Marek MAZURKIEWICZ

MSc. water construction

DOI: 10.15199/180.2020.1.4

VOICE IN DISCUSSION ON THE LOWER VISTULA RIVER CASCADE

GŁOS W DYSKUSJI NA TEMAT KASKADY DOLNEJ WISŁY

Summary: *The Lower Vistula term concerns the Vistula River at 391 km-long segment from the mouth of the Narew River where a considerable increase of the catchment area and the level of flows takes place. Due to the total amount of the managed water, the Lower Vistula River is a basic resource of hydro energy in Poland in spite of the small gross head in total, amounting to ca. 70 m and a very uneven flow. The utilization of the mentioned energy potential was based upon the plan anticipating a cascade of the possibly high water damming up, and the power plants with the storage work systems. Water navigation was expected to become the equivalent user of the cascade.*

Key words: *Lower Vistula, cascade, water damming*

Streszczenie: *Określenie Dolna Wisła dotyczy Wisły o długości 391 km od ujścia Narwi, gdzie następuje znaczący przyrost zlewni i wielkości przepływów. Dolna Wisła ze względu na ogólną ilość prowadzonej wody stanowi w kraju podstawowy zasób energii wodnej, mimo w sumie niewielkiego łącznego spadu brutto, wynoszącego ok. 70 m oraz bardzo nierównomiernego przepływu. Wykorzystanie tego potencjału energetycznego bazowało na planowaniu utworzenia kaskady możliwie wysokich piętrzeń wody, z elektrowniami o szczytowym charakterze pracy. Równorzędnym użytkownikiem kaskady miała być żegluga wodna.*

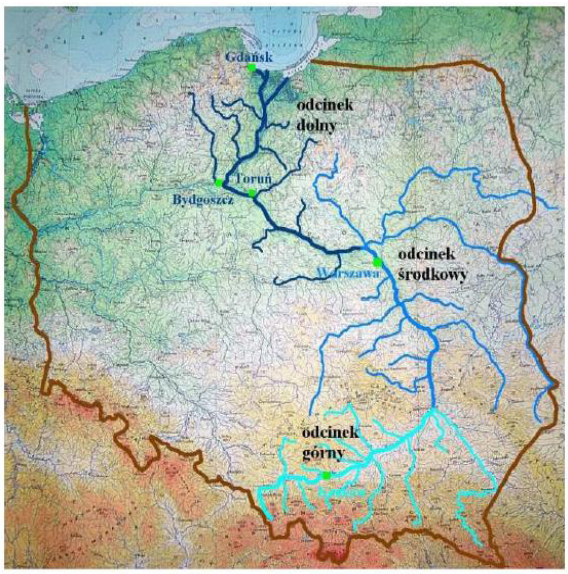
Słowa kluczowe: *Dolna Wisła, kaskada, spiętrzenie*

The implementation of the cascade was commenced in the sixties of the 20th century from the highest water barrage in Włocławek, with water head H = 11.5 m, with the storage power plant of discharge Q_i = 2150 m³/s, being more than twice higher than the mean flow. The construction of the successive barrage in Ciechocinek, which was expected to create the compensating reservoir for the electric energy plant in Włocławek has not been undertaken until now. The decades-long storage work system in the Włocławek power plant has brought about the erosion of the Vistula River bed above the barrage what is a threat to the stability of the dam.

In the power plant at the Ciechocinek barrage and later on, at the barrage with the changed name Nieszawa, there was anticipated the flow system work, with the installed discharge Q_i = ca. 1200 m³/s, i.e. ca. 1.3 $Q_{śr}$.

