

## CHANGES IN THE MIDDLE SECTION OF THE NAREW RIVER (BETWEEN OSTROŁĘKA AND ŁOMŻA) IN VIEW OF NATURAL FACTORS AND ANTHROPOGENIC PRESSURES

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Received: 2014.02.07

Accepted: 2014.03.17

Published: 2014.04.04

### ABSTRACT

Contemporary and archive cartographic materials illustrating horizontal profile of the middle channel of the Narew River (between Ostrołęka and Łomża) were compared in the GeoMedia application. The results of the analysis revealed that natural and anthropogenic factors had not significantly contributed to changes in the channel profile over a period of two centuries. Narew is a meandering river, and its activity is associated with intensified erosion of right-bank bends and lateral movement along its flat-bed channel. The most noticeable changes include reduced area of oxbow lakes, mainly due to succession, and suburban settlement in floodplains that had been regarded as unfit for development in the 20<sup>th</sup> century.

**Keywords:** Middle Narew River, horizontal profile, development of the riverbed, cartographic analysis.

### INTRODUCTION

Narew is one of the best preserved and most beautiful European rivers. Its catchment area is a manifestation of cultural landscape where natural processes and human activities are balanced or nearly balanced [Grabińska 2012]. The catchment area of the Narew River is characterized by a mosaic landscape, extensive farming practices, high forest cover and low levels of habitat conversion, in particular in the segment of the valley that is bound by the outwash plain of the Kurpie Plain in the north [Koncepcja szlaków... 2006]. The discussed landscape incorporates surviving fragments of the Kurpiowska Forest, extensive meadows, peatlands and agricultural biocenoses with traditional farming systems.

The Middle Narew Valley has been included in the Natura 2000 network, on account of its unique ecological value. It has also been designated as a Special Protection Area under the Birds Directive (area code: PLB 140014). The areas stretching along rivers Omulew and Pisa, right tributaries of the Middle Narew, play a similar role. The Na-

rew River with a strip of meadows and wetlands forms an international ecological corridor as a part of the ECONET Ecological Network. The corridor borders core areas: the above mentioned tributaries of the Narew River in the north and the Lower Bug River Valley in the south.

The natural resources in the catchment area of the Narew River stimulate local development, create opportunities for economic growth and constitute a source of economic and ecological indicators for continued development [Grabińska 2012].

The aim of this study was to evaluate changes in the horizontal profile of the Middle Narew channel (along a section of 56.8 km bounded by hydrometric profiles in Ostrołęka and Łomża) induced by natural and anthropogenic factors.

### MATERIALS AND METHODS

The usefulness of archive source materials and contemporary maps for evaluating changes in the natural environment, in particular in aquatic

habitats, has been emphasized by numerous authors [Myga-Piętek 2003, Kaniecki 2007].

A comparative analysis was performed based on archive and contemporary maps of the middle section of the Narew River between hydrometric profiles in Ostrołęka and Łomża. The hydrometric profiles are described in Table 1.

Source materials were acquired in accordance with standard procedures and were processed based on standard criteria for analyses of the type [Kistowski and Iwańska 1997, Bornette et al. 1998]. The following materials were used in the analysis:

- topographic maps in the 1:100 000 scale, developed by the former Military Institute of Geography (WIG) in the 1930s,
- topographic maps in the 1:100 000 scale, developed in the 1980's,
- topographic maps in the 1:100 000 scale, developed in the 1990's,
- digital map of Poland in the 1:200 000 scale, developed by the Institute of Geodesy and Cartography – used for control and comparison,
- cartographic materials (including archive resources) and technical data concerning hydraulic structures on the Narew River – supplied by the Regional Water Management Authority in Warsaw.

Source maps were processed in the GeoMedia Professional environment. Maps of the Narew river channel were vectorized based on georeferenced topographical raster maps in the 1:100 000 scale (WIG maps developed in the 1930s and maps dating back to the 1980s). If sections of the river overlapped in two different maps, raster tracing (tracing the existing sections) and snapping (creating new sections in the database) functions were used during the vectorization process. This approach was used to preserve the topology of the introduced objects and to ensure the cohesion of data relating to river sections.

Due to the large volume of the analyzed cartographic materials, only the section of the river

characterized by the most distinctive changes in profile was presented and discussed in this study (Figures 1 and 2).

Technical data concerning hydraulic structures on the Narew River and the results of field observations were also used. The results of the analysis were compared with the published findings of other research institutions.

## RESULTS AND DISCUSSION

### Natural factors

The development the middle channel of the Narew River has been influenced by numerous natural factors, including the geological structure of the stream bed, successive glacial periods, meltwater and the effect of changes in air temperature on river flow and plant cover.

