Water level + Qmax**	**3 methods**
3	**Flow variability**	**4 methods**

No comprehensive assessment of the hydrological regime

KEY MESSAGE

Hydromorphological methods describe river morphology relatively well, but the hydrological regime is often represented by only a limited set of indicators.

This creates a need for complementary assessment based on long-term hydrological observations.

Source: preliminary review of hydromorphological assessment methods (user-provided synthesis).

HIR – Hydromorphological Index for Rivers

Field-based assessment of river hydromorphological status in Poland

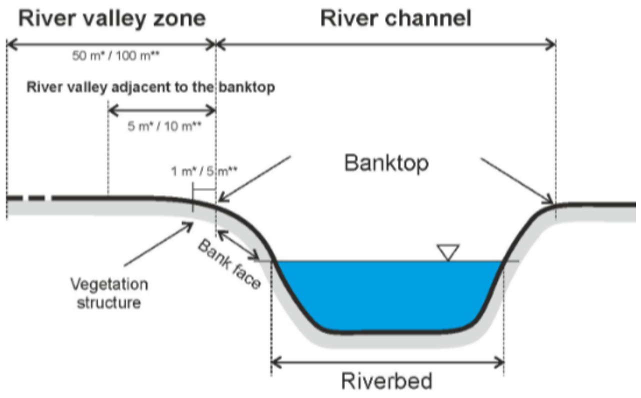
HIR links standardised field surveys with reference-based classification of hydromorphological status.

METHOD IN BRIEF

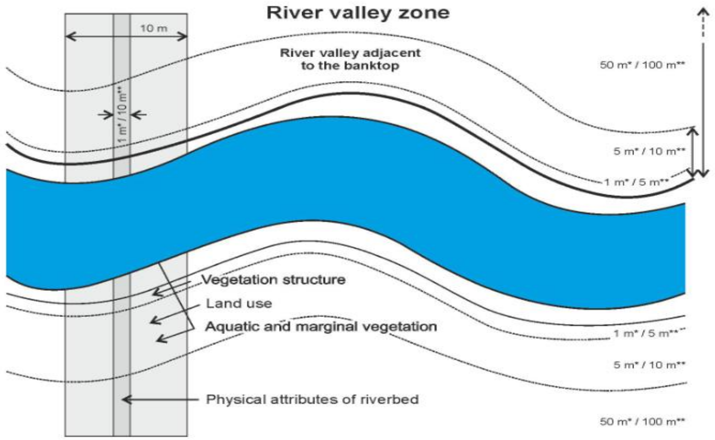
1. **Developed for monitoring of flowing waters in Poland**
   2017 method; WFD-compliant
2. **Integrated data sources**
   field survey + GIS + remote sensing
3. **Reference-based assessment**
   principal HIR value compared with reference conditions
4. **Five-class status system**
   classification of hydromorphological quality

FIELD SURVEY SCHEMES

First stage 10 spot-checks



Three evaluated zones: channel, banks, and river valley



Single spot-check profile: physical attributes, vegetation and land use

Assessed features: riverbed • bank structure • aquatic and riparian vegetation • land use • anthropogenic modifications

KEY POINT

At gauging stations, HIR surveys can be linked with long-term discharge and water-level records.
This creates a bridge between local field-based hydromorphological assessment and temporal analysis of the hydrological regime.

Source: Szoszkiewicz et al., 2017, modified; HIR method description.

The second stage is a synthetic assessment – 500 m /1 000 m

Two Components of the HIR Assessment

Natural hydromorphological diversity and anthropogenic modification are assessed separately and then integrated in HIR.

WRH – Hydromorphological Diversity

What does it describe? Natural heterogeneity of the river and its valley.

- channel geometry and variability
- flow and substrate diversity
- natural bed and bank features
- aquatic and riparian vegetation
- riparian zone and land-use diversity

Higher WRH → greater natural diversity

+

WPH – Hydromorphological Modification

What does it describe? Cumulative anthropogenic modification of the river and its valley.

- modified channel geometry
- bank and channel reinforcement
- hydrotechnical structures
- modifications recorded in survey profiles
- reduced river–floodplain connectivity

Higher WPH → greater human modification

HIR integrates both dimensions | WRH and WPH may change simultaneously – and even in opposite directions.

WRH – diversity of natural hydromorphological features | WPH – degree of anthropogenic modification

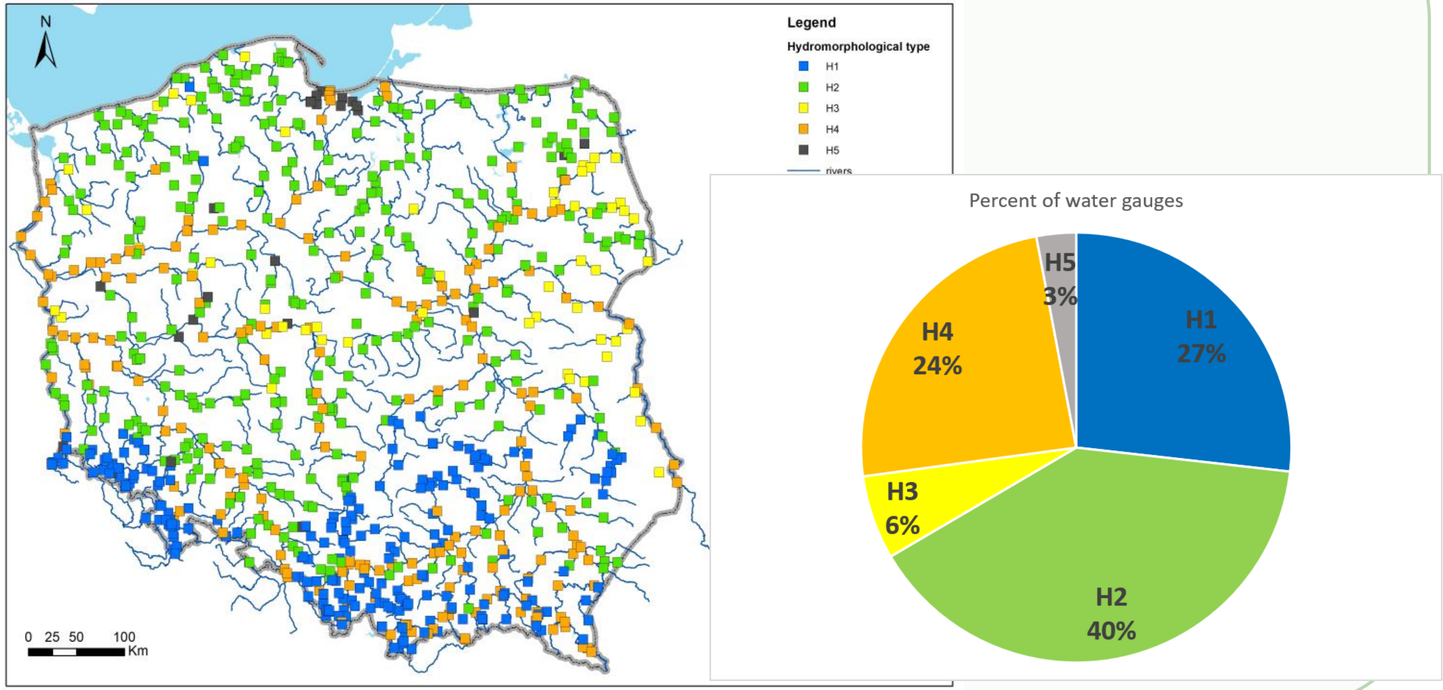
Hydromorphological River Types in Poland at the gauge station

