Flood protection in highly valuable river ecosystems
– middle delta system of the Nida River

Andrzej Strużyński
Department of Hydraulic Engineering and Geotechnics
Agriculture University in Kraków,

Abstract
The Nida River, which flows across the central part of Poland, creates a unique inland delta in its middle run, inhabited by many rare plant and animal species. After river training and reclamation works conducted in the 1980’s, retention capacity of the catchment has dramatically decreased. The run of the Nida River in the delta was shortened, which caused an increase in watercourse slope, resulting in the intensification of bedload transportation and bed erosion processes. At present, there are many ecological projects running in the Nida basin (i.e. the Natura 2000, Bird Directive, CORINE, etc). In order to improve the condition of water and flood protection in the middle delta, renaturalization works are proposed which safely restore valley retention.

Key words: flood defense, renaturalization, middle delta, multichannel system, landscape

Introduction
The lowland Nida River, left tributary of the Vistula River, can be regarded as predominantly close to nature, with many ecological projects running, at the moment, in its basin (i.e. the Natura 2000, Bird Directive, CORINE). Flowing through the central part of Poland, the Nida River had created a unique multichannel system called “an inland delta.” In its middle run close to the town of Pińczów. In this part of the river valley, many rare plant and animal species could have been found, until the regulation works performed in the 1980’s. At that time, the Polish government did not pay particular attention to nature conservation issues, focusing on the intensification of agricultural production instead. The main assumption was not reached and what is more, the damages caused after river training are hard to overestimate. The retention in the catchment had been decreased, which resulted in uncontrolled flooding and disappearance of numerous valuable species from the “delta” region. The river, often in flood, had been fortified, which changed water relations. The Nida River run was shortened, which resulted in the increase of the slope of the flowing water. Consequently, the processes of bedload transportation and riverbed erosion intensified. Another damage involved the change in bedload granulometry in the middle delta as well as deposition processes increasing the elevation of the riverbed near the town of Pińczów. The balance between the water flowing in the river and the valley ecosystem had been disturbed. The problem turned out to be very complex also due to the sandy substratum of the valley and the marching processes found in previously rich habitats.

The investigations performed in this area involved, among other things, the interpretation of satellite and aerial images as well as bathymetry data gathered in the field. The data was used for creating the restored channel network solved hydraulically in HEC-RAC hydro-informatics software. This concept had been also preceded by long term biological studies and has received approval of the local authorities. When all investigations are finalized, the expected benefits will involve the following: the increase of valley retention and decrease of flood risk, the development of recreation base, and the improvement of biological diversity.

THE ANALYSIS OF HYDRO-MORPHOLOGICAL PARAMETERS OF THE NIDA RIVER AND THE NIDA RIVER VALLEY
The Nida River flows across the central part of Poland. The length of the Nida River is 151.2 km and the area of the basin equals 3 862.8 km². The area of the sub-basin in Pińczów
cross-section equals 3 352 km². Characteristic discharges in Pinczów are as follows: \( Q_{50\%} = 150 \) m³/s and \( Q_{1\%} = 450 \) m³/s. The river itself is called Nida below the connection of the Czarna Nida (flowing from the east) and the Biała Nida (flowing from the west). The Biała Nida River is classified as an upper run of the Nida River. The lower run of the Nida starts from the outlet of the Mierzawa River. In its middle run, the Nida River is characterized by a slope of about 0.5 per mille. All three branches are very curvy and, starting from the middle delta, the Nida River managed to build very well-developed meanders. In its middle run, the Nida River often forks into a few channels and the old river channel system is especially well developed in the so-called “middle delta.” The “middle delta” is localized upstream from the estuary of the Mierzawa River at the village called Rębów. In this area, there are sandy soils and sands mixed with the peat [1,2].

