XLII INTERNATIONAL SCHOOL OF HYDRAULICS

Freshwater system health: a hydraulic perspective

Modelling impacts of sediment transport and climate change on flood hazard zones

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IAHR AIRH International Association for Hydro-Environment Engineering and Research

May 20-23, 2025 RADOCZA / near Cracow, POLAND

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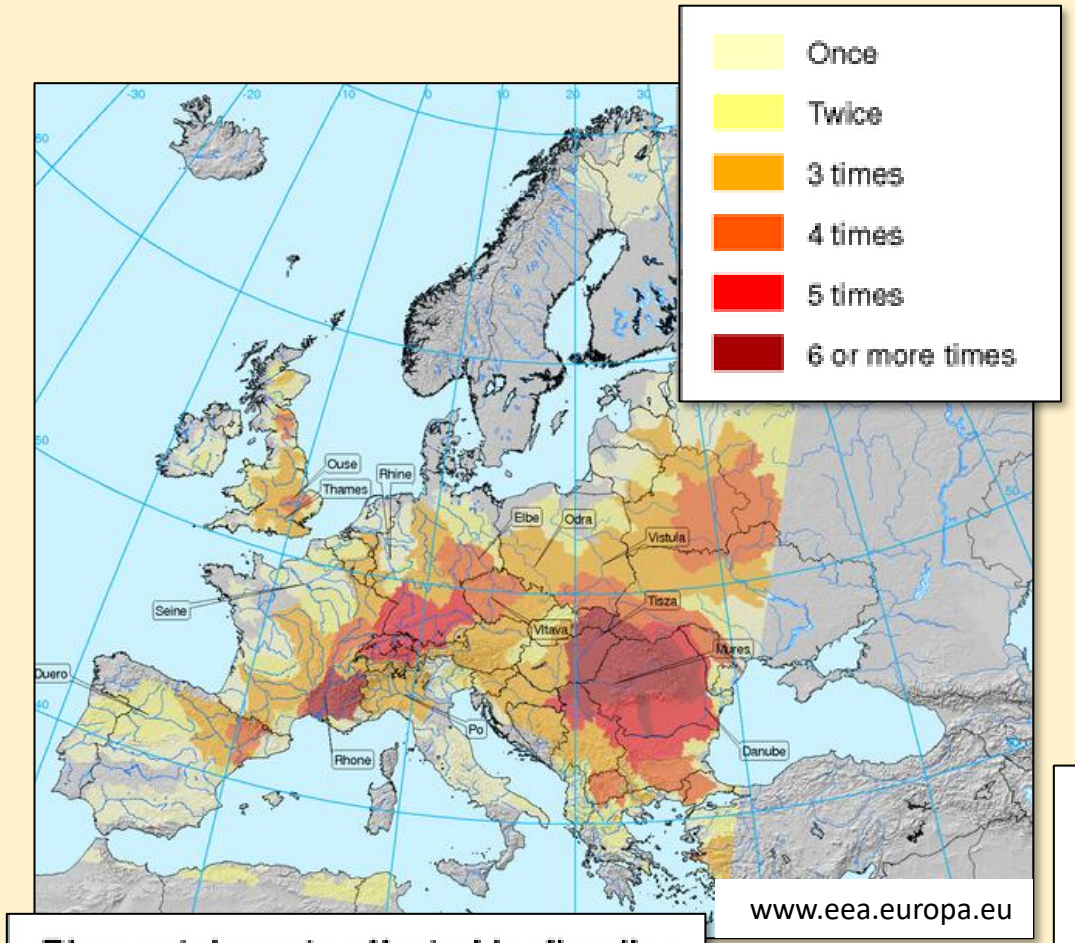
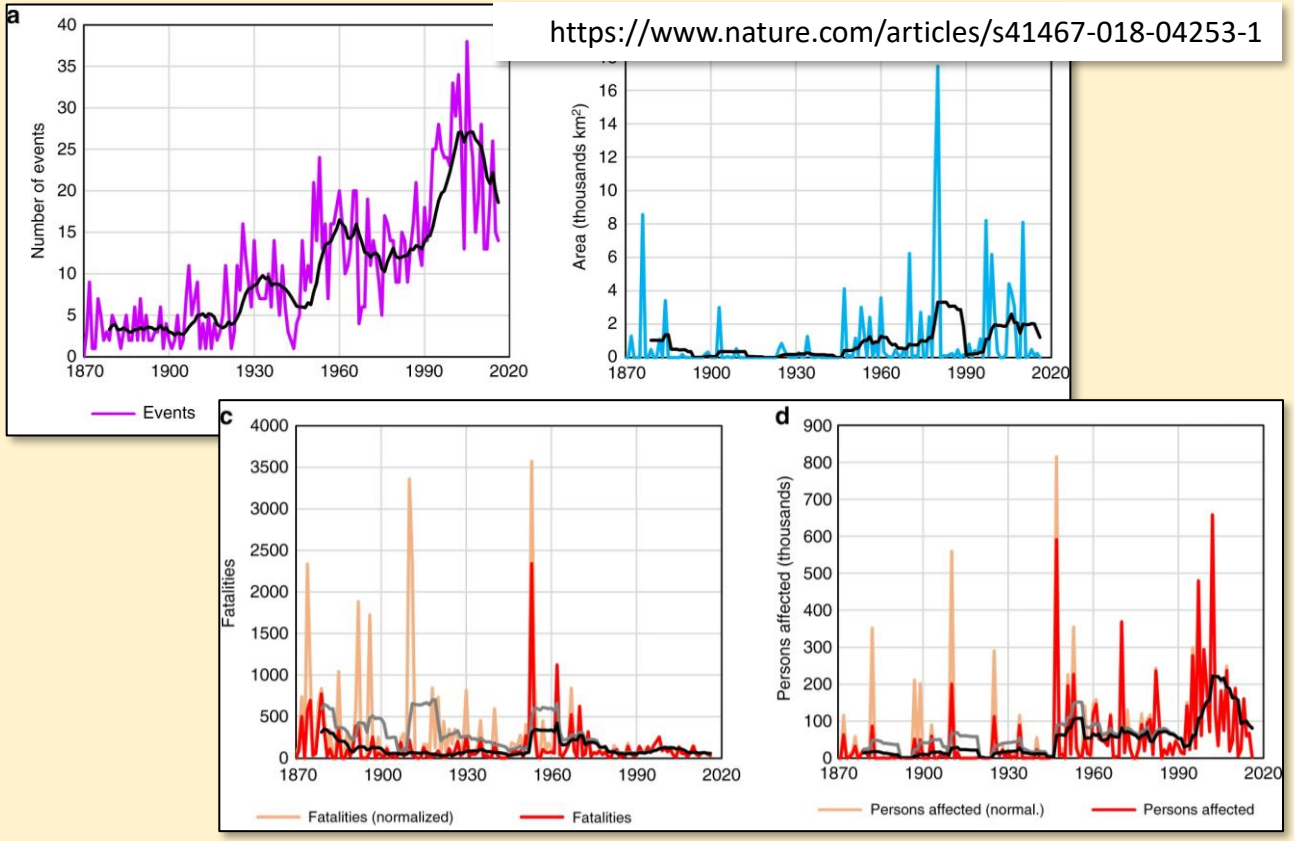
Introduction

Flood losses in Europe



River catchments affected by flooding (1998-2005)

https://www.nature.com/articles/s41467-018-04253-1



6.11.2007 EN Official Journal of the European Union L 288/27

DIRECTIVE 2007/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 23 October 2007

on the assessment and management of flood risks

Flood hazard maps in Poland

Historical perspective

FLOOD 1997

- one of the most severe floods in the southern part of Poland

FLOOD 2001

- series of smaller floods in different parts of the country

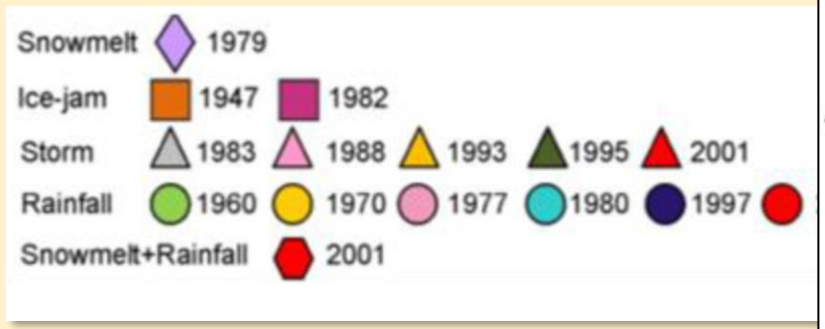
FLOOD 2010

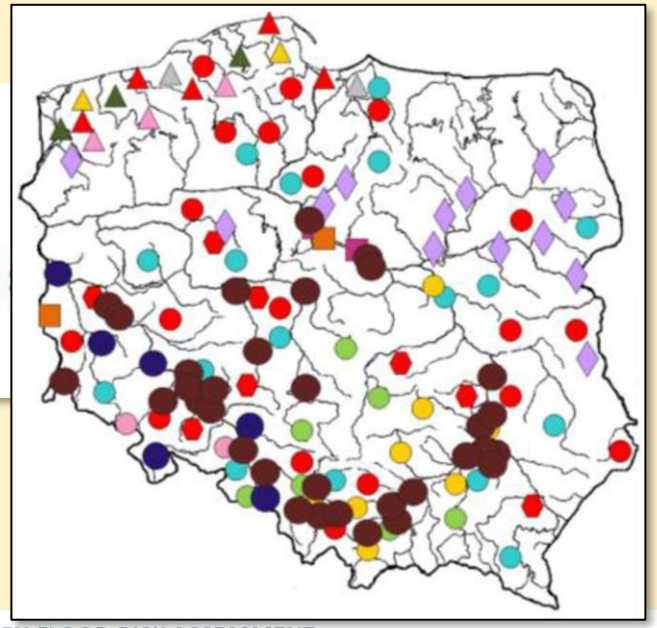
- repetition of 1997, but the magnitude was smaller

FLOOD 2024

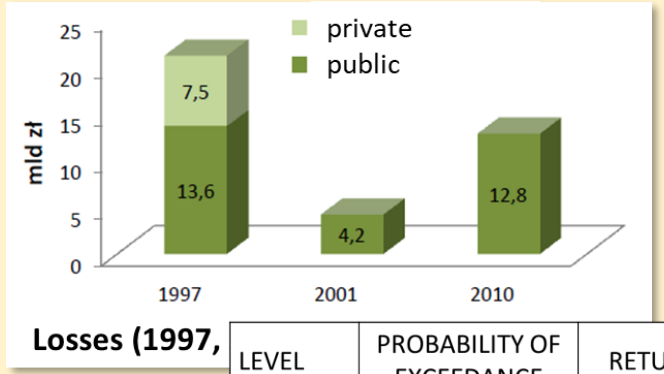
- smaller, but unexpected impacts in the south-western part of Poland

Kundzewicz et al., 2023, Water



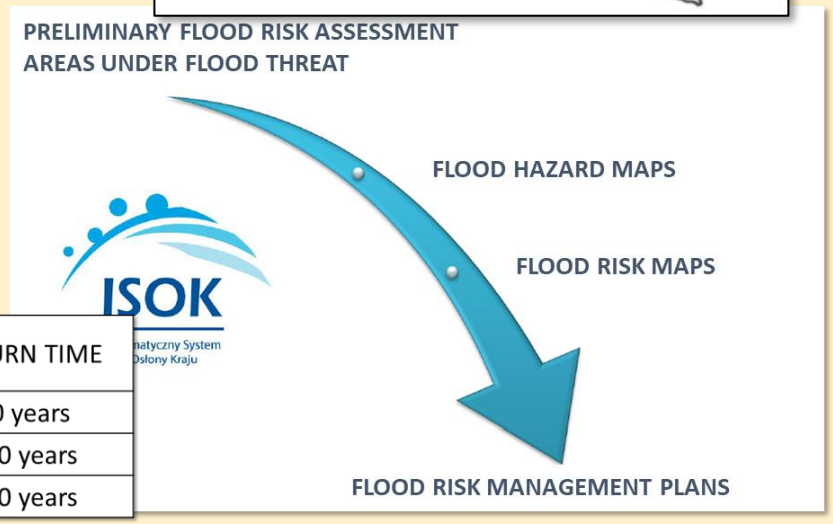


Monika Ciak-Ozimek, ***Scope of report on FHM and FRM resulting from EU Flood Directive and Water Law,*** National Board for Water Management



Losses (1997,

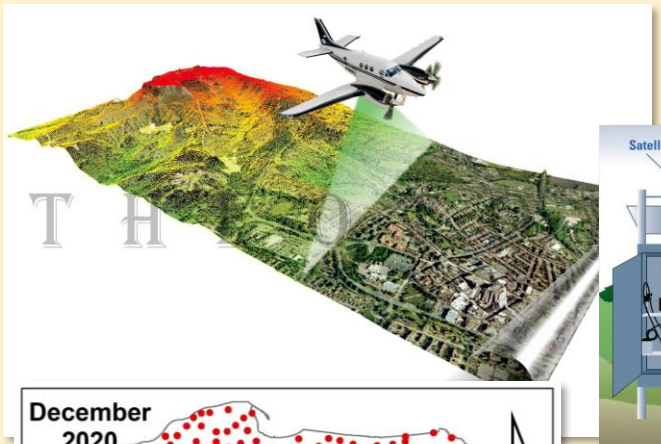
LEVEL	PROBABILITY OF EXCEEDANCE	RETURN TIME
high	10%	10 years
moderate	1%	100 years
low	0.2%	500 years