River typology provides the basis for type-specific interpretation of hydromorphological status

H1	Upland & mountain rivers	≤ 30 m
H2	Lowland rivers outside peat valleys	≤ 30 m
H3	Lowland rivers in peat valleys	≤ 30 m
H4	Large rivers	> 30 m
H5	Artificial canals	—

The width of the riverbed

Spatial distribution of hydromorphological river types



WHY DOES RIVER TYPE MATTER? Different river types have distinct natural channel forms, substrates, flow characteristics and valley settings. Hydromorphological status must therefore be interpreted in relation to river type.

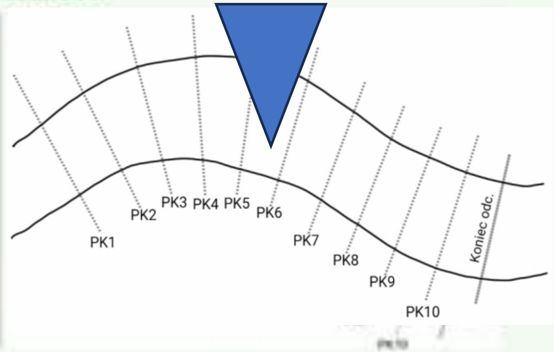
There is no single morphological pattern of a river in good status.

How is HIR implemented in the IMGW-PIB monitoring network

Hydromorphological Status at IMGW-PIB Gauging Stations

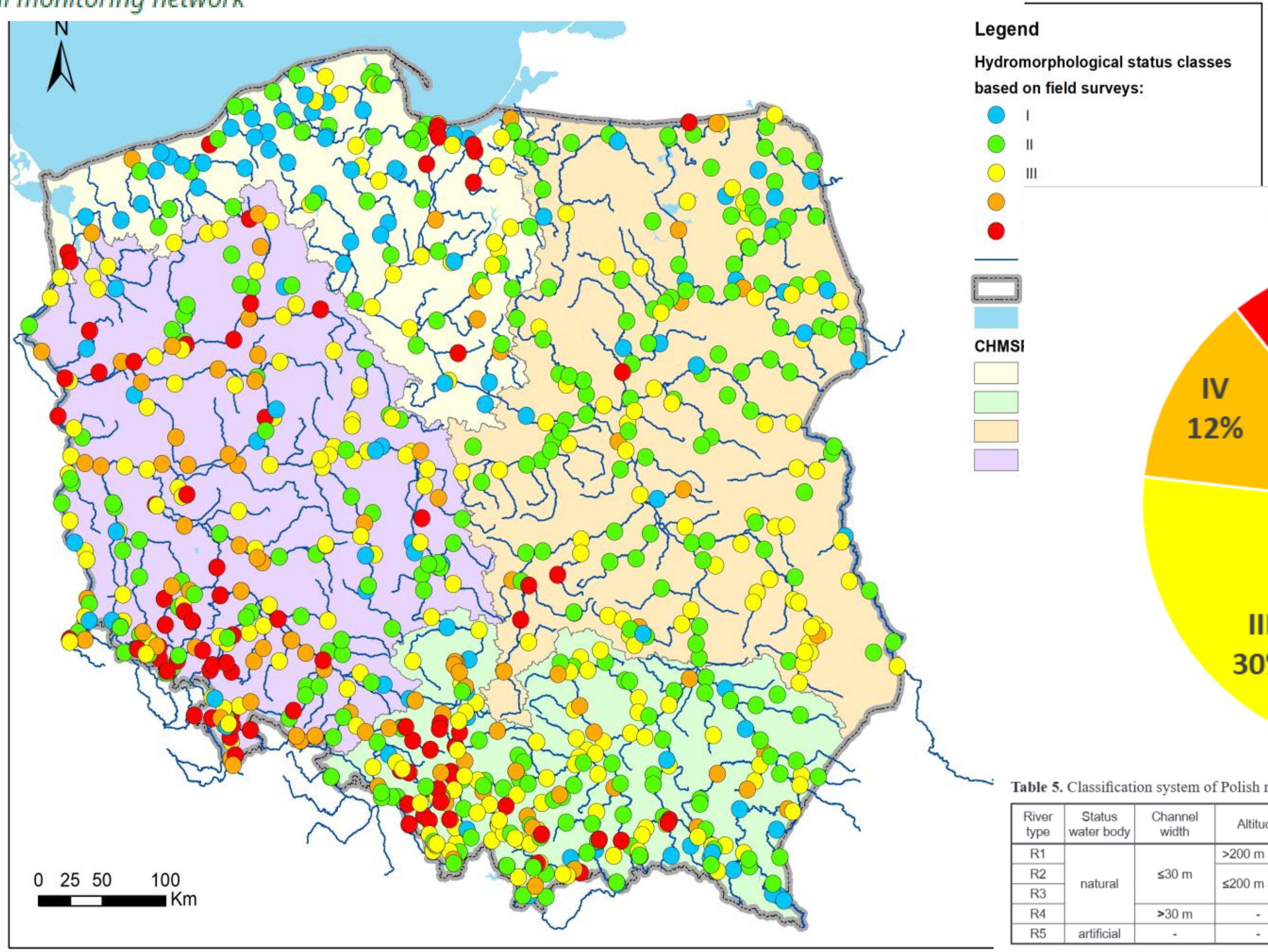
HIR field assessment combined with the national hydrological monitoring network