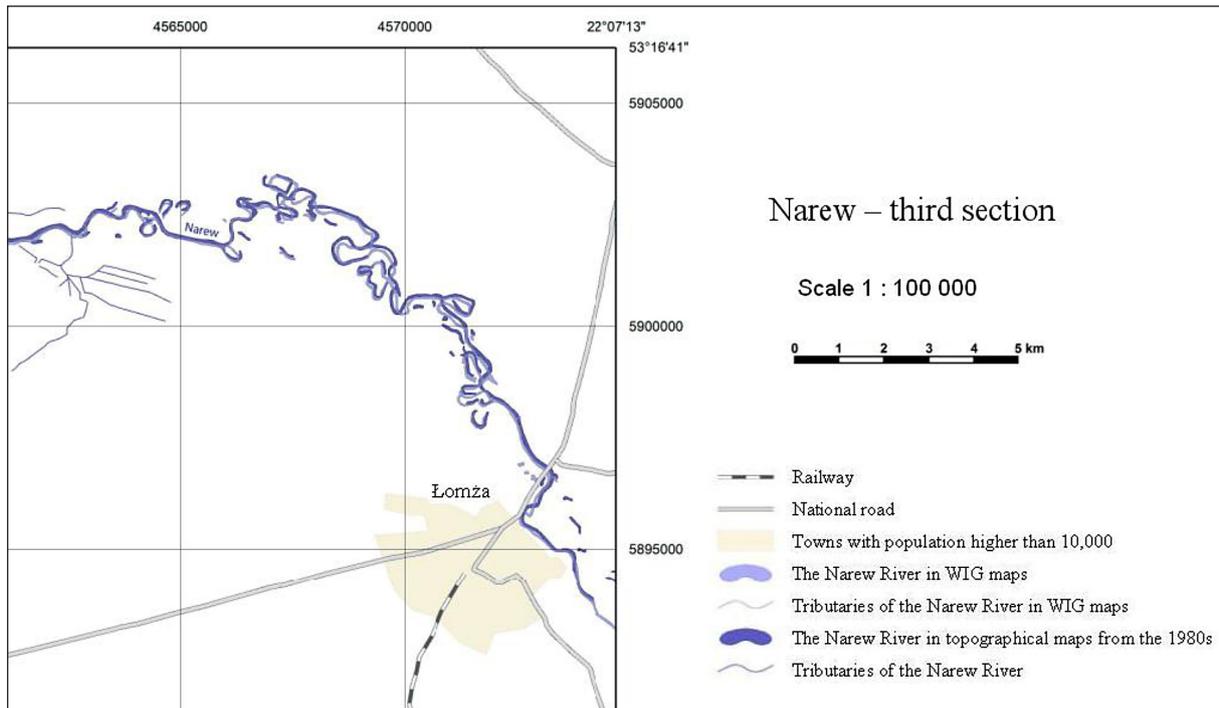
The geological structure of the stream bed has a major impact on the river network in the Polish Lowlands [Cesnulevicius and Morkunaite 2003, Falkowski 2010]. The development of the Middle Narew valley was influenced by the presence of an extensive basin in the sub-quadernary surface that had been deformed during successive glacial periods and under the influence of meltwater [Kondracki 2000, Grabińska and Kubeł 2011].

The left bank of the analyzed section of the Middle Narew valley is characterized by postglacial landform that was shaped during the Middle Pleistocene and transformed by periglacial and postglacial processes. Today, it is a nearly flat plain with slopes not exceeding 2%. The monotonous landform of the Łomża Interfluve is broken by the morainic hills of Czerwony Bór, flat and extensive dead-ice depressions, fluvial and denudation valleys. The left bank of the Middle Narew features distinctive edge zones with slopes greater than 20%. Outside developed areas, the landscape on the left bank of the river is formed by small farms and forest enclaves, mostly pine [Kondracki 2000].