**Historical review**

In its lower part, the Nida River basin is one of the first populated terrains of Poland. There are two old towns in the area called Wiślica and Nowy Korczyn. Since the intensification of human activity in the 15th century the impact of antropopressure has caused complex changes in fluvial processes in the Nida River basin. In spite of the long term human activity, the Nida River itself and its valley have always been characterized by the high biodiversity. The riverbanks were not fortified and the embankments were raised very sporadically. They could have been mostly found at the well-concentrated riverbed and in the lower run of the Nida River where the height of embankments reaches even 4 meters. In the 19th century, a lot of mills operated in the villages, which, locally, influenced the speed of the water-current. In the past, the river was also used as a transportation route. Kwiatkowski [3] reminds that, in 1447, Casimir the Jagiellonian, the king of Poland, issued a decision that all obstacles should be removed to allow water transportation along the Nida River. In a report from 1849, Wolski describes that afforestation has decreased and remained mostly in the Biała Nida River basin [3]. This caused a change in the flow regime. River became curvier and two well-developed peaks of flow in March and July appeared. Starting from Pińczów downstream there were a few parts of the Nida River where the watercourse developed particularly well (the meandering river passes this distance between 8 to 10 times longer than it would in a strait line); but also in the middle run, the sandy riverbed is very liable to meandering. Kwiatkowski describes that after 1902, rafting had already disappeared and in the meantime a narrow railway line was build, which intensified communication between two towns: Jędrzejów and Pińczów. Another communication route was build to Krakow, which omitted the river system, never easy for use in the past, due to a very curvy watercourse and a low water depth. After that, regular restoration of the Nida River was abandoned.

After the area of “middle delta” was uncovered it became more prone to creating new river-channels during floods. Historical data gathered by Łajczak [4] show, that since 1839, the multichannel system in the “middle delta” was changing dramatically many times after floods (Fig.1). Regarding the change of accuracy of the pictures describing the river system in the separate years, they present that the dynamics of the river system in “delta” is very high. The main channel appeared in many branches from the western to the eastern part of the valley and finally, in 1938, even created a new river-channel near the village of Sobowice. In the meantime, the western channel had disappeared and appeared again. The multichannel system was developing all the time.

**River training works in the 1980’s**

In the 1980’s river training works were conducted in the middle delta at the distance of about 13 kilometers of the present run (Fig.2). At the distance of 4 km, between the villages of Rębów and Motkowice, strictly technical river training was carried out. The slope of the river
flow in this part equals 0.7 ‰ and the main channel is shorter by 6.9 km.

Fig 1. Historical data show numerous changes of the Nida River morphology. Years: a) 1839, b) 1916, and c) 1938 [4].
The channels of the eastern and western Nida as well as the “Nida to Sobowice” fragment were cut off and 5 steps were built in the main channel. Longitudinal fortifications were raised at the fragment from Rębów to Motkowice on both riversides. Downstream from the village of Motkowice the flooding area was cut off by an embankment located to the right downstream to Pinczów. The left terrace is open for flooding from the LHS railway bank to the embankments of the new (regulated) channel of the Branka Stream. Fortunately, the biggest cut-off meanders were connected to the regulated river by a network of channels.

Ecological parameters were not taken into consideration, at the project design stage, but only the hydraulic and economic ones. The main goal of the performed river training was to increase agricultural production. The specific flow regime of the Nida River, which often floods the valley during springs and autumns, was not taken into consideration. What is more, the intensification of the agricultural use of the “delta” did not take place. The fertility of the drained sandy soils decreased and marching processes started on moors. Zawistowski [5] describes that, according to his expertise, soil fertility in the delta is below average and characterized by large permeability and low retention.

**The current state**

As long as the hydro-morphological parameters of the Nida River were close to nature, the water system in the “middle delta” functioned properly. The multichannel system, which developed after floods, resulted in big biodiversity of fauna and flora. The discharge of the network of all parallel channels was sufficient for passing floods. The predominant part of the valley was regularly flooded and the system speeded the pass of flow also decreasing its maximum level.

At present, the transformed river does not redistribute water as effectively as it did before. Additionally, conservation of the structures build during the 1980’s has not been performed.
properly, which has triggered the disappearance of old channels and degradation of wetlands. These adverse processes are responsible for the decreasing area of bird breeding grounds, habitats of protected molluscs and other species [6]. The decrease of flooded areas in the “middle delta” results in the increasing speed of floods passing through this region [1,2, 7, 8]. Due to bigger river slope, the intensification of bedload transportation can be observed; while below Pińczów, where the slope shrinks to the natural one, the full channel scale aggradation processes appear.