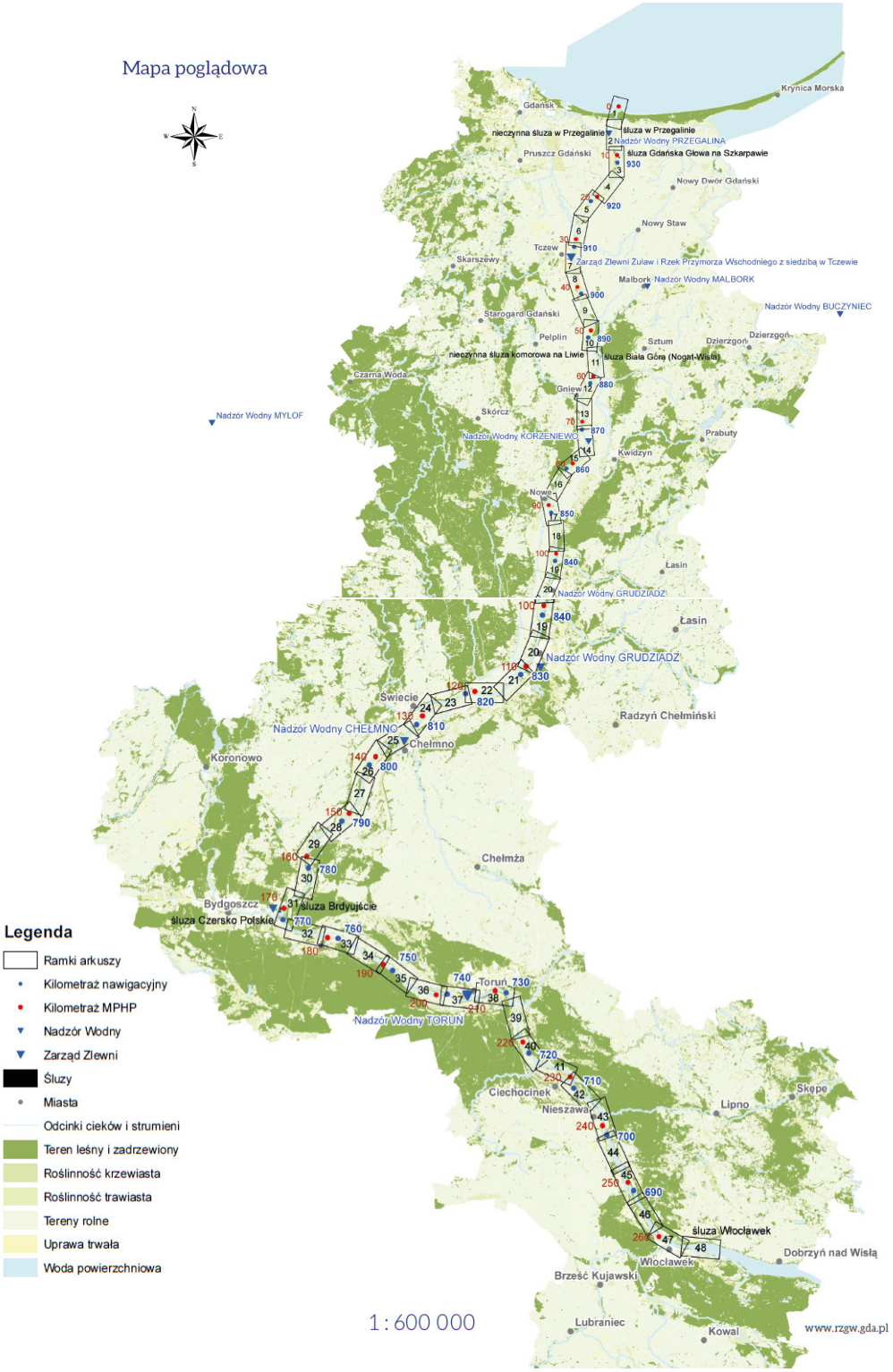
The suggestion of the discussed barrage under the name Siarzewo, being prepared by the Energy Sector, provides for the damming H = 8.5 m and construction of power plant with discharge Q_i = 1800 m³/sec. The installed capacity of the power plant was designed for the conditions of the head which would be created after the erosion of the lower stand. The intensive erosion was expected as the run-off from the Siarzewo barrage would occur to a natural segment of the river bed where the fluctuations of the water level between the mean flows (SNQ) and the installed flow, led down by the power plant were equal to ca. 2.5 m. The size of the fluctuations of the mentioned water levels would not be reduced by the targeted implementation of the next barrage at Solec Kujawski, being situated at the distance of 51.6 km from Siarzewo.