HIR survey at a gauging station



1 **Field-based HIR status**
local river reach assessment

2 **Long-term H and Q records**
temporal hydrological context



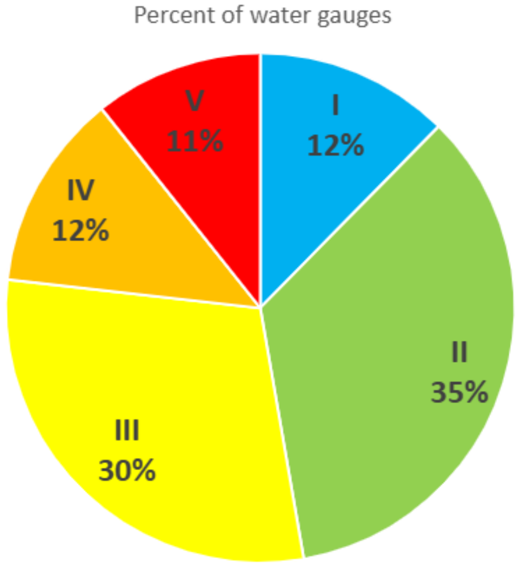


Table 5. Classification system of Polish rivers based on HIR index

River type	Status water body	Channel width	Altitude	Valley peat-bog	HIR multimetrix I	II	III	IV	V
R1	natural	≤30 m	>200 m a.s.l.	-	≥0.824	≥0.715	≥0.600	≥0.485	<0.485
R2			≤200 m a.s.l.	no	≥0.761	≥0.639	≥0.500	≥0.375	<0.375
R3				yes	≥0.725	≥0.592	≥0.459	≥0.326	<0.326
R4		>30 m	-	-	≥0.728	≥0.613	≥0.486	≥0.359	<0.359
R5	artificial	-	-	-	≥0.513	≥0.420	≥0.342	≥0.253	<0.253

KEY QUESTION

Does hydromorphological status correspond to long-term hydrological regime alteration?

Hydromorphological alterations in Polish rivers

Selected Polish examples linked to the main hydromorphological quality elements

Pressures often affect more than one component at the same time.

Example	Pressure type	Main component	Process affected	Hydromorphological relevance
	**Kaczawa River/ channel regulation**	**Morphological conditions Sediment transport**	Constrained channel; reduced lateral mobility; altered sediment processes	Reduced lateral dynamics and simplified channel habitats
	**Ina River Weir / transverse structure**	**River continuity Hydrological regime**	Backwater effect; discontinuity; altered water levels	Migration barrier and changed hydraulics upstream and downstream
	**San River Solina reservoir**	**Hydrological regime River continuity**	Flow regulation, sediment trapping, and altered seasonality	Altered downstream flows and reduced sediment supply
	**Bystrzyca River Dam / impoundment**	**Hydrological regime River continuity**	Controlled water level; valley inundation changes	Transformation from dynamic river corridor to regulated water body
	**Navigation canal Artificial channel**	**Morphological conditions**	Reinforced banks; simplified bed and flow structure	Strongly modified watercourse with simplified habitats

Key message | **Visible structures are only the starting point. Hydromorphological assessment should interpret how each pressure modifies morphology, continuity and the flow regime.**

Photos: user-provided examples.

High Hydromorphological Diversity in selected Polish Rivers

ŁUPAWA, ŁUPAWA H4B LOWLAND RIVER, FAST CURRENT, SANDY AND GRAVEL BOTTOM, UNDERWATER TREE ROOTS, EXPOSED ROOTS ON THE BANK

MITRĘGA, KUŹNICA SULIKOWSKA, H1A A STREAM OR A SMALL UPLAND RIVER, LAMINAR CURRENT, SANDY BOTTOM, UNDERWATER AND EXPOSED TREE ROOTS,

SŁUPIA, SOSZYCA, H4B LOWLAND RIVER, RAPID CURRENT, SANDY BOTTOM, PLANTS COMPLETELY SUBMERGED, CREEPING AMPHIHITES

MŁYNISKA STREAM, ZAKOPANE STRĄŻYSKA VALLEY, H1B TATRA STREAM, OVERFLOW AND RISING CURRENT, BOTTOM STONES AND BOULDERS, EXPOSED AND OVERGROWN BOULDERS, FALLEN TREES

ŁEBA, MIŁOSZEWO, H4B LOWLAND RIVER, RUSHING CURRENT, ROCKY BOTTOM, OVERGROWN BOULDERS, UNDERWATER TREE ROOTS, EXPOSED ROOTS ON THE BANK, FINE DEBRIS

GRABIA GRABNO H4B LOWLAND RIVERS, SANDY BOTTOM, LAMINAR FLOW, DEBRIS, SUBMERGED AND EMERGED VEGETATION

Multi-Indicator Assessment of Hydrological Regime Alteration

Long-term comparison based on 17 hydrological regime measures at 161 gauging stations

RELATIVE MEASURES

H • P • D • α

ABSOLUTE MEASURES

V • WWQ • SWQ • SSQ
SNQ • NNQ • SSq • A • Cv • Z

ANTHROPOGENIC-PRESSURE MEASURES

SSQ/SWQ • SNQ/SSQ
WWQ/NNQ • (WWQ–NNQ)/SSQ

LONG-TERM DATA

161 gauging stations

Comparison of
1951–1980 (reference)
and 1981–2020 (future)

CHANGE INDEX

Calculated for each measure

Magnitude of change between the two observation periods

WZ = 1 – (WXreference/ WXfuture)