Another problem is that during the pass of 1% probability flood, the water level in the river valley is about 0.40 meters higher, compared to natural conditions [7]. This is dangerous for the citizens of Umanowice, a village situated the lowest in the delta. These citizens are threatened almost every year by spring and autumn floods. Fortunately, the narrow railway line running from Pińczów to Jędrzejów is high enough to work as a longitudinal fortification. However, the water can infiltrate the sandy soils from the eastern Nida which passes very close to Umanowice. This old river channel bed is shallow and when it is supplied by the Hajdaszek Stream, it can increase flood hazard in Umanowice [8].

THE PROJECT OF FLOOD PROTECTION TAKING INTO CONSIDERATION NATURE CONSERVATION ISSUES

As long as human activity in the Nida basin runs parallel to natural processes, there is no easy definition of natural parameters of the Nida River hydraulics. When planning a renaturalization project it should be stressed that in spite of degradation processes existing in this area, there are still many species of fauna and flora (birds, fishes, butterflies, molluscs), whose habitats should be improved or restored [6, 9, 10]. On the other hand, a substantial area of the river valley is still cultivated. Consequently, a renaturalization project has to deal with all of the mentioned problems i.e.: it should take into account the safety of the passing floods, increase riverbed stability, restore the proper flow conditions in the main channel and in the old channels, as well as improve the ecological state of the whole system. It could be possible for some fields to be taken out, transformed into the meadows or consolidated to create bigger wetlands.

In search for optimized conception

As flood protection cannot be taken into consideration on its own, without other parameters, the solution in the middle delta should be searched among the historical data, the actual state, and the possibilities of the future development of this region. This sensitive multichannel system should be restored after studying its natural variations in the past as well as actual ecological aspects with the support of sustainable development of the region. The authors decided to focus on extending the possibilities for people so as to improve the standard of living in villages surrounding the delta. As long as the intensification of agricultural production takes place, there is currently no need to use the area localized closest to the river so inhabitants of the local villages have stopped cultivating the wettest fields. Many of the agriculturally used fields have been changed into meadows or pastures and used not intensively. Many of these areas have been converted into landscape parks and can be used as a recreation base for surrounding cities. Even now, there are, for example, excursions from Krakow aimed at visiting the “delta” by the narrow railway called “Express Ponidzie”.

After analyzing the historical data, one can see that the best results could be reached after opening of whole valley. The riverbanks of all of the developed river channels should not be fortified, which would allow free meandering within the whole delta. This would be most advantageous for the local species. However, local properties do not allow for a solution like this. Some parts of the delta have to be excluded from flooding and all of the restored river channels need to have meandering limits. This can be reached by searching for the stable river channel
system characterized by optimal watercourse and river channel bandwidth adapted to the needs of water supplying the valley. The revitalized and rebuild channels should let the system function properly during low flows and should be large enough to ensure safety of passing at the time of annual floods [1, 7].

**Detailed description**

The first step is to design the restoration of the old channels in the delta (Fig.2). The system of the inland delta was changed about 20 years ago but many of the old channels, even if they are presently dry, are still visible in the contemporary aerial photographs. The picture below (Fig.3) shows a part of the designed area with a visible dead old river channel and the channel after river training.

With the help of ortho-photo-images, the multichannel system of the Old Nida River, Western Nida, Eastern Nida and Nida to Sobowice was chosen (Fig.2). The Old Nida forks into the Eastern and Western Nida upstream from Umianowice. The Eastern Nida, close to Umianowice, is supplied by the Hajdaszek Stream and near Skowronno Gorne by the Branka Stream. The Eastern Old Nida flows into the Nida River near Zalesie while the Western Nida between Imielnica and Sobowice. The channel of the Eastern Nida is well visible in aerial photographs and not as well visible in pictures presented in Fig.1. In the project, it is supposed to act as a drainage river for the eastern part of the valley separating the inland delta from the narrow railway and Umianowice and carry out water from the Hajdaszek and Branka streams. The old river called the Western Nida will supply the central part of the delta. “Nida to Sobowice” appears in Fig.1 in 1938 as the main channel. The renovation of this river channel will create a very interesting meander with rich fauna and flora. The Eastern Nida below Skowronno will create wetlands, where many species (molluscs, amphibians, and others) shall be restored [6].