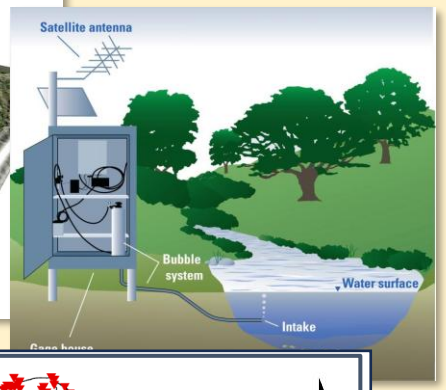


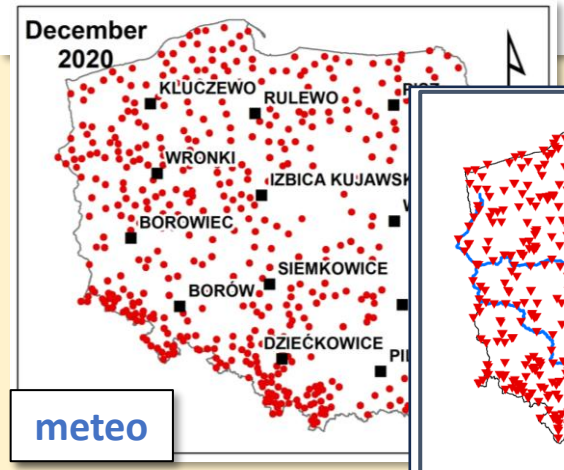
Flood hazard maps in Poland

Results and by-products

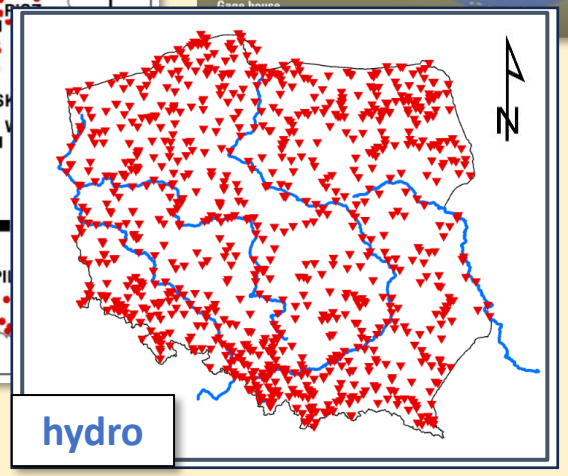
Data collection …





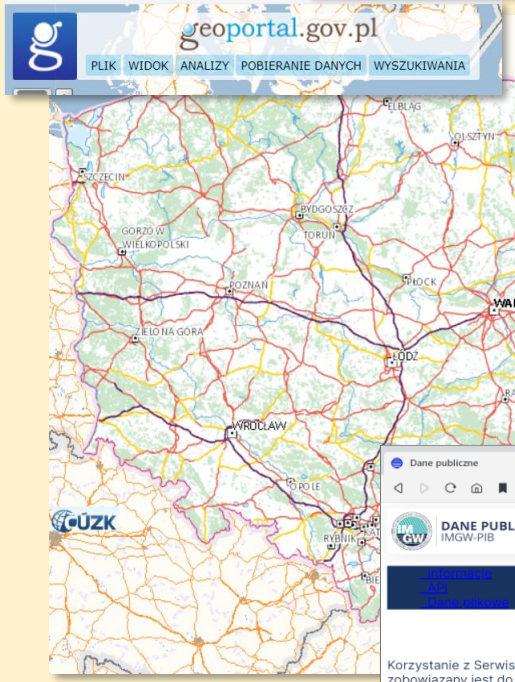


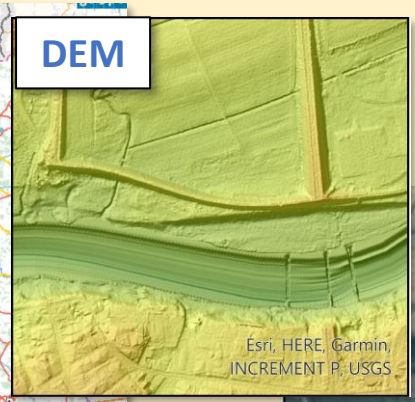
meteo



hydro

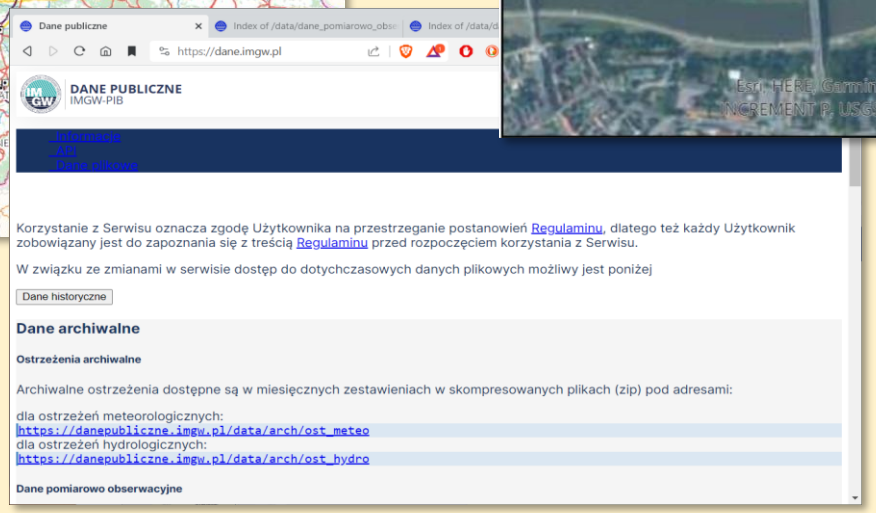
Public access to the data





DEM

orto



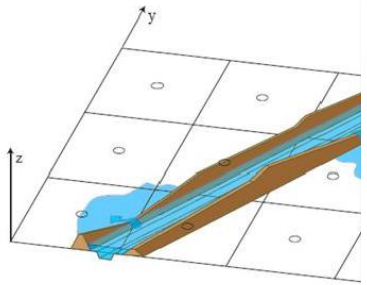
Flood hazard maps in Poland

Results and by-products

Hydrodynamic modeling

MZP Z GŁĘBOKOŚCIĄ WODY

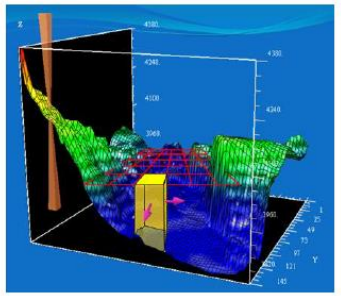
MODELOWANIE JEDNOWYMIAROWE (1D)



MZP Z PRĘDKOŚCIĄ WODY

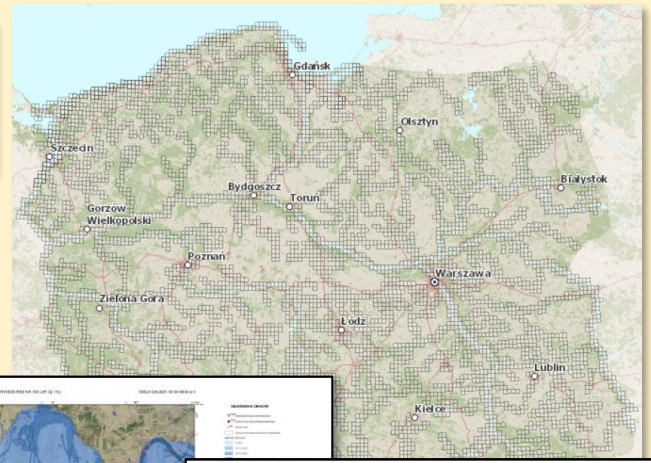
MODELOWANIE HYBRYDOWE (1D/2D)

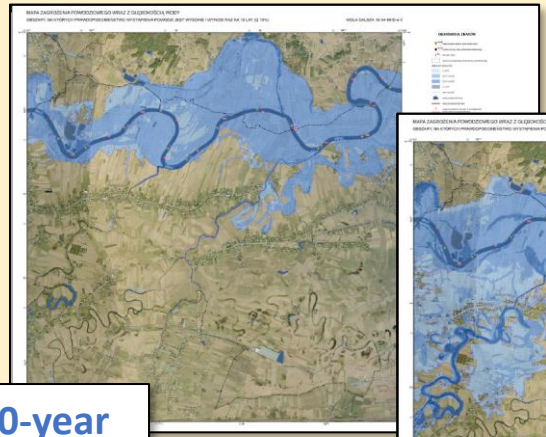
- MODEL 1D W KORYCIE RZEKI, MODEL 2D DLA TERENYÓW ZALEWOWYCH
- MIASTA NA PRAWACH POWIATU, WOJEWÓDZKIE, LICZBA MIESZK. > 100 000



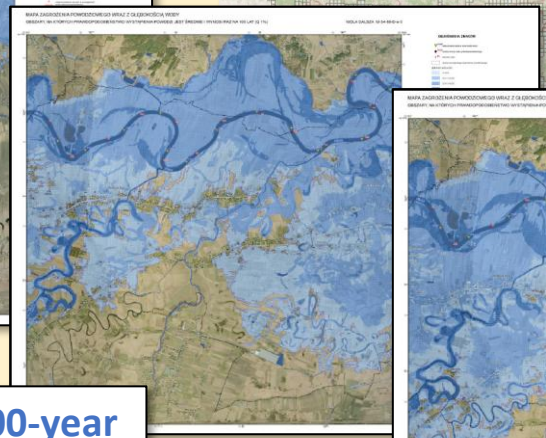
Hydroportal

ISOK Informatyczny System Osłony Kraju

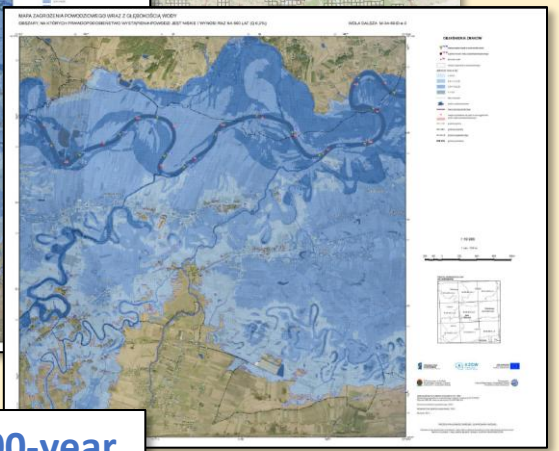




10-year



100-year



500-year

Monika Ciak-Ozimek, KZGW, 2016

Flood hazard maps in Poland

Uncertainty: data quality vs. non-stationarity

DATA QUALITY

- DEM resolution
- roughness determination
- maximum flows

…

- type of modeling applied

…

- type of flood

NON-STATIONARITY

- land cover/use
  - → *artificial land use alternations*
  - → *vegetation growth*
- climate change
- sediment transport
  - → *short-term*
  - → *long-term*

Uncertainty related to non-stationarity

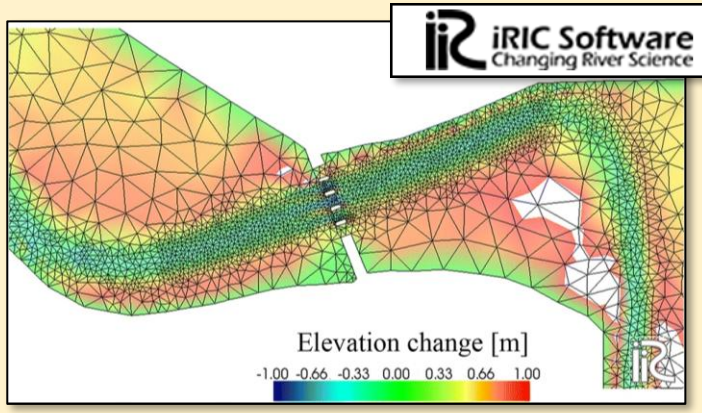
Short-term sediment transport

Examples of studies

2019 Nones, *Acta Geophysica*

2024 Sanz-Ramos et al., Water

…



shallow water model

+ sediment routing

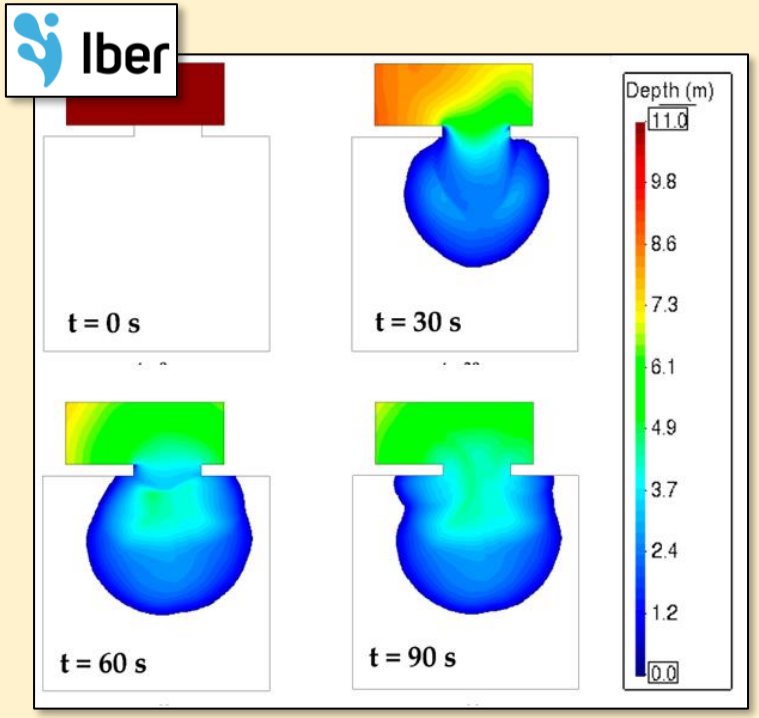
shallow water model

+ sediment routing

+ rheological model

$$S_f = \frac{1}{\rho g h}\left(\frac{3}{2}\tau_y + 3\frac{\mu_B v}{h}\right)$$

$$S_f = \mu + \frac{v^2}{\xi h}$$



MAIN IDEAS:

- run the sediment transport model with flood routing model
- run the rheological model of sediment and water mixture

Uncertainty related to non-stationarity

Long-term sediment transport

Available publications

1995 Sear et al., *Earth Surface Processes and Landforms*

2007 Lane et al., *Earth Surface Processes and Landforms*

2008 Lane et al., *Geomorphology*

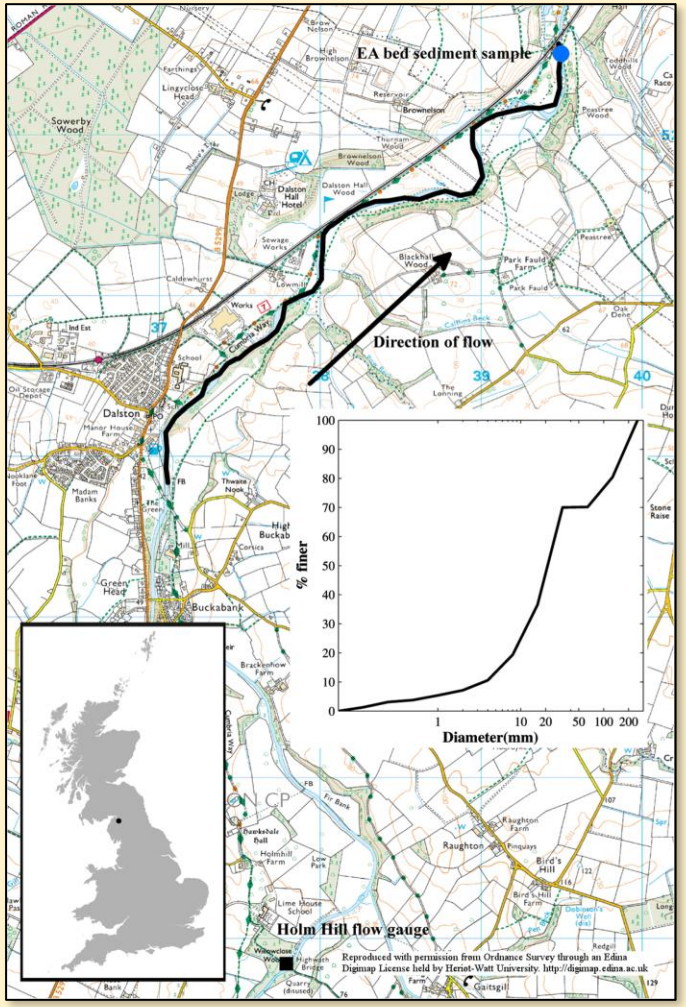
2009 Neuhold et al., *Natural Hazards and Earth System Sciences*

2011 Neuhold et al., *IntechOpen*

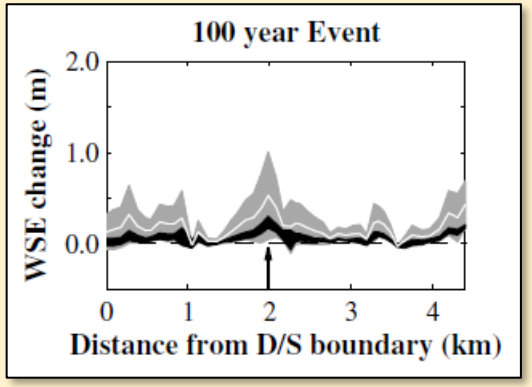
2013 Radice et al., *Journal of Flood Risk Management*

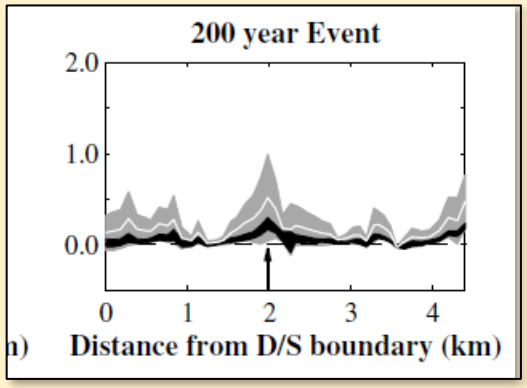
2016 Radice et al., *Water*

2016 Pender et al., *Journal of Hydraulic Engineering*



Pender et al., 2016





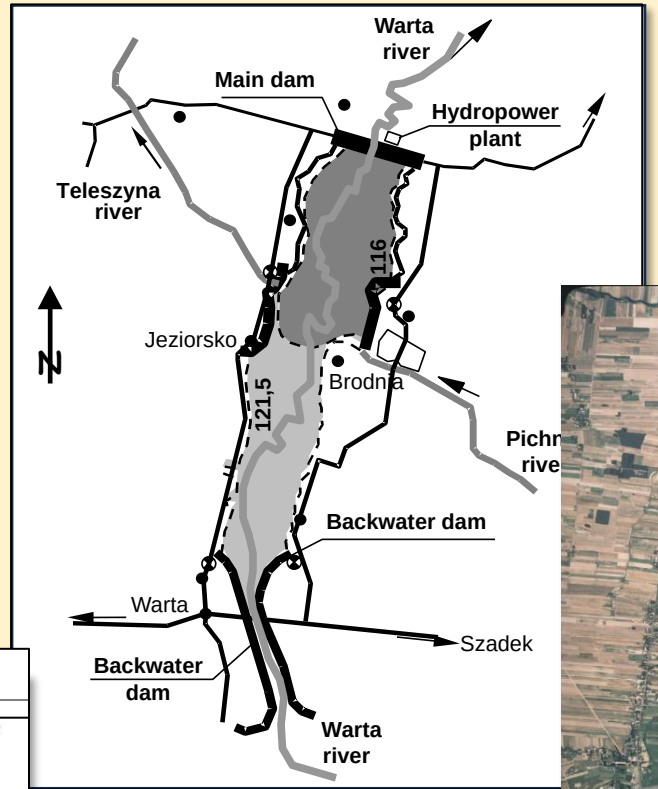
Uncertainty related to non-stationarity

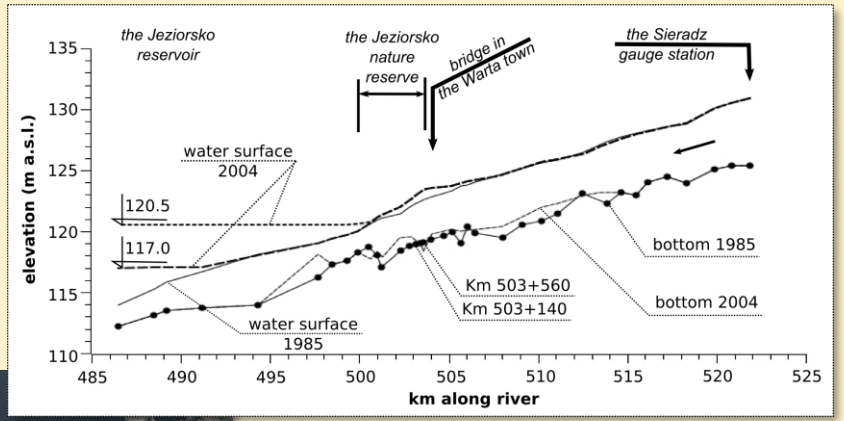
Long-term sediment transport

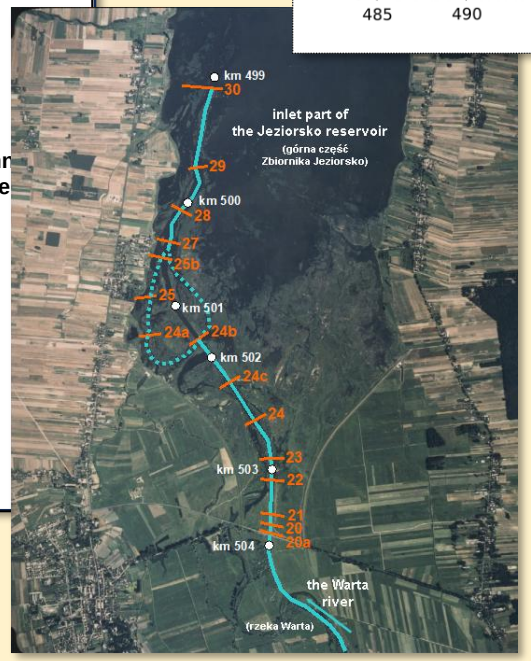
Jeziorsko Reservoir

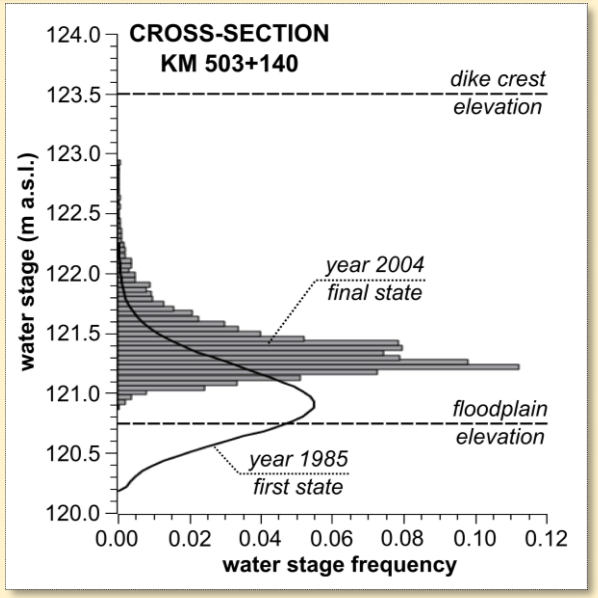
- *morphodynamic changes on the basis of*

  design of the reservoir: 1985, field measurements: 1997, 2004
- *measurements of vegetation and estimation of roughness changes*
- *modeling with HEC-RAS 3.x (no GIS tools involved)*









Pol. J. Environ. Stud. Vol. 20, No. 6 (2011), 1441-1451

Original Research

Application of Hydrodynamic Simulation and Frequency Analysis for Assessment of Sediment Deposition and Vegetation Impacts on Floodplain Inundation

Tomasz Dysarz*, Joanna Wicher-Dysarz 2011

Uncertainty related to non-stationarity

Long-term sediment transport

Changes in WSE in Ner River

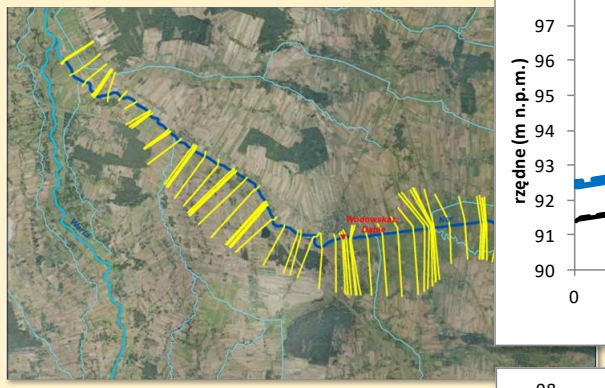
- *data:*

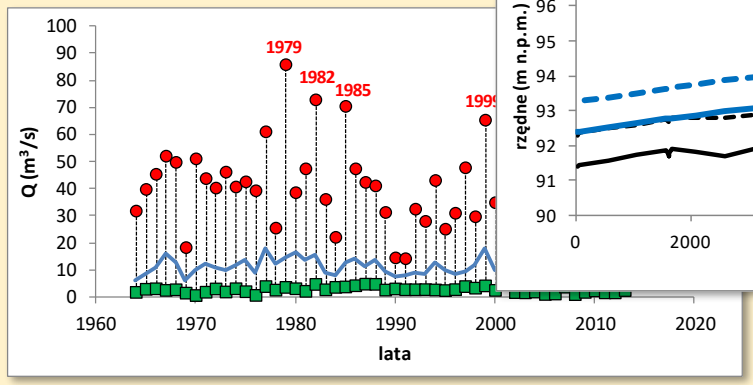
  hydrology
  DTM + cross-sections, sediment samples
- *tested formula*

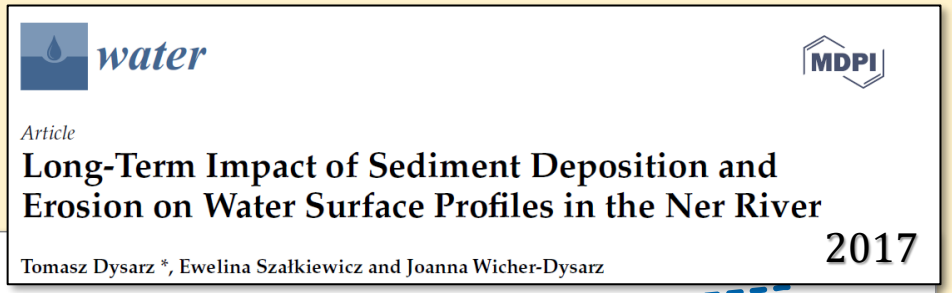
  MPM, Engelund-Hansen
- *hydrographs 20 x 10 years*
- *discrepancy of results*