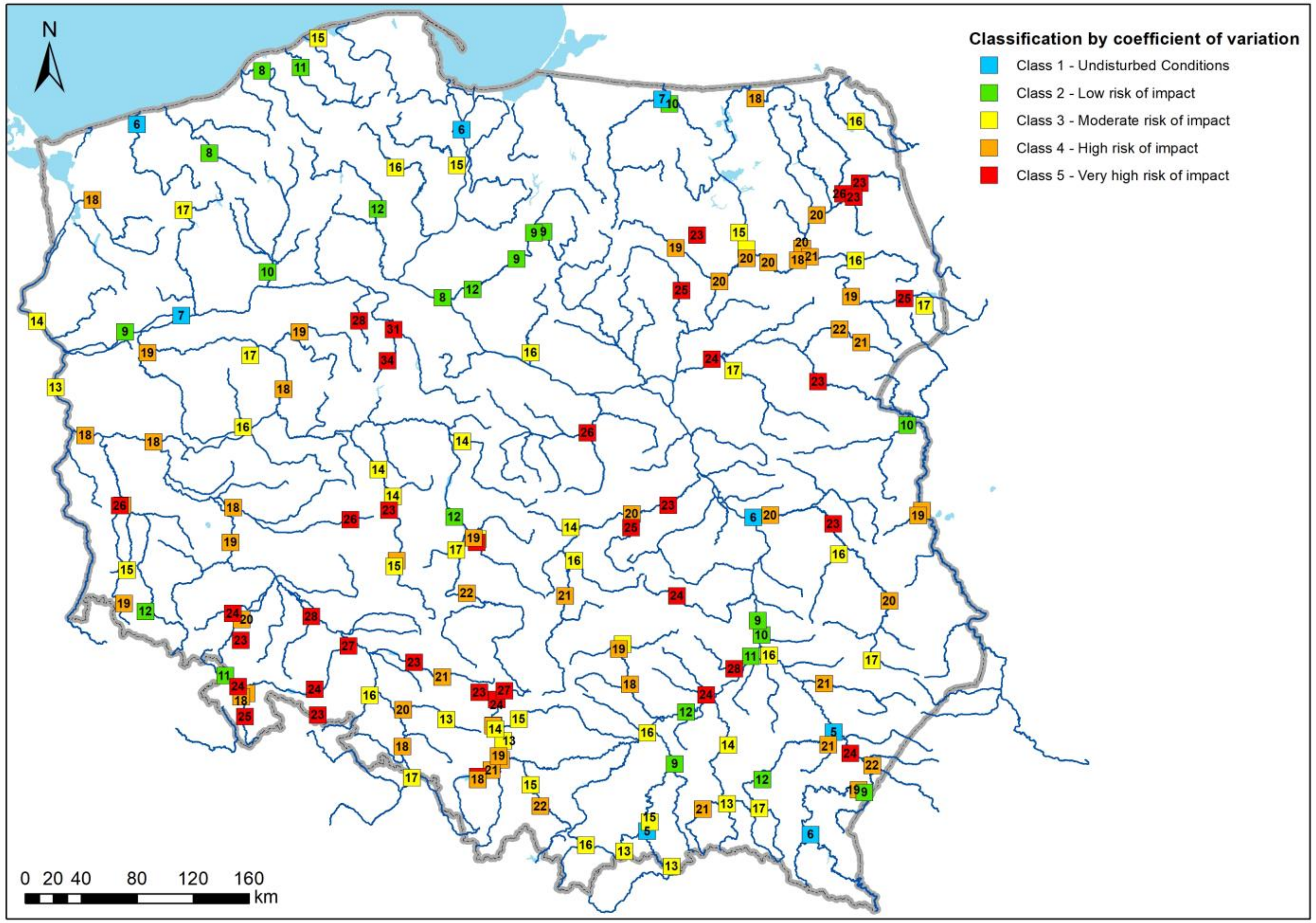
ALTERATION CLASSES

I	Very small
II	Small
III	Moderate
IV	High
V	Very high

Multiple measures → change index → five alteration classes

Historical Hydrological Regime Alteration in Polish Rivers

Spatial distribution of alteration classes based on long-term observations



Changes in the hydrological regime influence sediment transport and deposition, aquatic and riparian vegetation, channel morphology and bed structure.