At the moment, the regulated river flows with an average slope of 0.73 ‰ which, after activating meanders, will be decreased. In the old channels, the slope will vary from 0.31 ‰ to 0.65 ‰. Channel curves, measured in the river, make it possible to compare the natural and regulated parts (Fig.3). The Nida River currently flowing through the delta is characterized by the parameter of trace expanding:

\[ s = \frac{L_{rz}}{L_d} \]

where: \( L_{rz} \) – the length of the watercourse measured in the river axis, \( L_d \) – the length measured parallel to the slope of the valley

and the parameter of curvation of the river arcs:

\[ s_t = \frac{L_{rz}}{H} \]

where: \( H \) – the length of the chord of the river arc.
The $s_L$ in the existing Nida River curves is about 1.06, while in the unchannelled old ones, it varies from 1.1 to 1.4. The $s$ parameter in the regulated Nida varies from 1.09 to 1.3 in separate distances while after renaturalization, it can reach even 1.8. The natural parts are described by the $s$ parameter in values from 1.3 to 1.7. These parameters characterize the river with weakly developed curvatures, not naturally found in the middle and lower Nida, which is the reason for inordinate bedload transportation and instability of the bed during floods.

The next step was to provide calculations of the flow bandwidth of the modified or restored river channels. The parameters of regulated and restored river channels are collected in table 1:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>river width</th>
<th>river depth</th>
<th>flooded area ($Q_{1%}$)</th>
<th>valley capacity ($Q_{1%}$)</th>
<th>water depth in the valley during flood ($Q_{1%}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>current state</td>
<td>25</td>
<td>0.6</td>
<td>7.6</td>
<td>4.7</td>
<td>1.2</td>
</tr>
<tr>
<td>after restoration</td>
<td>14 - 50</td>
<td>0.4 – 0.8</td>
<td>11.2</td>
<td>8.7</td>
<td>0.8</td>
</tr>
</tbody>
</table>

The parametrization done with the help of Lambor’s method [7] shows that the width of the stable bed should be about 34 meters and the depth should equal about 0.5 meters. The Old Nida system is characterized by smaller channels of width ranging from 8 to 15 meters. The simulation was conducted by using the HEC-RAS model (Fig.4). The safety of passing floods will be preserved when the flow in the old channel river system will not exceed 25% of the total flow. Discharge in the main channel should not exceed $40.5 \, m^3/s^1$. Bankfull discharge in this region
equals 52 m³s⁻¹. The well balanced flooding of this area will flatten the peak of the flood wave and improve valley retention [11].

Fig. 4. The flooded area before and after the opening the valley of the middle delta.

The communication network state also increases the problem of flood hazard. The two roads and two railway lines run perpendicularly to the Nida River middle delta. The old narrow railway is not damaged as it runs on a low embankment equipped by numerous culverts. The local road from Skowronno to Sobowice is situated high enough to resist lower floods but the new extended bridge build over the revitalized Eastern Nida will solve the problem. The real border of the “delta” valley is national mining railway (LHS). It runs on very massive and high embankments. Unfortunately, it cannot be rebuilt so only two existing bridges are available: one for the main channel and the other one for the old river channel. Fortunately during floods, the main bridge is wide enough for the passing flood so backwater does not appear in the main channel. However, crossing the valley it blocks the slope flows and infiltration within the valley. This results in huge wetlands created upstream from the railway. The problem of backwater from the national road bridge is more realistic because during bigger floods it dams up water up to 1 meter. This cannot be accepted because the created backwater is dangerous for the citizens of Motkowice. To improve flow conditions, 100 meters of adjoining embankment should be taken down and the bridge should be elongated. After this is done, the bank will decrease to 0.3 meters [7].