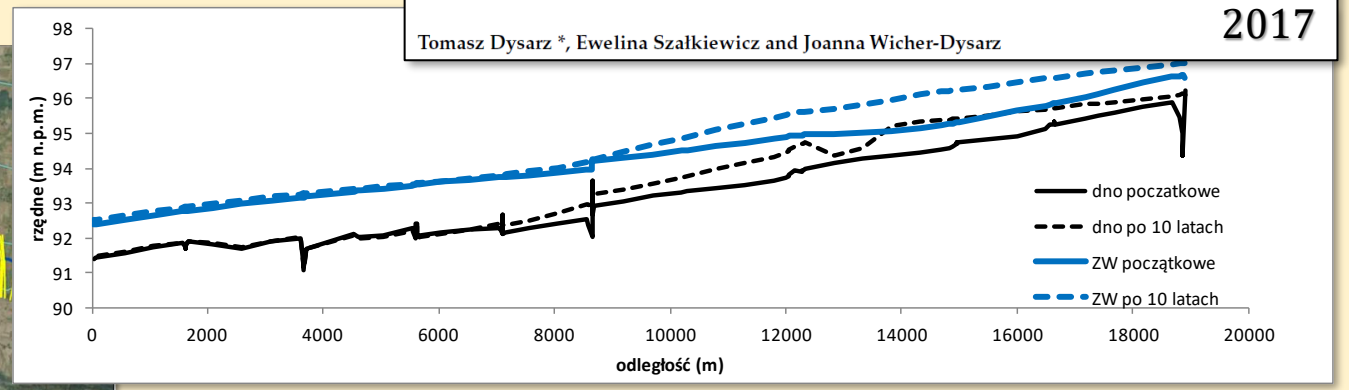
Challenges …

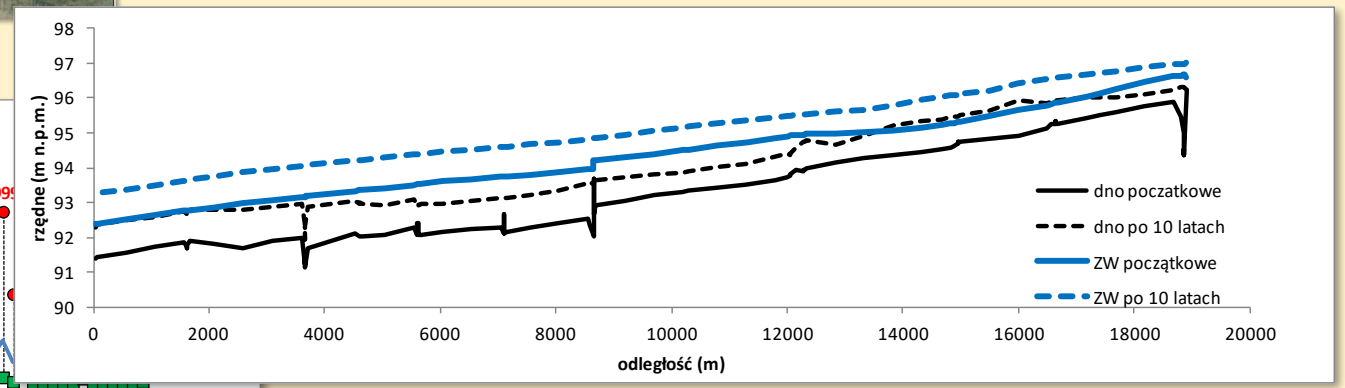
- *great number of scenarios*
- *integrations with GIS*
- *reconstruction of channel bed*






water
MDPI
Article
Long-Term Impact of Sediment Deposition and Erosion on Water Surface Profiles in the Ner River
2017
Tomasz Dysarz *, Ewelina Szałkiewicz and Joanna Wicher-Dysarz

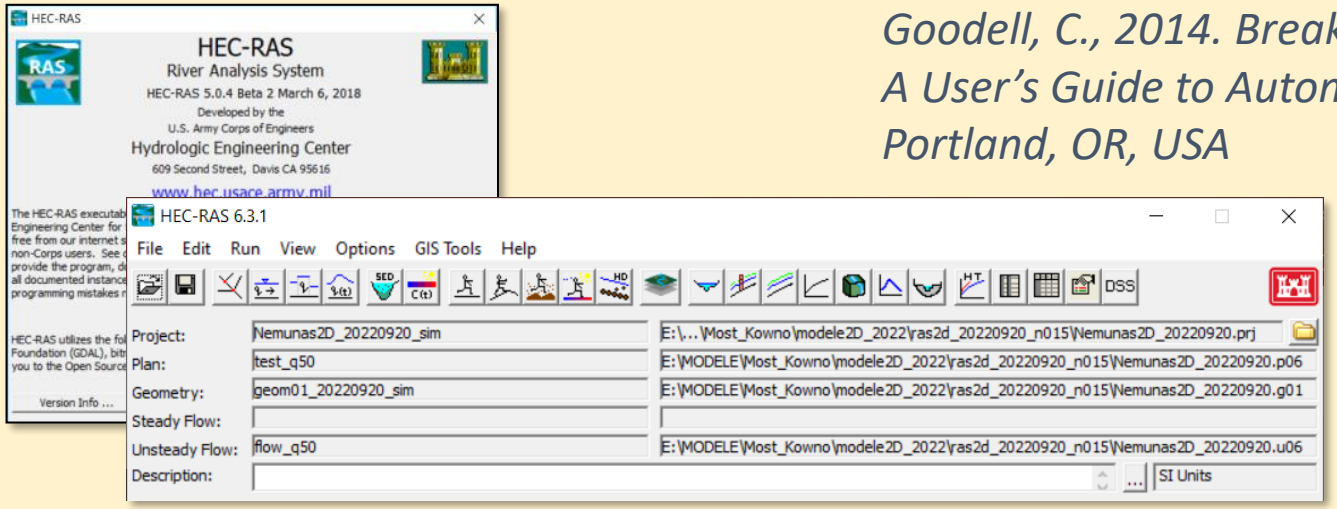




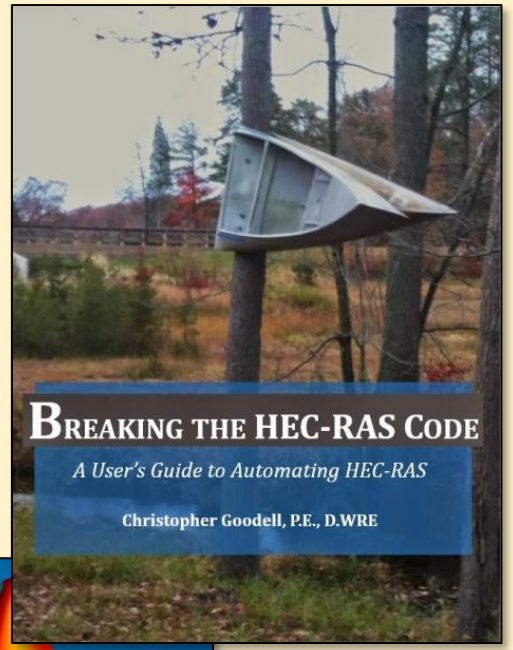
Dysarz, Szałkiewicz & Wicher-Dysarz, XXXV OSH, 2016
Wicher-Dysarz & Dysarz, XXXIII OSH, 2014

Simulation requirements

Automation of simulation process



Goodell, C., 2014. Breaking the HEC-RAS code. A User's Guide to Automating HEC-RAS, h2ls: Portland, OR, USA

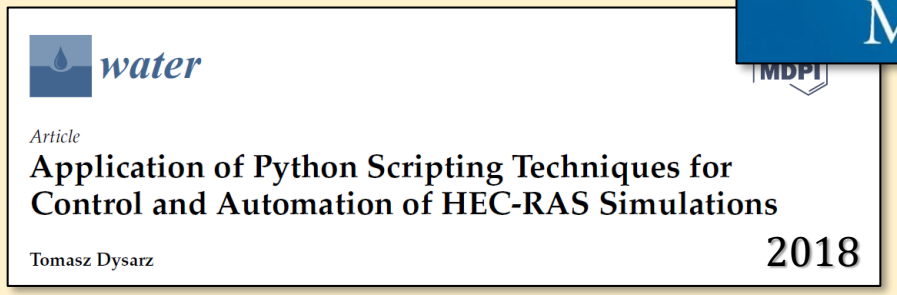


RAS Controller → Python

- *independent scripts*
- *integration with modules of Python*
- *integration with GIS (ArcGIS, QGIS)*
- *processing of formats HDF, XML, XLS(X)*

Microsoft VBA

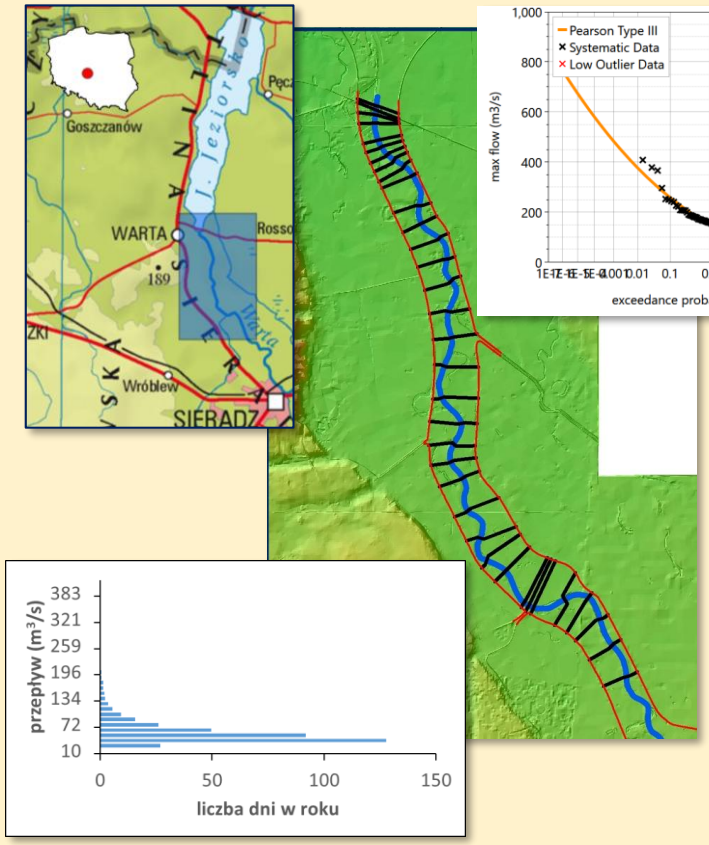
MATLAB



Simulation requirements

Automation of simulation process

Study object



Dysarz, XXXVII OSH, 2018

Types of tests

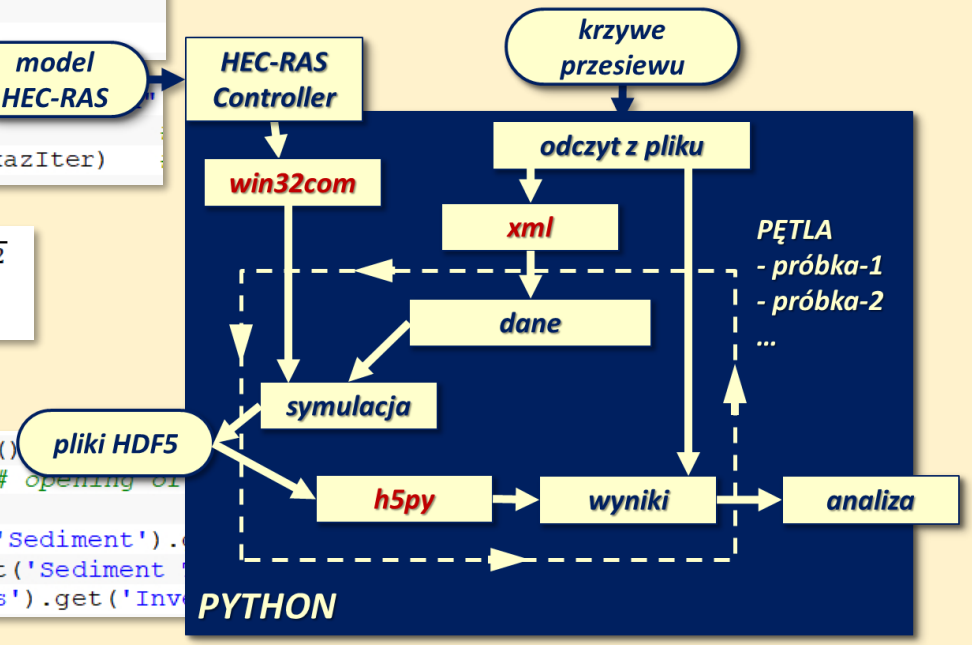
- *water surface profiles*
  - *model calibration*
  - *sediment transport*

water
MDPI
Article
Application of Python Scripting Techniques for Control and Automation of HEC-RAS Simulations
Tomasz Dysarz
2018


```
1.  import win32com.client, os, math
2.  import numpy as np
3.  from scipy import optimize as opt
55. print "\nIteration process: Nelder-M
56. x0 = np.array([0.08,0.014,0.08])
57. Xopt = opt.fmin(ObjFun,x0,callback=PokazIter)
```

$$F(x) = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(WSE_i^{(c)} - WSE_i^{(o)}\right)^2}$$