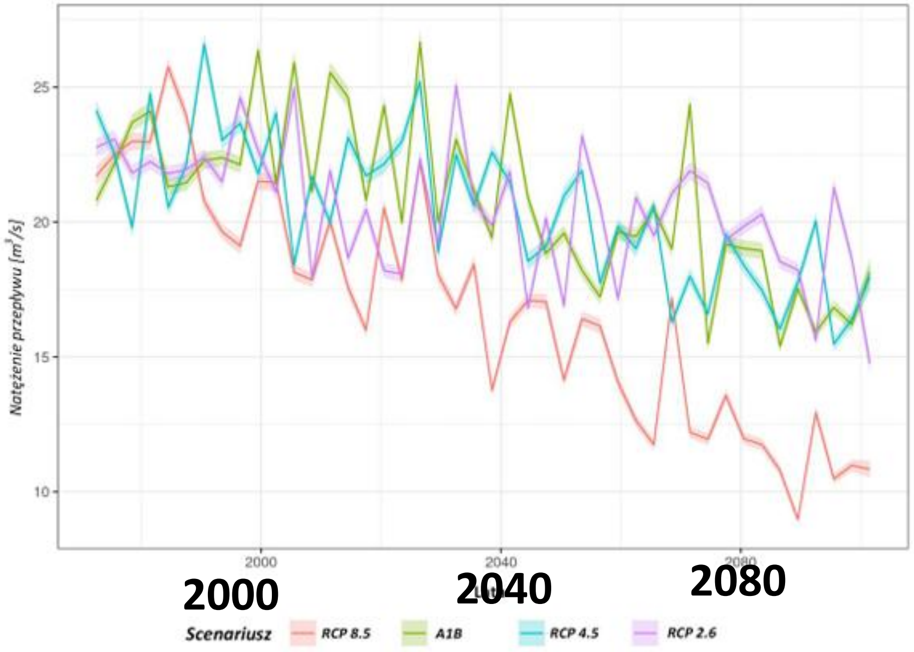
Share of alteration classes

I	5%
II	14%
III	27%
IV	31%
V	23%

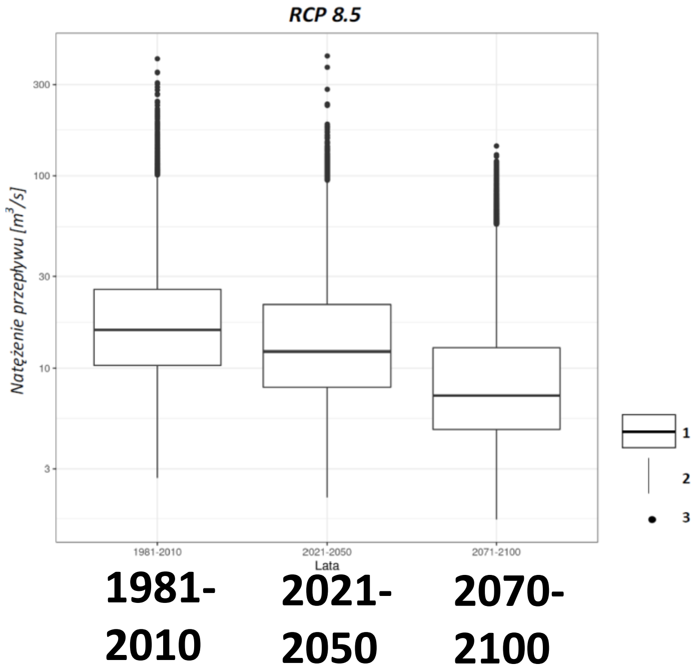
54% High or very high alteration

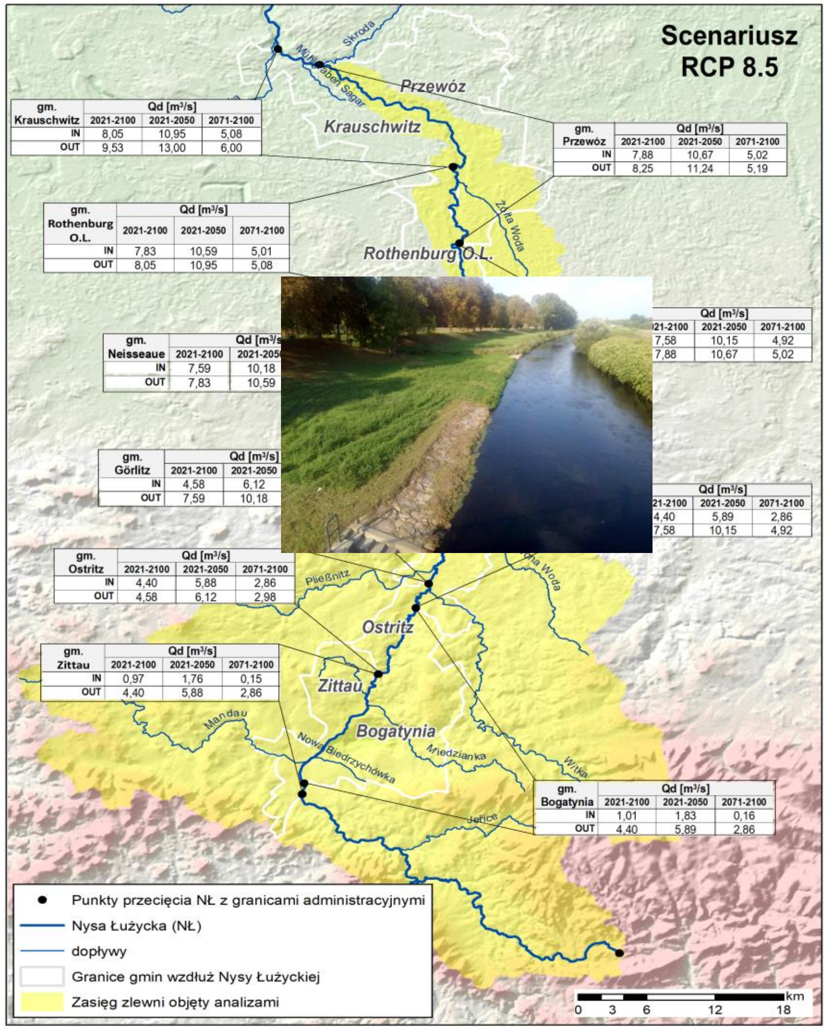
The classification shows where the regime has changed most strongly — it does not identify the cause of change.

Projected discharge on Przewóz under different climate scenarios,



Ranges of projected flow rates for the RCP 8.5 scenario





Rainfall–runoff modeling indicates a long-term decline in river discharge under the analyzed climate scenarios, with increasing pressure on low-flow conditions.

A rainfall–runoff model was developed for the upper Lusatian Neisse catchment to simulate future river discharge under different climate change scenarios..

The simulations indicate a long-term shift towards lower river flows. Under RCP 8.5, the flow distribution progressively shifts towards lower values from the reference period to the end of the century.

Why do low flows matter for hydromorphology?

Low flow can make existing river modifications more important for aquatic life

LOW-FLOW CONDITIONS

Simplified channel

Fewer deep pools, side areas and other places where aquatic organisms can find refuge.

Barriers

Weirs and other barriers become more difficult for organisms to pass when water levels are low.

Less available habitat

A smaller wetted channel means less space and fewer suitable habitats for aquatic organisms.

KEY MESSAGE | Low flows can amplify the effects of existing hydromorphological pressures.

This is why low-flow conditions are particularly relevant when comparing hydrological regime alteration with HIR status.

Hydromorphological Resilience to Low-Flow Conditions

Good hydromorphological condition can support a river's ability to maintain its functions during prolonged low flows

GOOD HYDROMORPHOLOGICAL CONDITION

Channel diversity

Pools • variable depth
natural substrate
morphological refugia

Riparian vegetation

Shade • bank stability
habitat diversity
river-edge protection

Connectivity

Longitudinal continuity
river–floodplain links
movement of organisms

Natural flow regime

Flow variability
functioning river processes
adaptation to low flows

GREATER RESILIENCE DURING PROLONGED LOW FLOWS

Hydromorphological status can therefore indicate river susceptibility when assessing the potential impact of low-flow alteration.