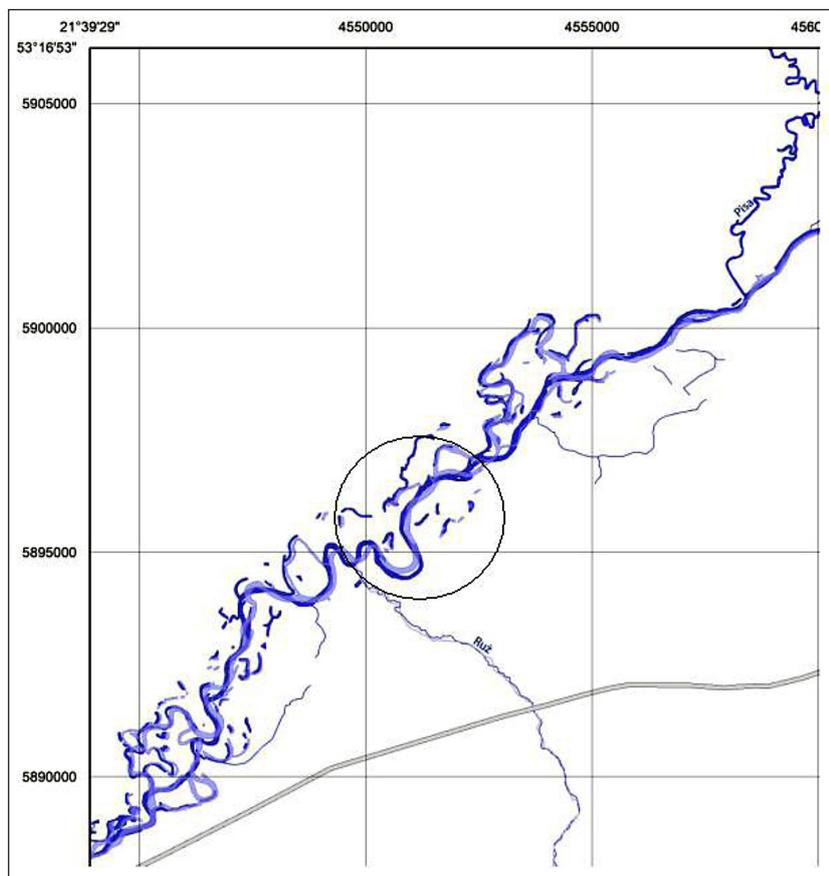
**Table 1.** Hydrometric profiles limiting the middle section of the Narew River

Parameter	Hydrometric profile in Ostrołęka	Hydrometric profile in Łomża
Location	below the city	above the city
Kilometers along the river's course [km]	146.8	203.6
Catchment area [km <sup>2</sup> ]	21 862.0	15 296.5
Share of total catchment area (excluding the Bug River) [%]	77.3	54.1

**Source:** Own elaboration based on *Atlas hydrologiczny Polski* [1987].



**Figure 1.** Horizontal profile of the Narew river channel below Łomża in topographic maps from the 1930s and 1980s  
 Source: own elaboration based on cartographic materials supplied by the Institute of Geodesy and Cartography in Warsaw



**Figure 2.** Horizontal profile of the Narew River channel above Łomża (right bank – municipality of Lelis, left bank – municipality of Rzekuń) in topographic maps from the 1930s and 1980s  
 Source: own elaboration based on cartographic materials supplied by the Institute of Geodesy and Cartography in Warsaw. Refer to Figure 1 for a list of symbols

On the right bank, the Narew River valley is enclosed by outwash plains and the Kolno morainic plateau. Narew's tributaries have flat and often water-logged stream beds. The areas between tributaries feature numerous aeolian formations, mostly dune ridges overgrown by pine forests. The local landscape is complemented by vast grasslands, patches of extensively farmed land on low-quality soils as well as fallow land [Kondracki 2000, Grabińska 2010].

The landscape of the river corridor is replete with clusters of osiers. The increase in the area occupied by this broad-spreading shrub indicates that evaluations of the local landscape should account for the influence of natural and anthropogenic processes on the growth of the above species [Kowalska 2009]. The floodplains of the Narew River are characterized by a predominance of osier and alder streamside forests, osier shrubs, rush plants and birch coppices on drier land. Floodbanks are largely covered by meadows and pastures, which are also found on the edge of forests and in wetland basins. Forests and meadows are overgrown by shrubs and herbaceous plants (burdock, mugwort, nettle and currant communities) [Ochrona Środowiska 2011].

The results of our field survey were largely consistent with the findings of Adynkiewicz-Piragas and Lejcuś [2009] who analyzed the continuity Narew's corridor and demonstrated that the river section between Ostrołęka and Łomża is characterized by undisturbed flow.

### Anthropological factors

The landform of the analyzed fragment of the Middle Narew valley has undergone considerable transformations resulting from human activity, including hydraulic structures, land improvement systems, road and bridge embankments, moats surrounding post-war fortifications, sand and gravel pits, and settlements [Stan czystości wód... 1998].

In the past two centuries, extensive drainage and regulation works had been carried out in the catchment area of the Middle Narew to convert wetlands (riverside swamps) into farmland. Those efforts involved the construction of drainage canals as well as seasonal irrigation channels to improve meadow productivity. Substantial parts of the catchment area were completely deforested. The most recent transformations in the landscape of Narew's corridor involve valley drying, which is caused by an increase in mean winter air temperatures [Grabińska 2010] and changes in river flow resulting from the construction of the Siemianówka dam reservoir [Gospodarowanie wodą... 2002].

In the analyzed section of the Narew River and in the section between Różan and Ostrołęka [Grabińska and Szymczyk 2012], hydraulic structures have been developed to stabilize and direct the current and prevent erosion. Flood walls with total length of 3.5 km and spur dikes were built in the discussed section of the Narew River (Table 2).