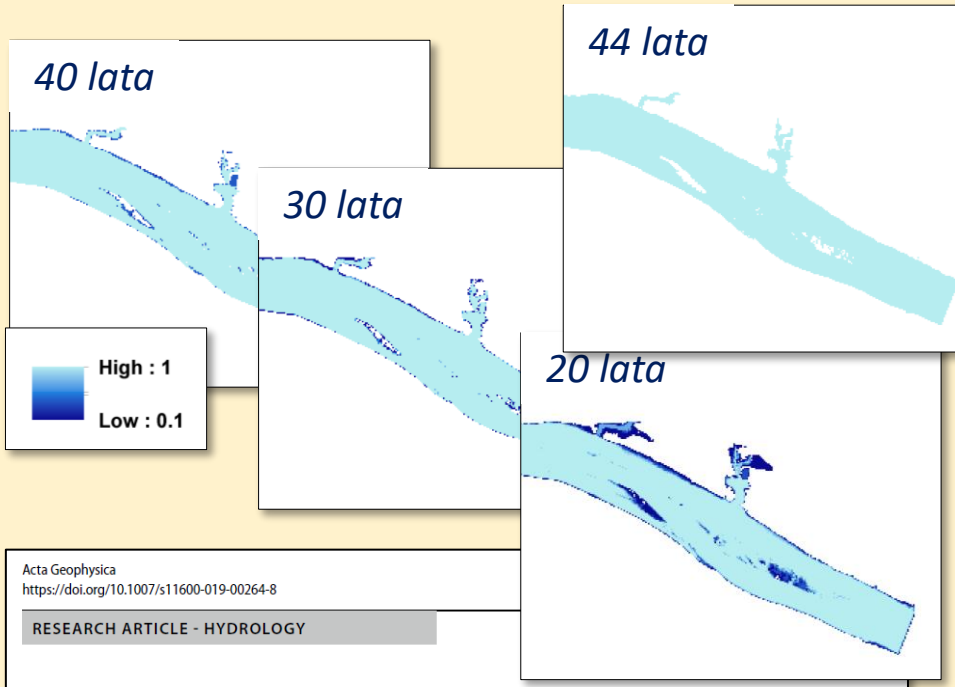
```
44.     hdfname = os.path.join(os.getcwd()
45.     dane = h5py.File(hdfname,'r')    # opening of
46.     # accessing bed elevations
47.     XSbed = dane.get('Results').get('Sediment').
48.     XSbed = XSbed.get('Sediment').get('Sediment
49.     XSbed = XSbed.get('Cross Sections').get('Inv
```



Simulation requirements

GIS integration and map generation

Uncertainty of maximum flows



Acta Geophysica
https://doi.org/10.1007/s11600-019-00264-8

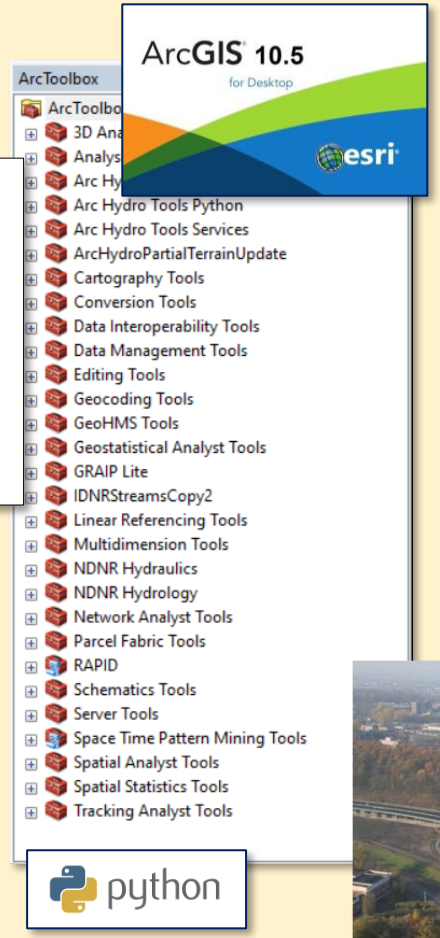
RESEARCH ARTICLE - HYDROLOGY

Analysis of extreme flow uncertainty impact on size of flood hazard zones for the Wronki gauge station in the Warta river

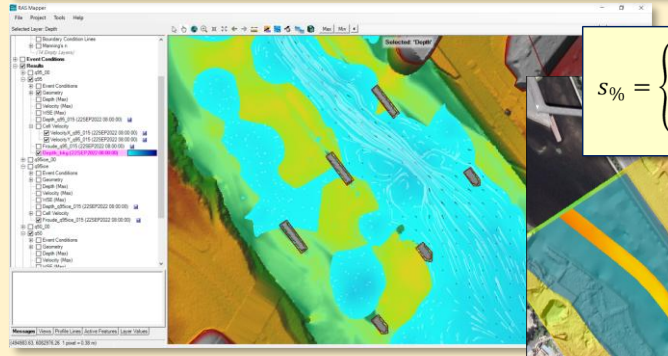
Tomasz Dysarz[1] · Joanna Wicher-Dysarz[1] · Mariusz Sojka[2] · Joanna Jaskuła[2]

2019

Wicher-Dysarz et al., XXXVII OSH, 2018



Waterway in Nemunas River, Lithuania



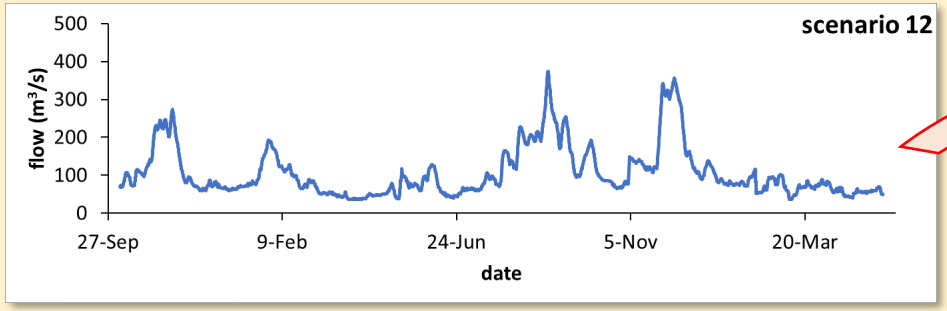
$$s_{\%} = \begin{cases} \frac{h - 1.15}{1.15} \times 100\% & h \geq 1.15 \\ 0\% & h < 1.15 \end{cases}$$

Dysarz, XXXVII OSH, 2018

Simulation requirements

Sediment transport modeling

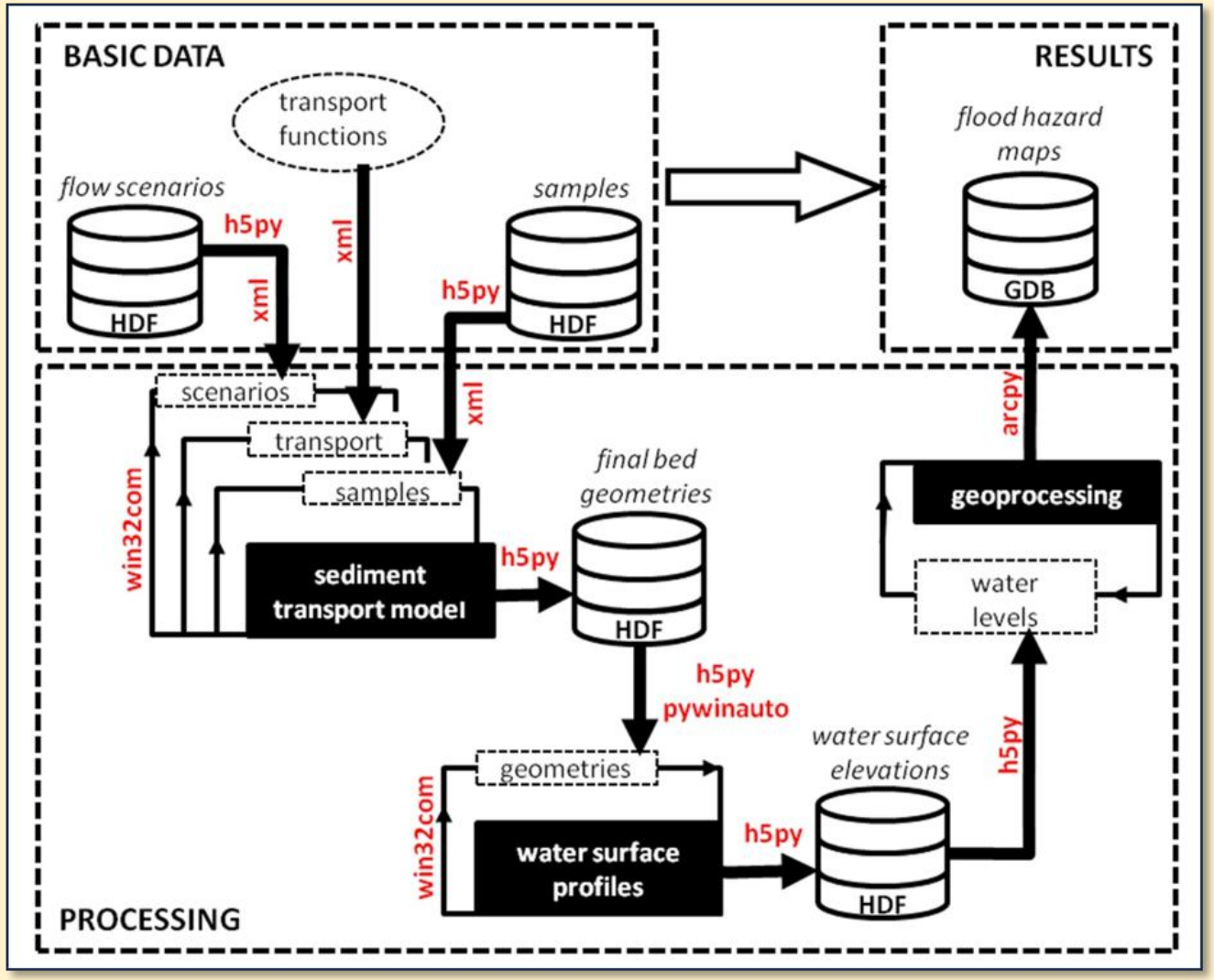
Computational flowchart



period 1971-2017

gauge station	*river*	*10-year flood*	*100-year flood*	*500-year flood*
		(m³/s)		
Oborniki	*Warta*	*495.57*	*730.14*	*868.06*
Wronki	*Warta*	*548.08*	*814.85*	*973.43*
Kowanówko	*Wełna*	*59.62*	*115.74*	*155.22*

flow scenarios		*flood events*		*maps in total*
240	×	3	=	720



Simulation requirements

Climate change impact

The team

Warsaw University of Life Sciences - SGGW

- *Dorota Mirosław – Świątek*
- *Mikołaj Piniewski*
- *Paweł Marcinkowski*

Poznan University of Life Sciences

- *Tomasz Dysarz*
- *Joanna Wicher-Dysarz*
- *Zbigniew W. Kundzewicz*

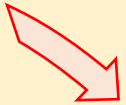
The concept

Database of climate projections for Poland

- *Mezghani A, Dobler A, Haugen JE, Benestad RE, Parding KM, Piniewski M, Kardel I, Kundzewicz ZW (2017) CHASE-PL climate projection dataset over Poland–bias adjustment of EURO-CORDEX simulations.*

Regional Climate Models (RCM)