Low-Flow Regime Alteration in Polish Rivers

Assessment based on long-term hydrological observations at gauging stations

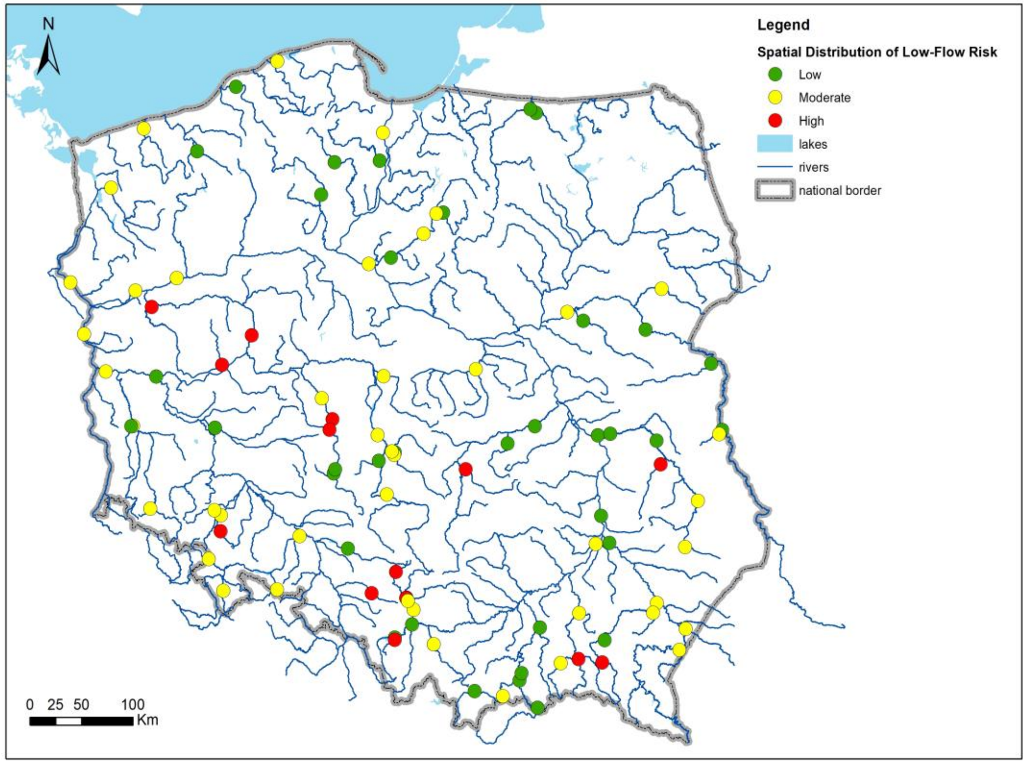
Fot. River Neisse

Low-flow conditions reduce the wetted channel area and may amplify the effects of existing hydromorphological pressures.

Degree of low-flow alteration

SMALL	38%
MODERATE	46%
HIGH	16%

Examples of gauging station assessment



K **CONSEQUENCE**
Change in NNQ
(minimum-flow conditions)

×

P **PROBABILITY OF IMPACT**
Hydromorphological status
of the river reach

=

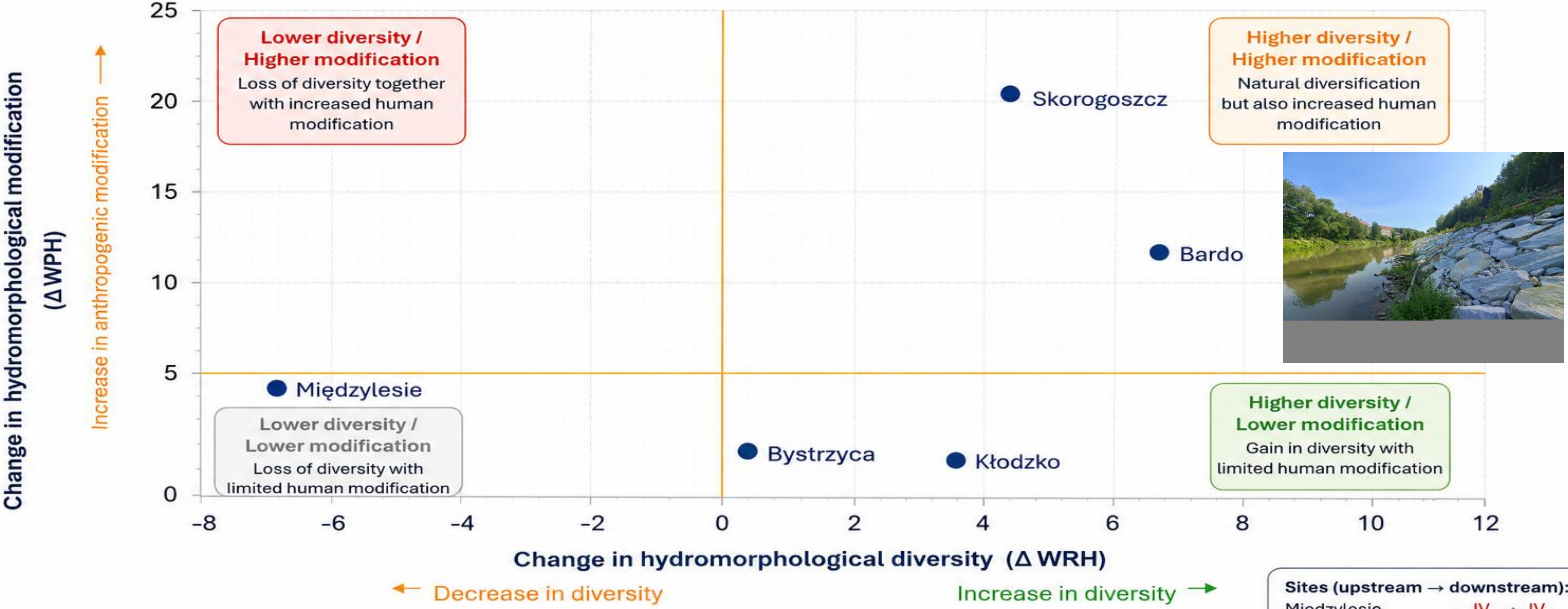
R **RISK**
R = K × P
Low • Moderate • High

$WZ_{NNQ} = 1 – [NNQ (1981\text{-}2020) / NNQ (1951\text{-}1980)]$,

KEY RESULT | 62% of analyzed stations show moderate or high risk related to low-flow regime alteration.

Hydromorphological Response to the 2024 Flood and Post-Flood Interventions

Changes in component indicators (before–after flood)



Sites (upstream → downstream):

Międzylesie	–	IV → IV
Bystrzyca Kłodzka	–	III → III
Kłodzko	–	IV → IV
Bardo	–	III → III
Skorogoszcz	–	III → III

(No change in hydromorphological status class at any site)

Key message: The hydromorphological status class did not change after the 2024 flood, but the component indicators reveal substantial changes within the river system.

A stable hydromorphological status class does not necessarily mean a stable hydromorphological system.

WRH – hydromorphological diversity | WPH – hydromorphological modification | HIR – hydromorphological index for rivers

From Diagnosis to Hydromorphological Resilience

Understanding river resilience requires spatial, temporal and climate information

HYDROMORPHOLOGICAL STATUS

What is the condition of the river?

HIR • WRH • WPH
morphology • connectivity • modifications

HYDROLOGICAL REGIME

How does the river function over time?

long-term H & Q
low flows • high flows • variability

CLIMATE CHANGE

How may conditions change?

precipitation • temperature
drought • extremes • future flows

HYDROMORPHOLOGICAL RESILIENCE

Can the river maintain its functions under changing hydrological conditions?

CATCHMENT-SCALE PERSPECTIVE

Runoff • retention • land use • water use • upstream pressures

A river is supplied by its catchment — resilience cannot be understood from local river-reach assessment alone.

Hydromorphological processes must be considered at the catchment scale

Hydrological observations provide the temporal dimension needed to interpret hydromorphological change.

What acts on the catchment?

Processes are generated by the water cycle and modified by landscape storage.