Twenty-one side weirs have been built along the Narew River, of which the shortest has the length of 100 m, and the longest has the length of 750 m and is additionally reinforced with a diversion embankment of similar length. Side weirs have the combined length of 9.8 km. Passenger and cargo shipping operations do not take place on the Narew River. The middle and upper sections of the river cannot be used as transport corridors due to shallow waters and an absence of hydraulic structures [Mikulski 2000].

The picturesque landscape of Narew's corridor, in particular its edge zone, contributes to the development of human settlements and recreational facilities, which leads to the gradual elimination of agricultural land. The areas extending above the escarpment of the Narew valley in municipalities of Rzekuń, Miastkowo and Nowogród enjoy the greatest popularity on account of their

**Table 2.** Hydraulic structures in the section of the Narew River between Ostrołęka and Łomża

Type of structure	Number of structures	Length [m]		
		minimum	maximum	total
Spur dikes	93	10	110	5059
Flood walls	21	100	750	3520
Earth dams	2	35	90	125
Side weirs	21	70	710	9853
Diversion embankments	1	–	–	690

**Source:** Own elaboration based on 2011 data supplied by the Regional Water Management Authority in Warsaw.

attractive landform, climate and scenery. Residential and commercial construction projects are initiated on territories that had been regarded as unfit for development in the 20<sup>th</sup> century, including in the Lower Pisa Valley and the Narew Valley where Pisa feeds into Narew, their floodplains and extensive water-logged meadows on the right bank of the Narew River. Residential estates require the construction of embankments containing rubble and soil excavated from building sites. Catch basins are filled, shrubs and trees are cleared, and the area of oxbow lakes is reduced. Those measures lead to considerable changes in the structure of the Narew Valley.

Water quality analyses revealed that settlements have a minor impact on environmental conditions in the Narew Valley [Grabińska 2010], and much higher pollution levels were reported in the Warta River [Ilnicki et al. 2001]. The annual pollutant loading from soluble substances in Narew was comparable to that noted in catchment areas covered by forests and farmland [Glińska-Lewczuk and Koc 2003]. The catchment area of the Narew River is free of heavy-metal contamination [Grabińska 2010]. Water quality in the catchment differed across years and seasons subject to weather conditions, flow volume and land-use structure. Agricultural production on drained land with mostly light soils and intensive animal farming in the valleys of Narew's tributaries led to a deterioration in water quality [Mioduszcwski 2006, Grabińska 2012].

According to 16<sup>th</sup> century maps presented by Niedziałkowska [2002], Middle Narew was a braided river in the region of Ostrołęka, and its channel was intersected by numerous mid-channel bars (islets). Similarly to other rivers in the Polish Lowlands, the transformation of the Middle Narew from a branched to a meandering river was prompted not only by natural factors (changes in flow rate), but also by anthropogenic influences because rivers played an essential role in economic development throughout history [Czaja 1997, Kalicki 2006]. Despite the above, a comparison of digital images illustrating changes in the course of the Narew River resulting from the development of hydraulic structures, infrastructure and human settlements did not reveal significant differences in the horizontal profile of its middle section. Irregular loops were formed, meander necks were cut off and the area of oxbow lakes was considerably reduced, mainly due to ecological succession. Distinctive changes in the

stream channel were observed above Ostrołęka (Figure 2) where the river intensively meanders and contributes to erosion of right-bank bends. The course of the river shifted laterally across the channel bed in the area of a well-developed floodplain. Erosion controls have been implemented on the edge of the left bank of the Narew River.

## CONCLUSIONS

1. Contemporary and archive cartographic materials were compared to evaluate changes in the horizontal profile of the Middle Narew channel along the section bounded by hydrometric profiles in Ostrołęka and Łomża. The analysis revealed that the transformation of the Middle Narew from a branched to a meandering river resulted mainly from human activities, including settlement, river regulation, hydraulic structures and agriculture.
2. The natural factors that have exerted the greatest influence on the development the middle channel of the Narew River include the geological structure of the stream bed, successive glacial periods, meltwater and valley drying due to changes in mean winter and spring air temperatures.
3. At present, Narew freely meanders in the river valley, and its flow is not restricted. River activity is associated with intensified erosion of right-bank bends and lateral movement along its flat-bed channel. The most noticeable changes include reduced area of oxbow lakes, mainly due to plant succession, suburban settlement and commercial development.
4. Patches of lush vegetation along river banks (in particular the right bank) and hydraulic structures, which have been developed over a period of two centuries, stabilize the Narew channel. Narew is not used as a water route. Agricultural practices in its catchment area are characterized by low productivity and do not deteriorate water quality.
5. Geomorphological changes (edge erosion) are increasingly frequently observed in the Middle Narew. The analyzed section of the river is renowned for its scenic beauty, which contributes to the development of settlements and commercial facilities in areas that had been regarded as unfit for development in the 20<sup>th</sup> century.

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