emission scenarios RCP4.5,RCP8.5



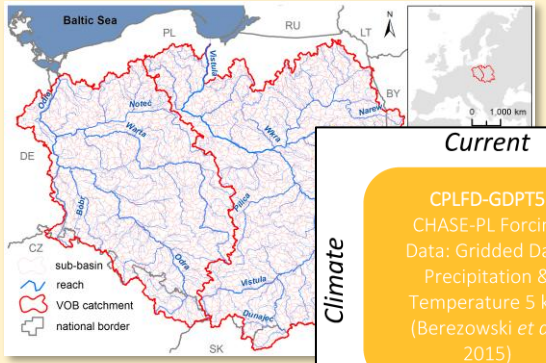
CHASE-PL climate projection dataset

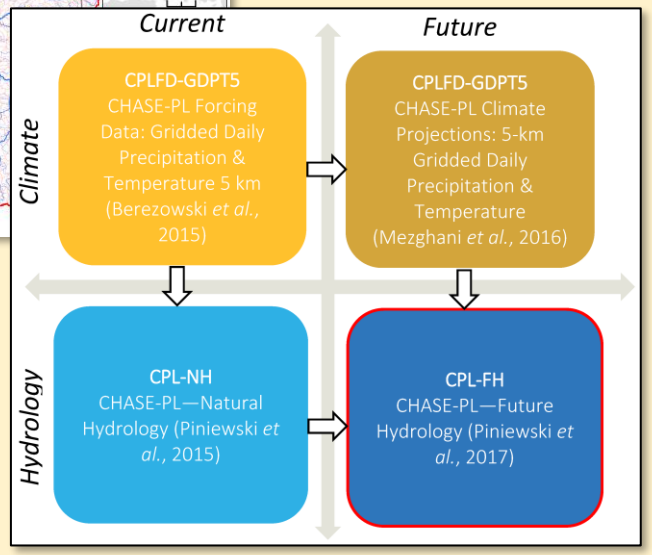
Simulation requirements

Climate change modeling

The transformation to flow data

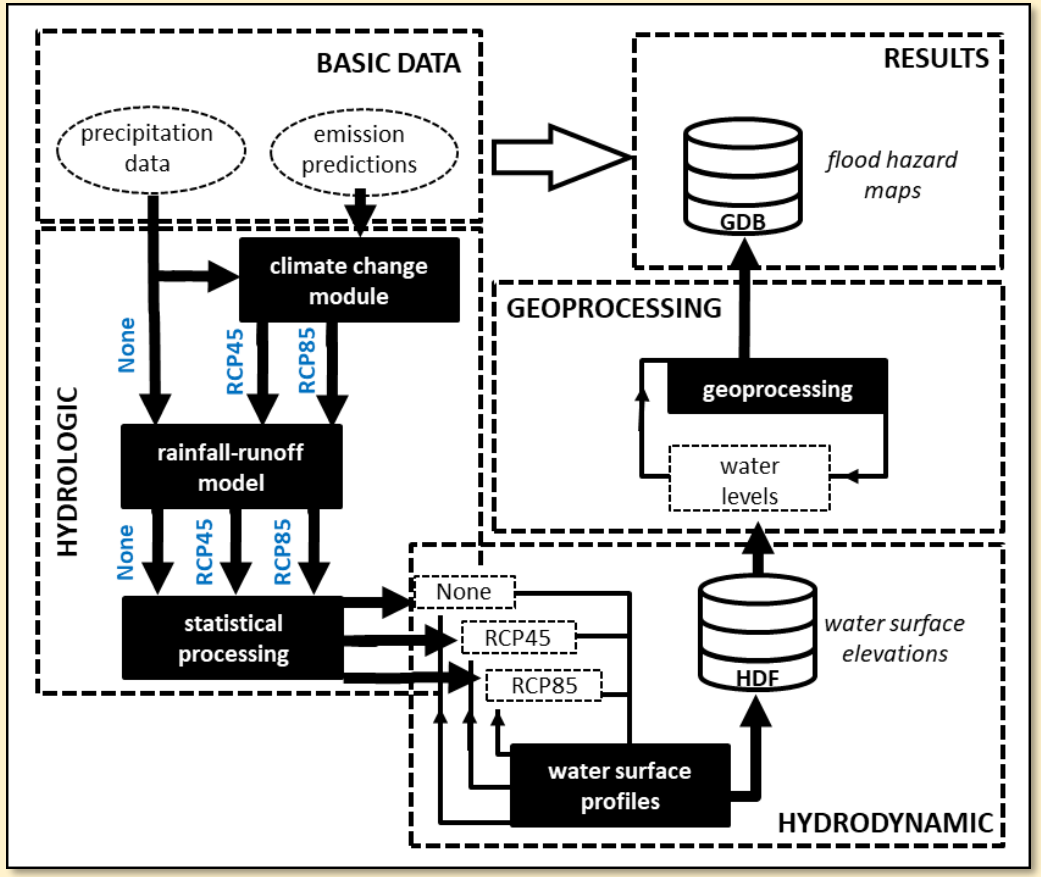
- *Piniewski M, Szcześniak M, Kardel I (2017a) CHASE-PL—Future hydrology data set: projections of water balance and streamflow for the Vistula and Odra Basins, Poland. Data 2(2):14. https://www.mdpi.com/2306-5729/2/2/14*





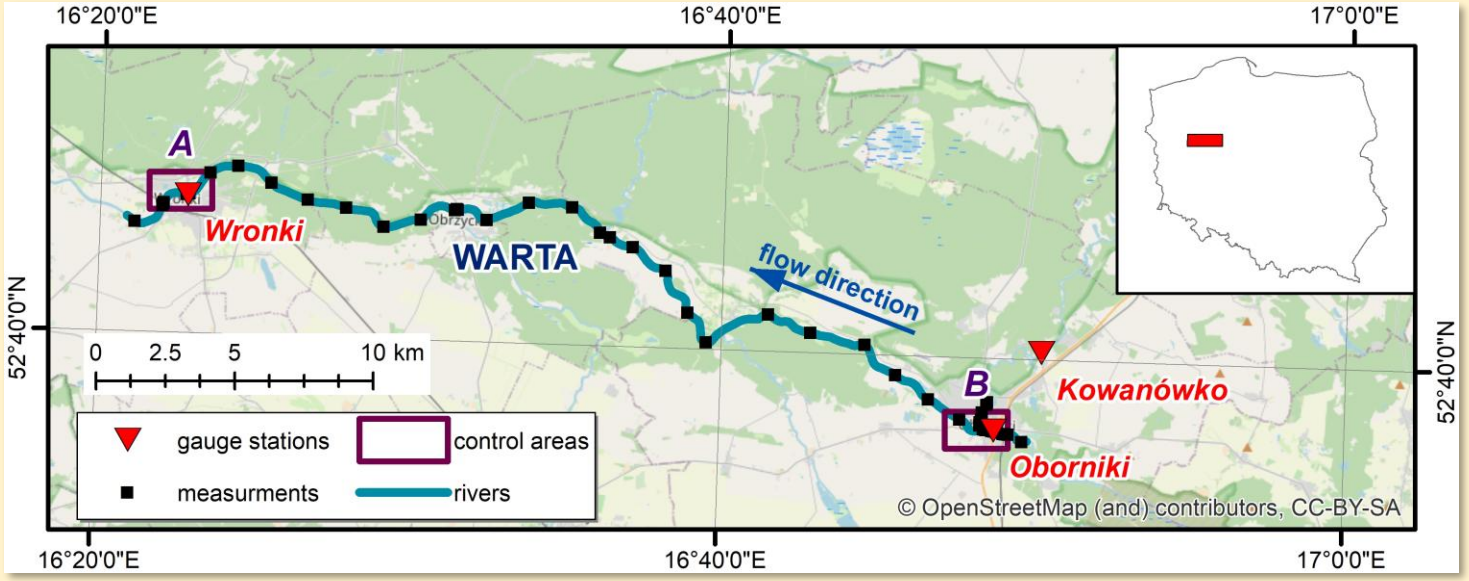
SWAT Soil & Water Assessment Tool

Computational flowchart



Example and selected results

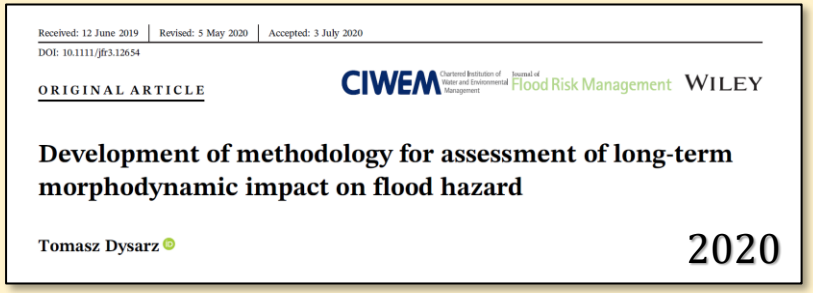
Study case: the Warta River reach



period 1971-2017

flow	*mean*	*max*
	m^3/s	
Oborniki	*112*	*806*
Wronki	*122*	*928*
Kowanówko	*8.37*	*96.4*

gauge station	*river*	*10-year flood*	*100-year flood*	*500-year flood*
		(m^3/s)		
Oborniki	*Warta*	*495.57*	*730.14*	*868.06*
Wronki	*Warta*	*548.08*	*814.85*	*973.43*
Kowanówko	*Wełna*	*59.62*	*115.74*	*155.22*


Received: 12 June 2019 | Revised: 5 May 2020 | Accepted: 3 July 2020

DOI: 10.1111/jfr3.12654

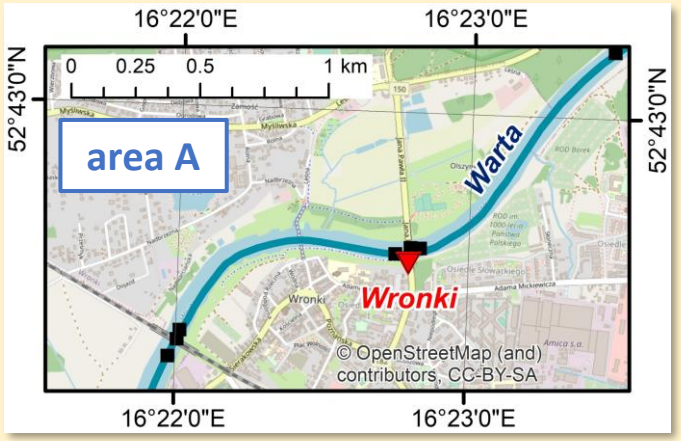
ORIGINAL ARTICLE

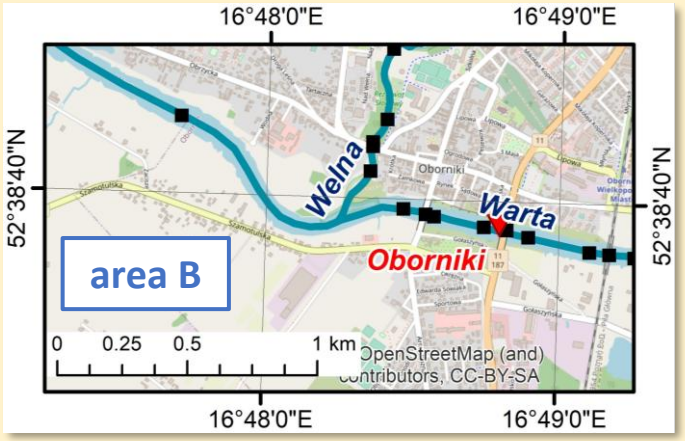
CIWEM Chartered Institution of Water and Environmental Management | Journal of Flood Risk Management | WILEY

Development of methodology for assessment of long-term morphodynamic impact on flood hazard