Fig. 1. Map of the Vistula divided into zones
Source: www.doi.prz.edu.pl



The work of hydro plant in the peak system with discharge Q_i = 1800 m³/s causes that with the damming H = 8.5 m. the energy head with the mentioned flow will amount only to 4.9 m. the reduction of the installed discharge to Q_i = 1200 m³/s and the change into the basic work scheme may increase production of the energy plant by more than 20%.

Map 1. Characteristics of the Lower Vistula Inland Waterway (from 684,000 km to 942.300 km)



The existing barrage in Włocławek divides the Lower Vistula River Cascade into two parts. The upper part should be considered as being commenced at the Vistula River from the future barrage, stabilizing the level of water in the Warsaw Vistula River (km 524.5) and at the Narew River from the Dębe barrage. The lower 267 km-long part begins below Włocławek. According to the analyses and the preliminary proposal of the National Water Management Polish Waters („Wody Polskie"), in this part, there is anticipated the implementation of 5-barrage cascade (Variant W3C) with the parameters shown in Tab. 1.

The main purpose of the mentioned barrages is to utilize the energetic and navigation potential of the Vistula River below Włocławek.

Tab.1. The parameters of Lower Vistula River Cascade according to the project of the National Water Management „Wody Polskie"

Parameters	Cross-section of damming/Reservoir				
	Siarzewo	Solec Kujawski	Chełmno	Grudziądz	Gniew
Km of river	706.4	758.0	801.5	835.0	876.3
Level of damming, m above sea level	46.0	37.5	29.0	22.0	15.0
Height of damming H_{br} m	8.5	8.5	7.0	7.0	7.2
Size of head at SSQ m	6.1	6.7	5.5	4.0	5.7
Length of stand, km	31.9	51.6	43.5	33.5	41.3

The basic assumptions result from the situation and the long-time analysed connections. During the recent updating, the Tczew barrage has been given up. From the statement it is followed that after the years since development of the first conceptions of the cascade, its basic drawbacks have not been changed.

The suggested cascade may utilize only 38.2 m of the damming height H_{br} and ca. 28 m of head at SSQ 83% and 60% respectively, from the theoretical head H_{br} = 46 .0 m. The shortest stands are found in Siarzewo (31.9 km) and Grudziądz (33.5 km) reservoirs. The Solec Kujawski reservoir has the longest stand, i.e. 51.6 km. The natural river bed from Gniew to the estuary has a length of 65.2 km.

From Siarzewo to the mouth of the Drwęca River, there are the shallow sites which require dredging. The similar segments of shallow sites occur below the Brda River (km 767 – 782), in the region of Chełmno (806 – 815) from the mouth of the Mątowa River to Opaleń (km 850 – 860) and in the region of Tczew (km 905 – 920). The implementation of high damming shall not, therefore, eliminate completely the segments of shallowing.

Below the Siarzewo and Gniew barrages, the natural river segments are found where the intensive erosion may occur.

Fig. 2. Wisła at the height of Siarzewo (May 2016)
Source: www.commons.wikimedia.org

Apart Siarzewo, the power plants, being situated at the barrages, have the installed discharges 1300 m^3/s each and they will probably work according to the scheme of sub-peak work.

For few years, after having signed the AGN Convention by Poland, the Lower Vistula River Cascade has obtained a strong support as the element of the international waterways: E70 in the segment from the Brda River mouth to Nogat and E40 in the segment from Gdańsk to Warsaw.

However, the indisputable approval of directions and international parameters of water ways, as established several dozen years ago without our participation, may not affect the support of the economic justification of the purposefulness of the Cascade implementation. The water way with the parallel direction from the west to the east is more important direction for Poland and the role of the Cascade may result from its linking with the mentioned parallel way.

The waterway may be fully utilized as late as after the completion of its last segment what may cause a long period of freezing the outlays, limiting the general effectiveness of the Cascade.

The heights of water lifting (8.5/7.0 m), as established for the adopted location of the barrages, correspond to the levels of the so-called determining (design) water flow, creating a big flood threats; for their limitation, it is necessary to prepare and maintain appropriately the expensive technical equipment. The discussed heights of damming:

- Deplete the capacities of inter-embankments to retain water at the flood flows (e.g. for Siarzew, the flood protecting capacity is equal only to ca. 10 million m^3);
- Cause a serious effect on the adjacent territories, requiring the performance of work and protective devices;
- Require rebuilding of majority of the flood embankments into side dams with considerably higher technical requirements and costs;
- Cause the concentration of flood flows on the width of the weir cross-section;
- Require deep foundations of the construction under the complicated water and river bed conditions.