Water cycle
precipitation, evaporation, runoff

Retention
soil, valley and landscape storage

Response time
slowing and desynchronising runoff

CLIMATE FORCING
precipitation • temperature • evapotranspiration

CATCHMENT PROCESSES
runoff generation • retention • groundwater exchange

RIVER NETWORK RESPONSE
hydrological regime + morphological response

LONG-TERM MONITORING
gauging stations and hydrological time series

Why monitoring matters

The gauging station records an integrated signal from the upstream catchment.

At the outlet
flow integrates upstream processes

Over time
long records reveal temporal change

With indicators
magnitude, timing, duration, frequency

KEY POINT

Field hydromorphological assessment gives the spatial picture; long-term hydrological monitoring adds the temporal context.
Together they help interpret whether changes reflect local pressures, upstream catchment effects, climate variability or their combined influence.

Nature-Based Solutions for Hydromorphological Improvement

Restoring processes, increasing catchment retention and improving river–floodplain connectivity

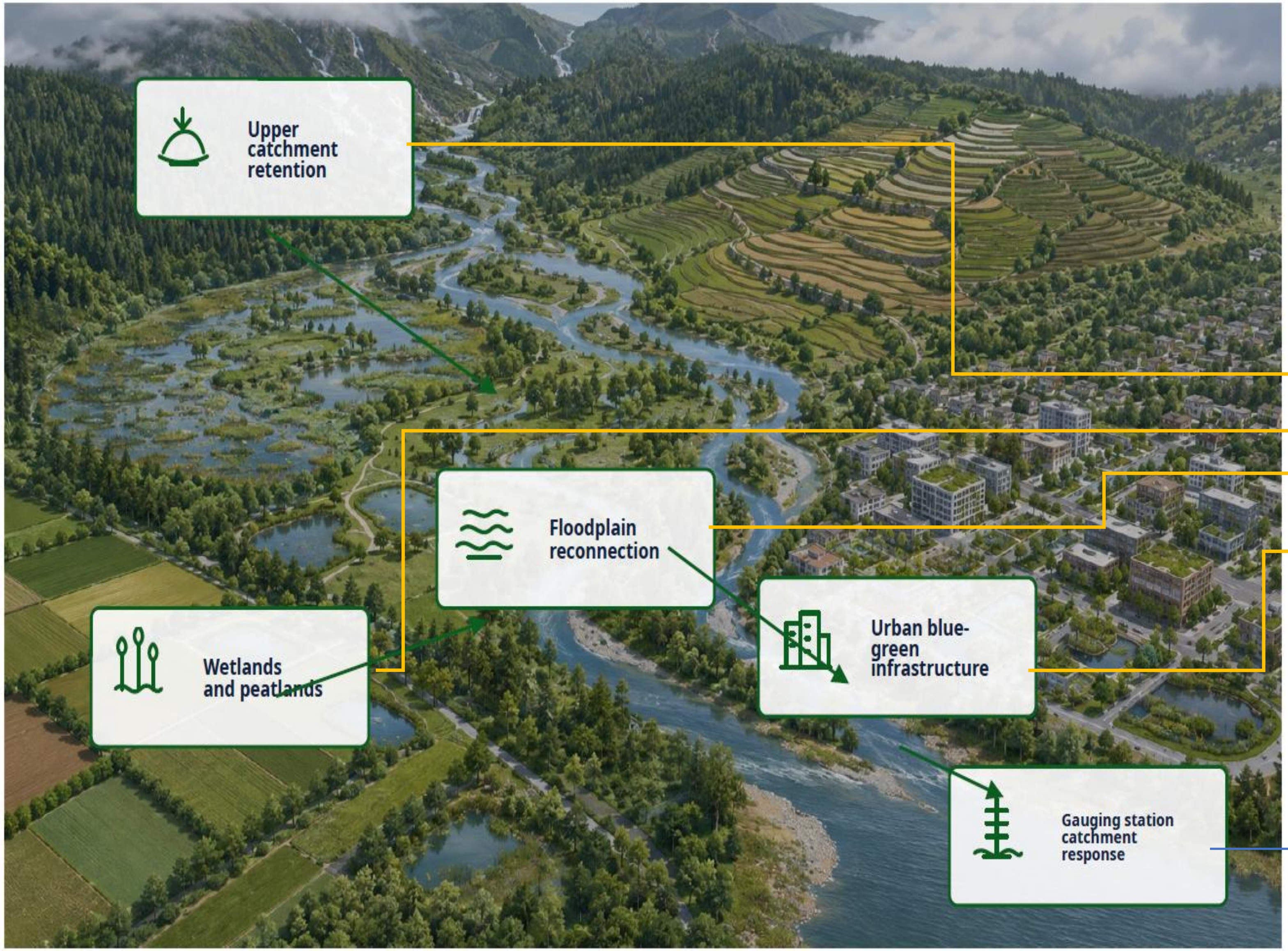
NbS should be selected according to the process that needs to be restored.

NbS measure	Hydrological function	Hydromorphological function
River restoration / re-meandering	slows flow; increases local retention	restores channel complexity and more natural river form
Floodplain reconnection	increases temporary water storage	restores lateral connectivity and floodplain processes
Wetland and peatland restoration	stores water; supports low-flow resilience	improves groundwater–surface water interaction
Small-scale retention	delays and attenuates runoff peaks	supports more stable flow conditions
Riparian vegetation restoration	reduces rapid surface runoff	stabilises banks, shades water, increases habitat diversity
Urban blue–green infrastructure	increases infiltration; delays runoff	supports more diverse urban watercourses

KEY POINT

The objective is not simply to retain water, but to slow and desynchronise runoff and restore natural hydrological and morphological processes at the catchment scale.

Nature-Based Solutions at the Catchment Scale.



Different NBS act locally, but their combined effects contribute to the catchment's overall response.