To open the valley down to the wetlands, embankments localized below the village of Skowronno Gorne should be taken down. Initially, they were built so as to channel the Branka Stream by the shortest way to the regulated Nida River. The left embankment running along the Nida River from the Skowronno cross-section to Kopernia is also no longer needed
The influence of restoring flood capacity on the safety of the citizens and the environment

After conducting a simulation for this region, it can be pointed out that the reconstruction of valley retention will be followed by decreased water depth during floods and increased time of water distribution within the delta, which is beneficial for Pińczów and other villages localized downstream [1,2,12]. In spite of the fact that the water level will lower after the revitalization of the middle delta, the narrow railway is planned to be rebuilt higher up by 0.5 meters in order to preserve the village of Umianowce from flooding. Additionally, due to high substratum permeability, the system of channels collecting water from Umianowice to the Branka Stream shall be developed.

The change in landscape design will increase the attractiveness of this area. Regular flooding of the valley will make the soils more fecund and marching processes will discontinue. There are many interesting historical places in Ponidzie, including the narrow railway line “Express of Ponidzie.” After creating tourists infrastructure for recreation, this area will be very interesting for amateurs of active rest.

Conclusions

The analysis of the historical data makes it possible to conclude that the development of the water system in the delta was halted after the river training works done in the 1980’s.

As there have been no remarkable land use changes from the 19th century to the present, renaturalization is the optimal way of increasing flood protection in villages surrounding the middle delta including Umianowice.

The planned works will restore flow conditions to the ones before river training, in accordance to the actual development trends of the villages surrounding the “middle delta.”

The benefits will be much higher then losses in the agricultural production. The area localized close to delta will be irrigated better, which can increase the productivity of the surrounding fields. Biodiversity in the delta will also increase, which will make this area more attractive for recreation.

The proposed renaturalization will open the Nida River valley in the middle delta and will contribute to the increase in valley retention. This will decrease flood hazard in the cross-section of Kopernia and villages localized downstream from Pińczów.

The complicated river network system can reflect restoration works in an unexpected way. Therefore, monitoring should be performed during and after the works to indicate the concept’s deficiencies.
References:
4. Łajczak A., 2006, Regulacja rzeki a zagrożenie powodziowe, na przykładzie Nidy (River training vs. flood exposure. The example of the River Nida, Poland ), Infrastruktura i Ekologia Terenów Wiejskich (Infrastructure and Ecology of Rural Areas), PAN Kraków, Z. 4/1, pp. 217-233, in polish,
8. Madeyski M., Łajczak T., Zając T., 1998, The remarks on the meliorating works done in Umianowice village in a view of the preserving of the existing water conditions in the Nida River valley and their influence on the local ecosystem of wetlands (Uwagi na temat przeprowadzenia prac odwodnieniowych na terenie wsi Umianowice z jednoczesnym zachowaniem dotychczasowych stosunków wodnych w dnie Doliny Nidy warunkujących funkcjonowanie unikalnego ekosystemu rozlewisk wodnych). An expertise done for the Świętokrzyskie Landscape Parks in Kielce, in polish,
11. Bik P., Florek J., Strużyński A., 2006, Ochrona przed powodzią obszaru delty śródlądowej rzeki Nidy (Flood protection in middle delta of Nida River), Zeszyty Naukowe Akademii Rolniczej we Wrocławiu, Inżynieria Środowiska XV, nr 534, 59-68,

Submitted by:
Andrzej Strużyński, ph. +48 12 662 4172, rmstruzy@cyf-kr.edu.pl
Department of Hydraulic Engineering and Geotechnics, Agriculture University in Kraków, Mickiewicza Ave. 24/28 30-059 Kraków

załączone pliki:
1. Nida-ejpau-Struzynski_popr_po_recenzji_20110224.doc
2. Ryc_1a_1839.gif
3. Ryc_1b_1916.gif
4. Ryc_1c_1938.gif
5. Ryc_2.gif
6. Ryc_3.gif
7. Ryc_4.gif
8. Nida-ejpau-Struzynski_popr_po_recenzji_20110224.zip