Fig. 3. Energa S.A. investment project in Siarzewo - visualization of the Siarzewo Water Step prepared by Biuro Projektów S. Source: www.wody.gov.pl/aktualnosci

The arguments concerning the purposefulness of considering the waterway in the cascade with a small quantity of locks to reduce the locking time are disputable. The time of locking is also dependent on some other factors, e.g. the effectiveness of navigation stock. There is an unrepeatable occasion for creating the completely new stock.

In the solutions of the Lower Vistula River Cascade, variant of lower damming of the order H = 4.0 ÷4.5 m has never been exhaustively analysed.

Only variant of the so-called Small Cascade with the adjective „ecological" (organic) revealed a certain link to such system of cascade. The mentioned variant (ESR) is referred to for the

justification of the choice of high water lifting (Variant W3C). Due to the range and accuracy of the mentioned elaboration, it could not give the results which might serve for the comparison with the high damming cascade, being always recognized as the only one variant of the Lower Vistula River development.

When developing the conception of the Small Cascade (variant ESR) with 11 barrages, the possibility of utilizing the cascade of barrages with the similar damming heights has not been employed although it would unify the solutions of the barrages and power plants. In the electric energy plant, the equal discharges Q_i = 1400 m^3/sec were adopted but the heights of the lifting amounted from 2.6 m to 5.2 m, causing a considerable differentiation of the solutions and difficulties in the implementation.

We should, however, pay attention to the fact that in the variant of the Small Cascade it is possible to eliminate the segments of shallow sites and the utilization of the water fall is significantly higher than in variant W3C. The general height of the Cascade dammings is equal to 41.75 m and the sum of the falls at the flows SSQ is 37.4 m what constitutes as much as 90% and 81% of the theoretical head H_{br} = 46.0 m, respectively.

Fig. 4. South Przegalina Lock.
Source: www.rzgw.gda.pl

Fig. 5 South Przegalina Lock, view of the upper gate from the water level.
Source: www.rzgw.gda.pl

The problem of the implementation of the cascade with lower damming is very important. From the nature of the river bed and the inter-embankments it is clearly followed that the application of dammings on the levels of shore water may create a new quality of investing and exploitation of the cascade; the more so because the values of flows on the whole length of the Cascade are inconsiderably changing.

The water engineering investments are generally long-lasting but also expensive and have a significant influence on the environment. The later „adaptations" or „supplements" are difficult and sometimes, impossible. Therefore, the programme of the investments must be precisely thought out and comprehensively justified. It will be the invested money of every citizen who should be considered as a shareholder. It is necessary to anticipate the possibility of their visits at the objects on each stage of the implementation and exploitation and to ensure the reasonable return of the costs and dividends.

Coming back to Siarzewo, we should remember that the barrage below Włocławek has to meet two basic goals: „supporting" the barrage in Włocławek and obtaining the appropriate compensating capacity for power plant in Włocławek. Meanwhile, the Siarzewo barrage looks like a successive Włoclawek, which may cause now the similar problems shifted into the Ciechocinek region and below it.

When designing Siarzewo, the main problem of the investor included probably the installation of maximum capacity and overcoming the different ecological and administrative barriers.

The installation of maximum possible power excluded the consideration of dividing the reservoir ***via*** the implementation of indirect barrage in the region of Bobrowniki.

The analysis of the two-barrage Siarzewo could be valuable for the determination of typical solutions and the application of uniform equipment and advanced pre-fabrication in the successive barrages of the Cascade with dammings up to 4.5 m what may decisively facilitate its implementation. Two damming constructions, replacing one, twice higher construction may be noticeably cheaper than the mentioned one.

The Lower Vistula River Cascade with the application of dammings of height H = 4.0÷$.5 m should be supplemented with the barrages in Tczew and Przegalina in the lower part and the „supporting" barrage in Dębe on the Narew River and the barrage on Warsaw Vistula River.