Tomasz Dysarz

2020

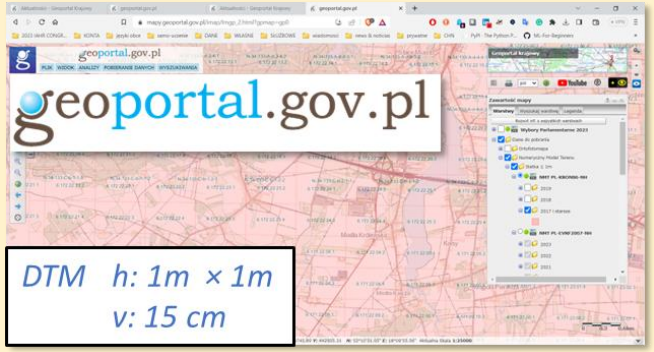


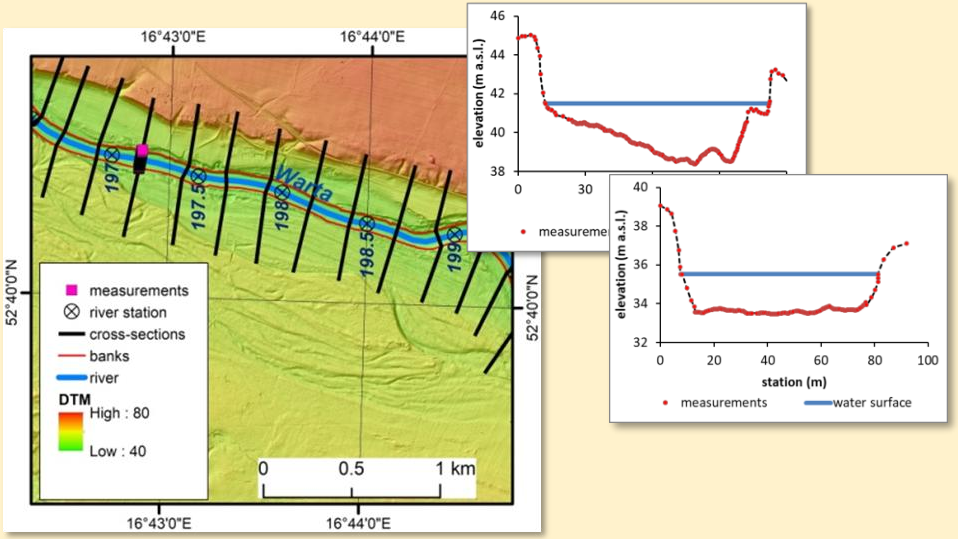


Example and selected results

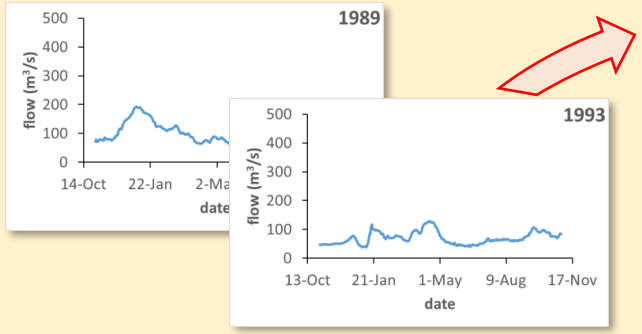
Study case: applied data

Public data

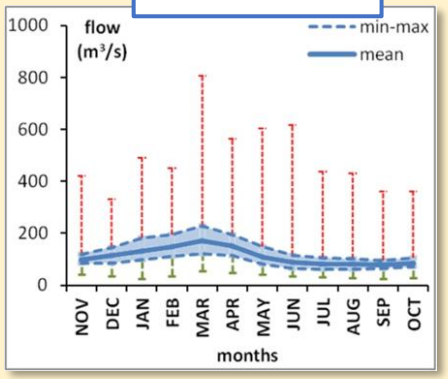




Instytut Meteorologii i Gospodarki Wodnej
Państwowy Instytut Badawczy

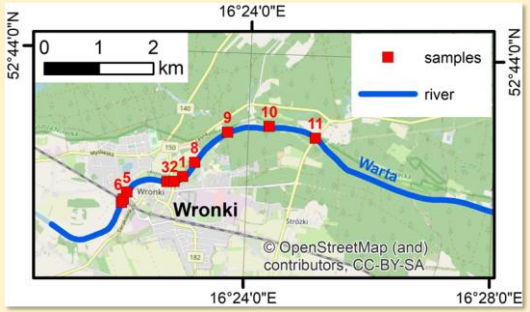


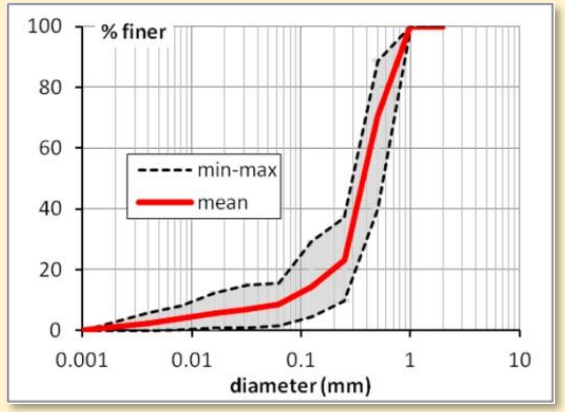
Oborniki



period 1971-2017

Own measurements

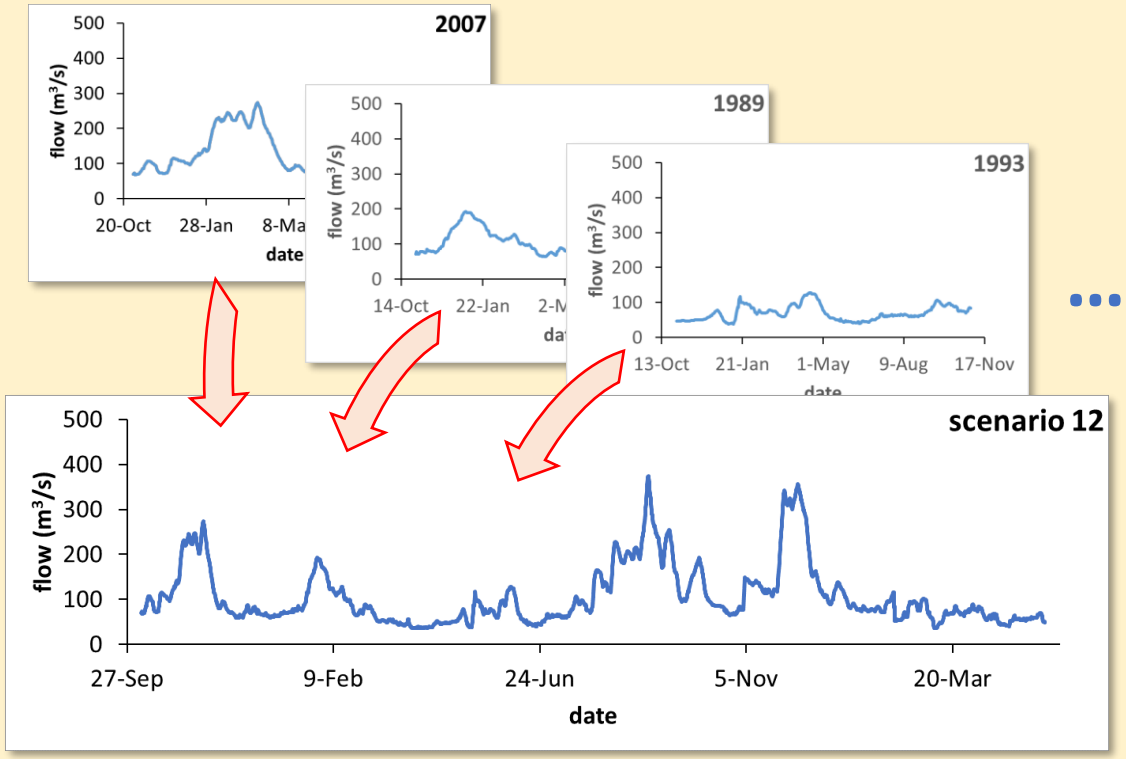




Example and selected results

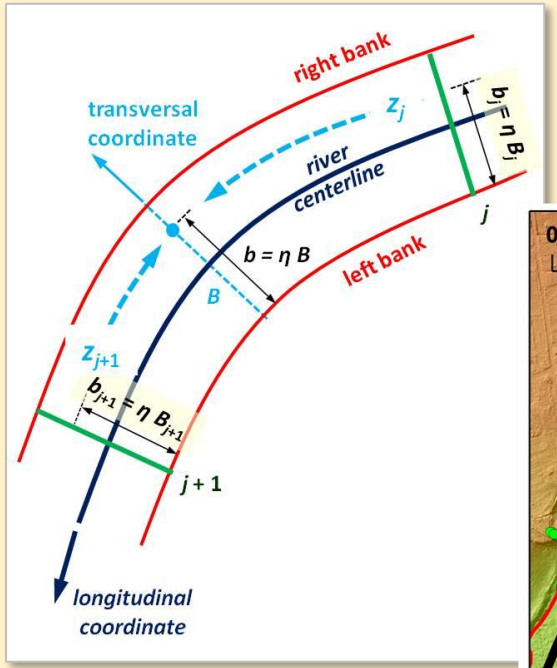
Study case: data processing

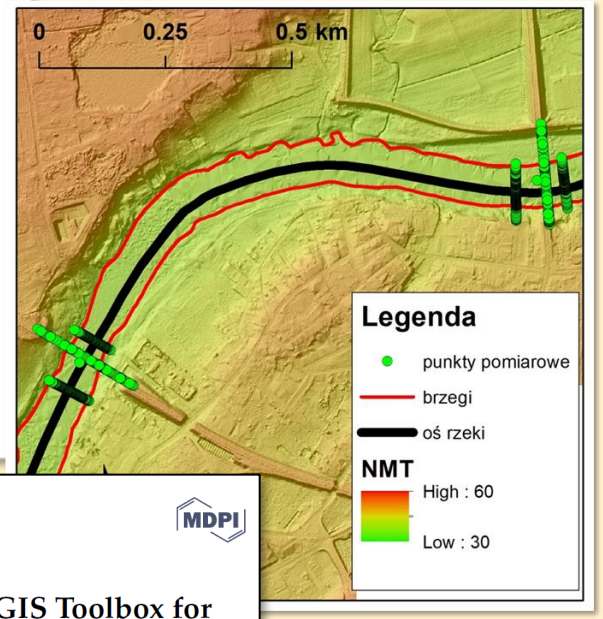
Inflow scenarios

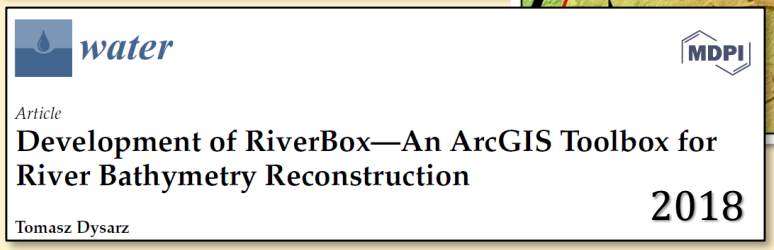


6 years → 30 scenarios x 4 formula = 120
12 years → 30 scenarios x 4 formula = 120
IN TOTAL 240