CUMULATIVE CATCHMENT RESPONSE

More distributed retention

Slower runoff

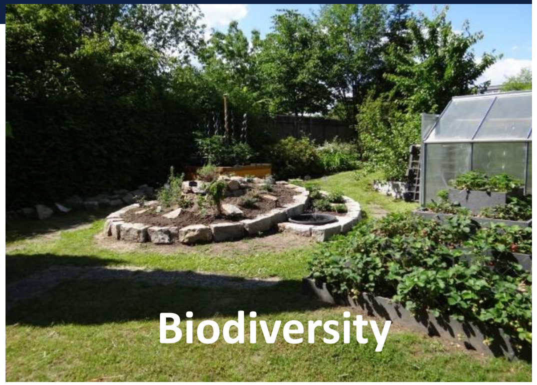
Improved connectivity

Greater river resilience

GAUGING STATION
Monitoring the integrated response

Projects Experience - NBS
Pilot Actions in the Polish–Saxon Border Region

Fot. www. WIKT, TRANSGEA



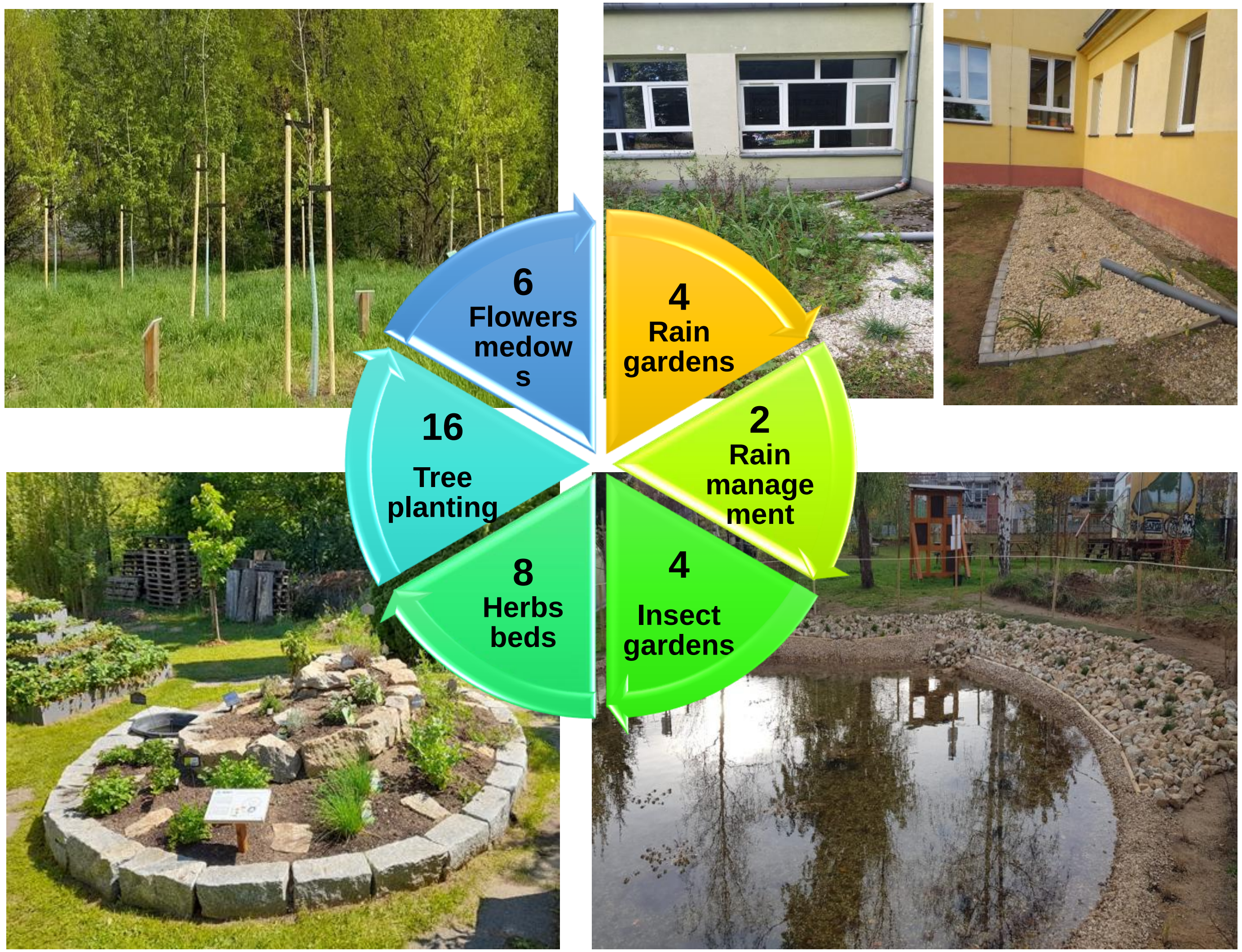
Numerous low-cost adoptions have been realised in the area presented. Including: tree planting, rain gardens, insect- and bird-friendly gardens, perennial and herbaceous beds, rainwater management, flower meadows, educational paths, climate stations and rain gauges.

Projects Experience - NBS
Hard (technical) NBS measures in the Polish–Saxon Border Region

Examples of Hard (technical) low-cost NBS measures – based on physical interventions in ecosystems:

Tree planting:
- Increase soil water retention
- Shade the soil and reduce evaporation
- Cool adjacent areas
- Increase atmospheric humidity

Perennial herb beds:
- They retain water locally
- Improve the microclimate
- Increase humidity
- These are drought-resistant plants



Rain gardens:
- Collect water
- Slow down runoff
- Store water for dry periods
- Support small-scale retention

Water biotopes:
- Retain water in the landscape
- Support groundwater replenishment
- Increase resistance to lack of rainfall
- Regulate natural hydrological processes

To monitor the local climate, eight meteorological stations and 20 rain gauges have also been installed.

Key Conclusions

From assessment to catchment-scale resilience

1 ASSESS TOGETHER

Hydromorphology and hydrology must be assessed together.

River morphology alone does not explain river-system change. Long-term hydrological monitoring adds the temporal context.

2 RIVERS ARE CHANGING

Long-term observations show substantial hydrological regime alteration.

Climate projections indicate that hydrological conditions may continue to change in the future.

3 THINK AT CATCHMENT SCALE

River resilience depends on both local condition and catchment processes.

Runoff, retention, connectivity and upstream pressures shape the response observed in the river.

4 BUILD RESILIENCE WITH NBS

NBS should form a coordinated catchment-scale system.

Different measures act locally, but their combined effects can support retention, connectivity and river resilience.

MONITOR → UNDERSTAND → RESTORE PROCESSES → BUILD RESILIENCE

The key is to move from monitoring change to understanding processes — and from understanding processes to building river resilience.

Lets Colaborate

Let’s Collaborate – Water4All 2026

Joint Transnational Call: Sustainable Water Management

TOPIC 1
5th Joint Transnational Call – 2026

Integrated Monitoring and Assessment for Sustainable Water Management

TOPIC 2
6th Joint Transnational Call – 2027

Nature-Based Approaches for Resilient Water Management at hydrological and hydrogeological system scale

Our potential contribution

Hydromorphological monitoring • Hydrological regime alteration • Catchment-scale assessment • Nature-Based Solutions

Interested in building a consortium? Let’s talk.

Call 5 opens: 8 September 2026 • Pre-proposal deadline: 10 November 202
Call 6 open: 7 September 2027 •

Thank you

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