The barrages on the Narew River and The Vistula River in Warsaw would commence the Lower Vistula River Cascade from the top. The barrages Tczew and Przegalina would facilitate the inflow of the sea ships as far as to Tczew and would allow the implementation of the modern linking of the Vistula River Lagoon and Gdańsk and Tczew, with four exits to the sea.

Summing up of the argumentation

The Lower Vistula River has a big energetic and navigation potential. It is justified to run the activities aiming at the management of the existing potential as a whole or in the parts.

The development of the mentioned potential is possible via the implementation of the cascade of the lifting barrages.

The management of the Lower Vistula River Cascade should be understood as a system of lifting barrages with uniform damming of the order from H = 4.0 to 4.5 m commencing from the Warsaw Vistula River and Dębe on the Narew River and ending at the Przegalina barrage, with the consideration of the existing Włocławek barrage, with untypical damming up H = 11.5 m.

The dammings up to 4.5 m, eliminating variants with dammings of height up to 8.5 m, as being considered until now, are found in the range of the levels of shore water, what facilitates:

- Reduction of the size of weir via inclusion of floodplain of inter-embankment to let pass WW;
- Maintaining the majority of the existing flood embankments without the necessity of their rebuilding into side dams;
- The complete exchange of the stored water during 2 – 3 days as early as at low flows;
- Preservation of the natural possibilities of retaining the flood waves in the existing inter-embankments;
- Limitation of the effect of damming on the adjacent environment;
- Stimulation of economic development of the neighbouring regions along the whole length of Lower Vistula River Cascade (in Polish: KDW) via arrangement of greater quantity of building sites and river passages.

The management of KDW by the application of the barrages with the uniform height of damming:

- Creates a waterway with similar depths on the whole length of the stands;
- Enables designing the typical technical solutions with the application of significant pre-fabrications and stream-like system of the implementation of barrages;
- Facilitates starting a profitable production of technological equipment.

In respect of the energetic utilization of KDW, giving up the system of peak work scheme is advised.

To justify the economic purposefulness of energetic utilization of the potential of the Lower Vistula River, the author of the present paper would recommend the performance of comprehensive analysis of technical solutions together with the application of greater number but smaller traditional turbines in power plant in vertical system, facilitating their build-in in weir constructions.

In the case of a shallow river, the application of smaller turbines limits the depth of the power plant situation. In rather complicated background on the Lower Vistula River, each decrease of the foundation depth will have a decisive influence on the costs and acceleration of the implementation.

The unification of the technological and energetic equipment for the whole KDW would facilitate the start up of the national production.

The implementation of the Lower Vistula River Cascade requires considering the theoretical, even being not widely employed solutions; in the engineering practice, the application of the cascade of lower barrages is a normal matter. It is better to think twice or thrice before commencing the field work, requiring the use of enormous financial means and their freezing for the period of the cascade implementation.

References

[1] Ekspert o Stopniu Wodnym Siarzewo. 2020, https://wody.gov.pl/aktualnosci/973-ekspert-o-stopniu-wodnym-siarzewo,

[2] Razem dbamy o przyszłość naszych wód. Informator nawigacyjny śródlądowej drogi wodnej Dolnej Wisły. Gdańsk 2014, RZGW Gdańsk,

[3] Wisła at the height of Siarzewo, May 2016, www.commons.wikimedia.org,

[4] www.rzgw.gda.pl,

[5] Physico-geographical regionalization of Poland Macroregion 314.8 Lower Vistula Valley, www.commons.wikimedia.org,

[6] Wiadomości z Torunia. Tama za 2,2 mld zł. Dwa lata na plany, potem budowa. Tomasz Ciechoński. 4 marca 2018, www.torun.wyborcza.pl,

[7] www.pl.wikipedia.org/wiki/Stopień_wodny_Siarzewo,

[8] Magdalena Januszek. Kaskada Dolnej Wisły – reaktywacja projektu w zasięgu ręki?, 2018, Źródło: GDMT geoinżynieria drogi mosty tunele 1/2018 [62], www.inzynieria.com

[9] Romuald Szymkiewicz, Problemy gospodarczego wykorzystania Dolnej Wisły, Budownictwo i Inżynieria Środowiska, 2017.110, DOI: 10.7862/rb.2017.110

Article reviewed

Received: 27.12.2019./Accepted: 08.04.2020