Longitudinal interpolation



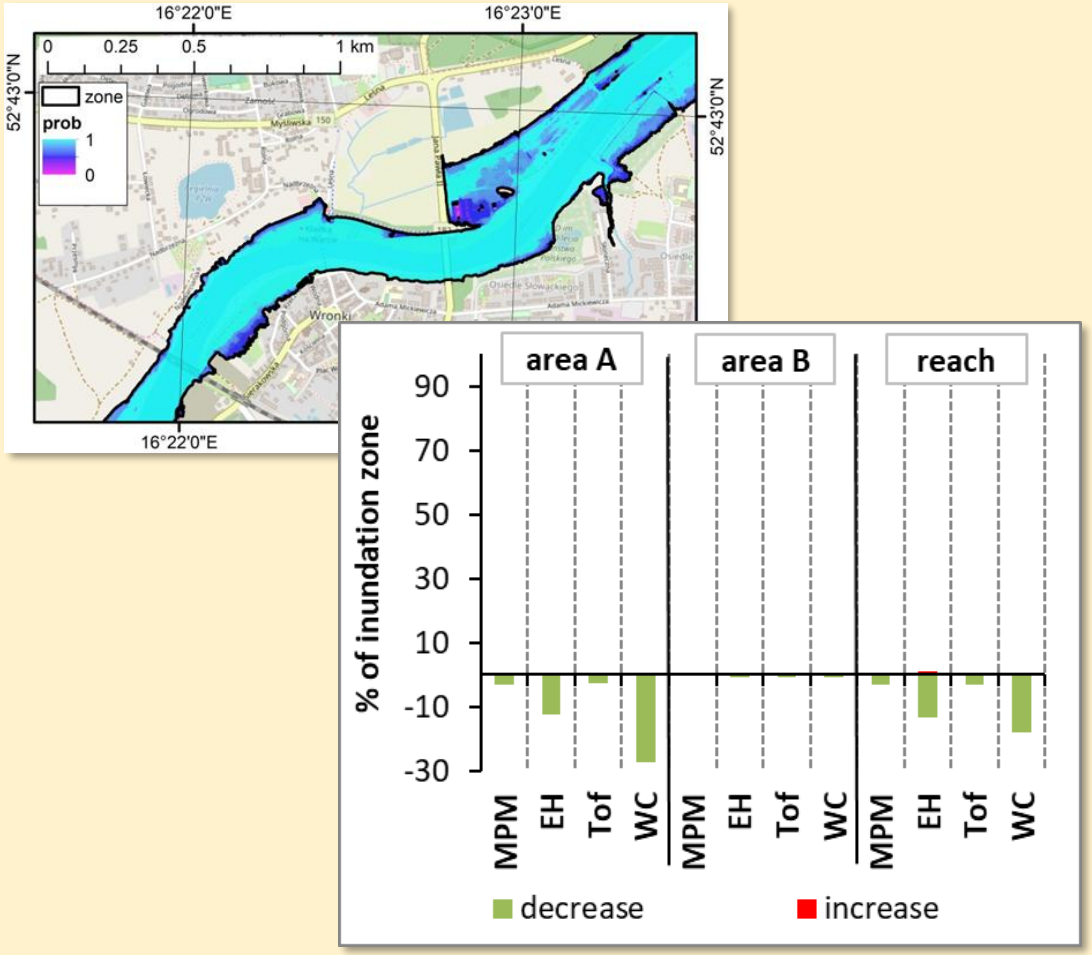




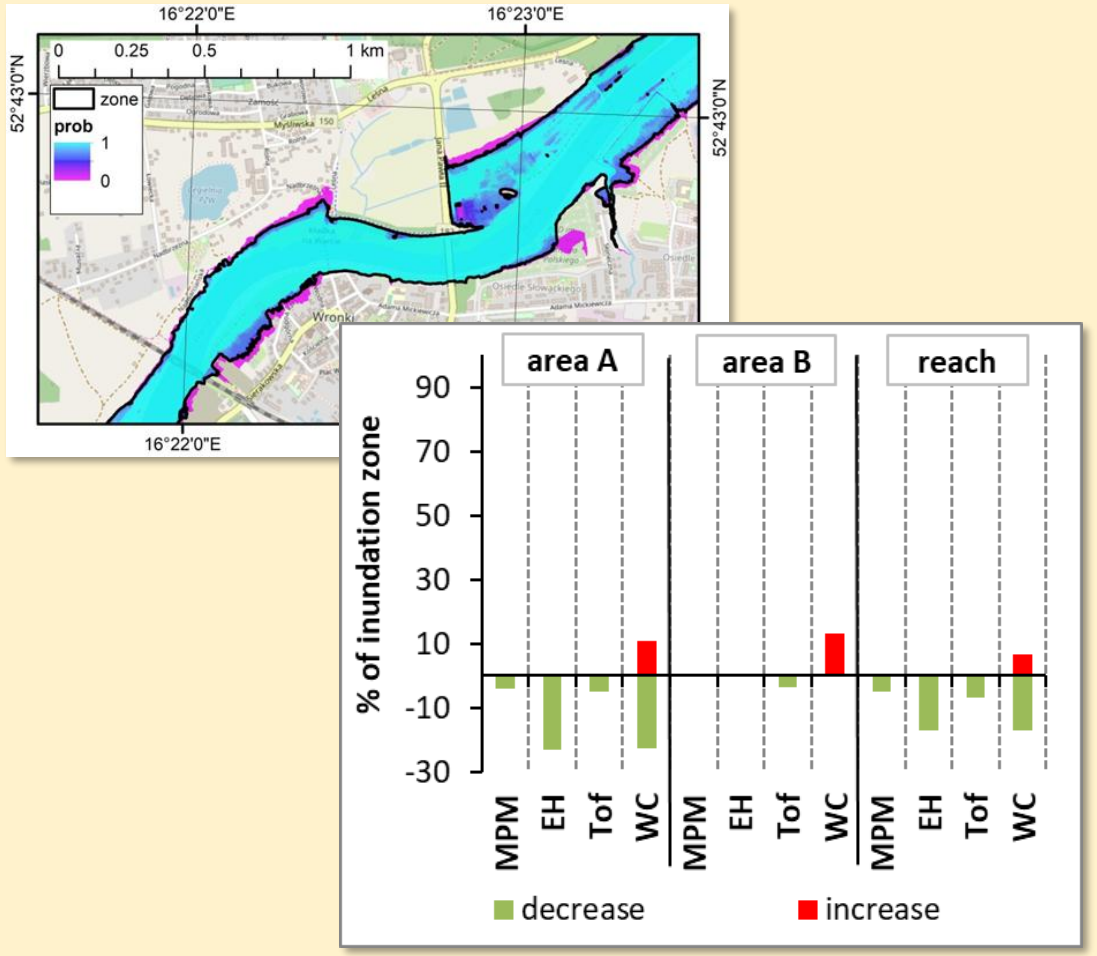
Example and selected results

Long-term sediment transport

SEDI: 6-year simulation

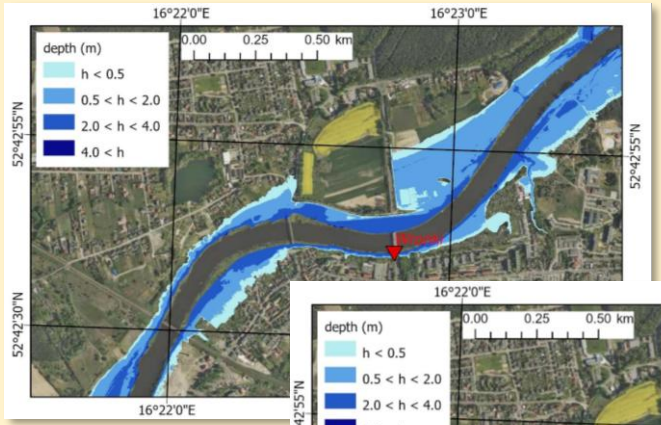


SEDI: 12-year simulation

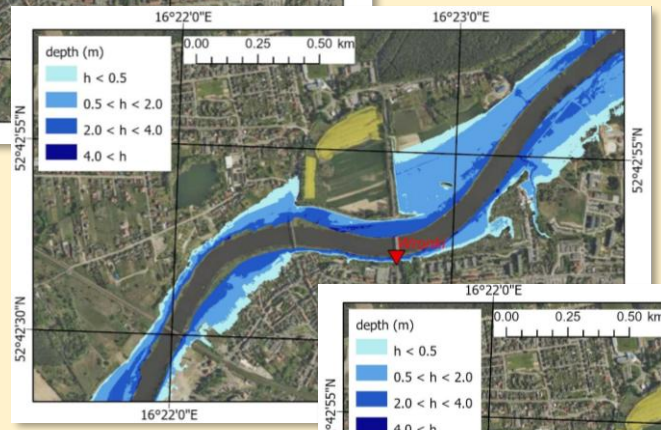


Example and selected results

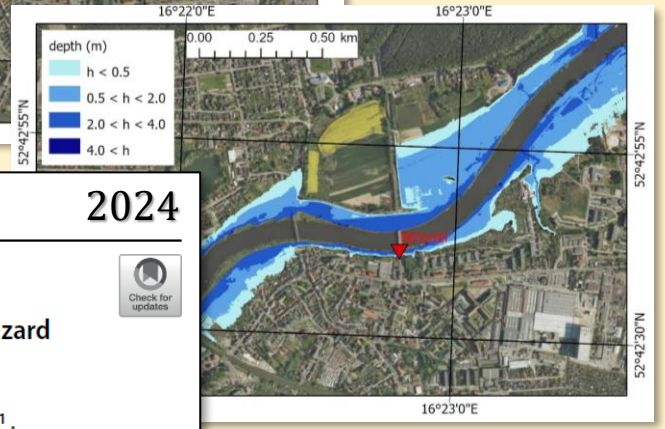
Climate change impacts



historical



RCP4.5



RCP8.5

Water Resources Management (2025) 39:963–977
https://doi.org/10.1007/s11269-024-04002-8

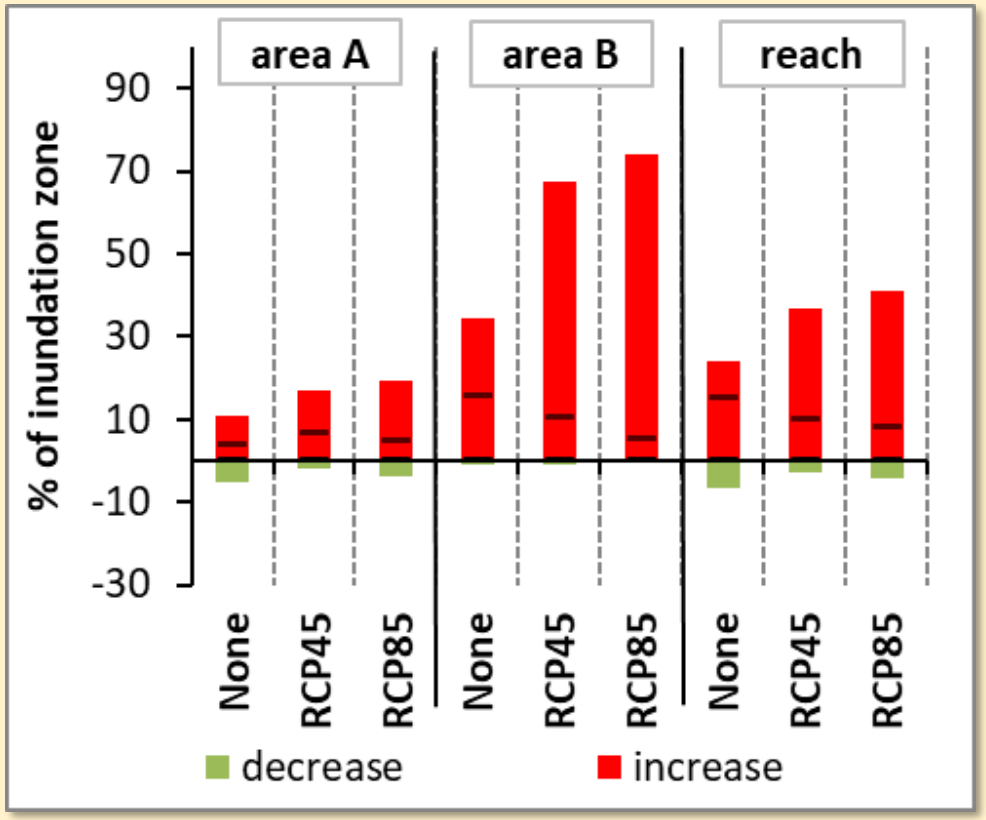
2024

Check for updates

Assessment of Climate Change Impact on Flood Hazard Zones

Tomasz Dysarz[1] · Paweł Marcinkowski[2] · Joanna Wicher-Dysarz[1] · Mikołaj Piniewski[2] · Dorota Mirosław-Świątek[2] · Zbigniew W. Kundzewicz[1]

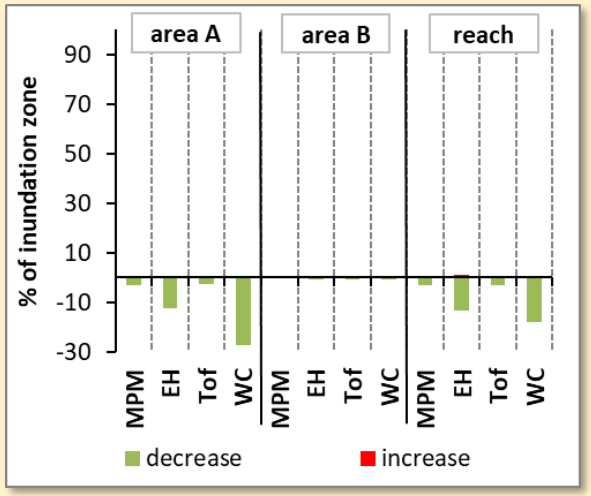
Summary of climate change



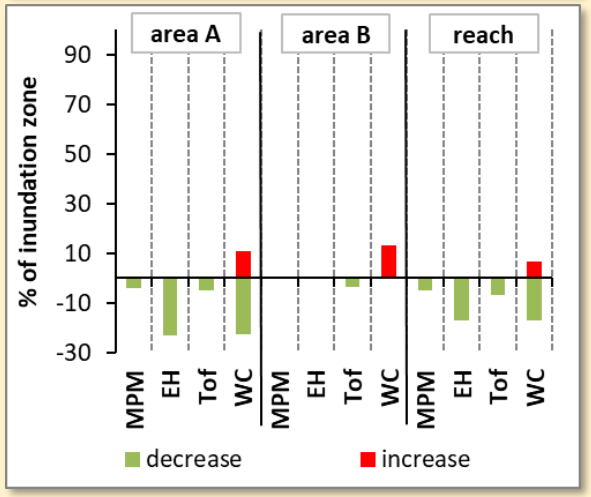
Example and selected results

Sediment transport vs. climate change

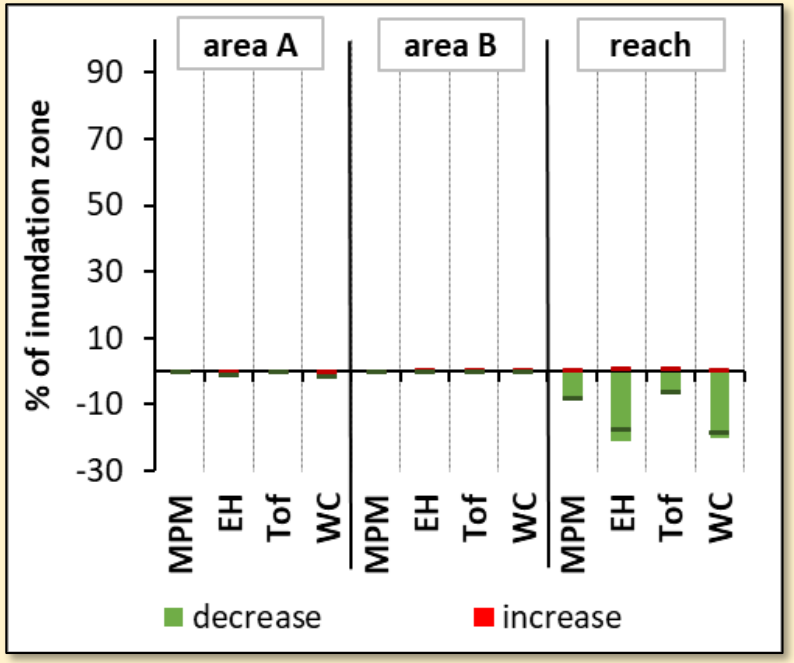
SEDI: 6-year simulation



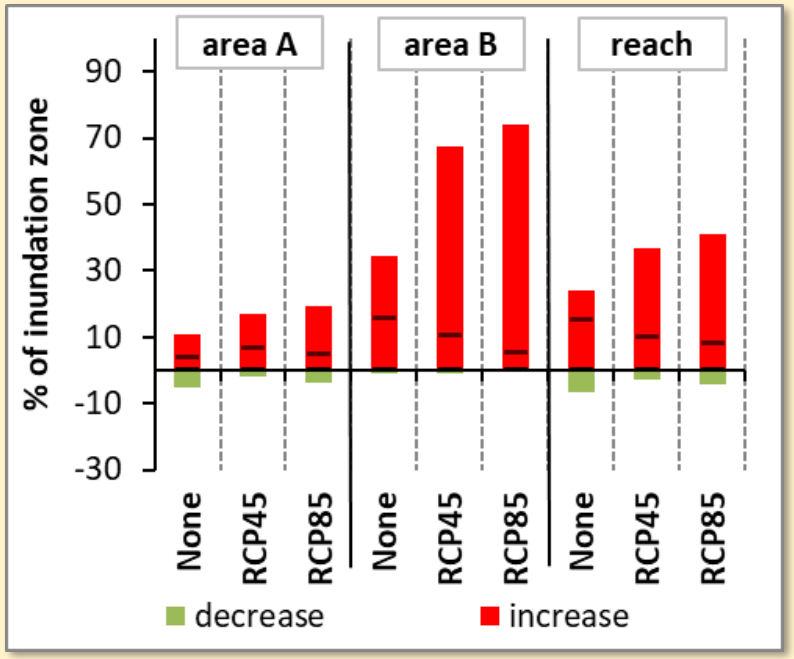
SEDI: 12-year simulation



SEDI: 38-year simulation



CLIMAT CHANGE



Summary and conclusions

- The EU Flood Directive and other directives are evidently important for collecting and accessing environmental data.
- The methodology can be effectively used for the assessment of sediment transport and climate change impacts in flood hazard.
- The analysis of the climate change impact provides rather unstable results due to the differences of RCM and long-time horizons.
- The impact of sediment transport may be crucial for evaluating the entire hazard and plays the major role in the short-term analyses.
- The flood hazard zones are changing and should be updated regularly, including new measurements and new available technology.

XLII INTERNATIONAL SCHOOL OF HYDRAULICS

Freshwater system health: a hydraulic perspective

Modelling impacts of sediment transport and climate change on flood hazard zones

Tomasz Dysarz

POZNAŃ UNIVERSITY OF LIFE SCIENCES

Institute of Geophysics Polish Academy of Sciences

IAHR AIRH International Association for Hydro-Environment Engineering and Research

May 20-23, 2025 RADOCZA / near Cracow, POLAND