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Modeling of Hydrological Conditions for the Restoration of Przemkowsko-Przecławskie Wetlands

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1. Introduction

Wetlands are defined as areas of shallow ground water table, and high soil moisture (permanently or periodically flooded), with mineral or organic soils [10] and characteristic flora, that forms hydrophilius vegetation habitats [14].

Wetlands, with their high biodiversity, have been classified as some of the richest ecosystems on Earth. Unfortunately, many previously existing wetlands face the danger [19, 20] of considerable transformation of their natural environment. The increasing dynamics of this process in last decades, which visibly exceeds periodic fluctuations, was the basis to formulate protection concepts and undertake wetland restoration measures.

Once the transformation of wetlands has been widely recognized, in many European countries, actions directed at the restoration of peat-forming plant communities have been implemented. In the same time, the requirements of wetlands protection were introduced into the field of water management, creating the need to elaborate new useful tools for the planning of operational missions in river catchments [15]. The tools, that easily gained usefulness and were considered to be practical in a straightforward manner, were mathematical models of ground water flow.

Nowadays, the execution of restoration measures demands to be preceded by the forecast of their influence on hydrological conditions of sites selected for restoration, and it also requires consideration, if there is the possibility to fulfill hydrological criteria, developed for certain wetland habitats. [8, 17]. This justifies the contemporary research objectives, directed at the elaboration of proper hydrological criteria for wetlands restoration, that can be used in modeling of surface and ground water levels on disturbed wetlands,in order to find out which plant communities would potentially appear on the restoration area, as a result of applying certain rules of hydraulic structures operation.

2. Material and methods

The goal of this paper is to model ground water flow on the disturbed wetland area for the proposed water management variants and compare the results of the modeling with the use of hydrological criteria. These criteria will describe characteristic ground water levels and inundation frequencies for different wetland habitats, on the basis of research performed on reference wetlands in the Valley of the Biebrza River in the North-Eastern Poland [12, 13]. The effect of the performed research will be the determination of such areas within the restoration site, that will be occupied potentially by swampy habitats and those areas, that will be covered by wet or moist meadows [1].

2.1. Study site

The selected study site is known as„Przemkowsko-Przecławskie Wetlands" located in the south western Poland, in the distance of about 100 km from the border with Germany (figure 1). They form a large, interrelated and highly valuable complex of wetlands, that used to be significantly transformed in last decades for the need of intensive agriculture [1, 3, 4, 9].

Rys. 1. Położenie Bagien Przemkowsko-Przecławskich, źródło: http://www.eko.org.pl/kropla/archiwum/jesien98/bag.htm
Fig. 1. Location of Przemkowsko-Przecławskie Wetlands, source http://www.eko.org.pl/kropla/archiwum/jesien98/bag.htm

2.2. Ground water model

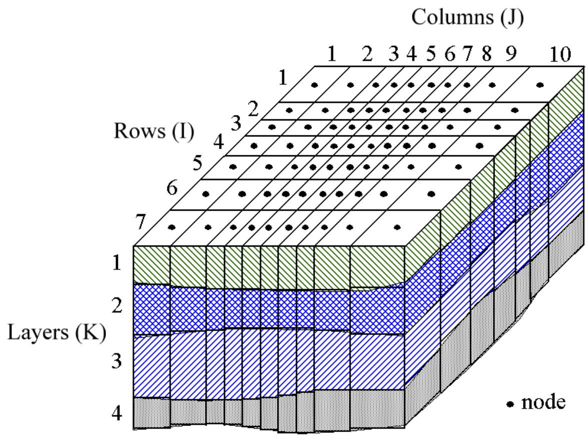
In this study we utilized a common and recognized computer code MODFLOW, for modeling ground water flow in fully saturated porous media. The governing, partial- differential equation of this model can be written in the following form [11]:

$$\frac{d}{dx}\left(T_x \frac{dH}{dx}\right)+\frac{d}{dy}\left(T_y \frac{dH}{dy}\right)+\frac{d}{dz}\left(T_y \frac{dH}{dz}\right)-W = S\frac{dH}{dt} \tag{1}$$

where:

T_x, T_y, T_z, – aquifer transmissivities in three directions: x, y, z [m^2/s],
H – hydraulic head [m],
W – inflow or outflow from internal sources or sinks of water [m/s],
S – specific yield [-], defined as the amount of water[m^3] that a unit area of an aquifer [m^2] can release with a unit decline in hydraulic head [m].
t – time [days, years etc.]

Analytical solutions of equation 1 are possible in only very few simple cases. That's why most often it should be solved numerically [11]. For the numerical solution, equation 1 is replaced by proper differential equations, that describe the mass balance for a set of finite cells, into which the ground water system is discretized (see example in figure 2).

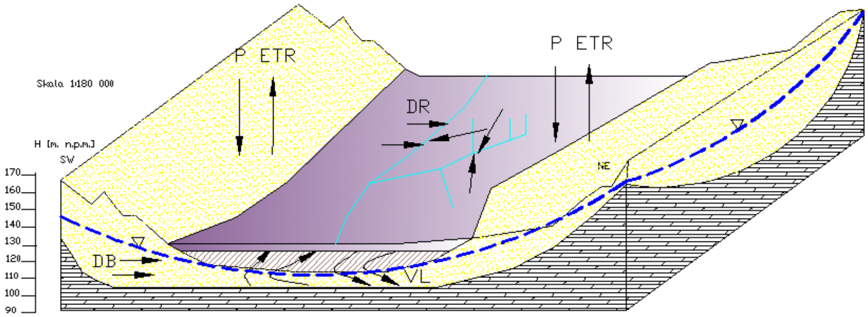


Rys. 2. Przykładowa siatka obliczeniowa (7 rzędów, 10 kolumn, 4 warstwy)
Fig. 2. Exemplary model domain (7 rows, 10 columns, 4 layers)

Input parameters include values of transmissivity (T) or saturated hydraulic conductivity (K_a) of main geological layers, the conductivity and the thickness of riverbed materials, vertical leakance (Vl) between main hydro-stratigraphic units (vertical flow term [11]), heads in the rivers, heads or fluxes on model boundaries, fluxes representing rainfall and evapotranspiration.

A simple geologic model was developed from the materials observed in 42 soil borings taken across the site (figure 3). The resulting model includes a basal layer of clay-rich glacial till that is overlain locally by 5 m – thick alluvial sand. The alluvial sand and till are, in turn, overlain by layers of loams an sandy loams that average 7 m in thickness. The top layer of the geological model, that overlays loams and sandy loams is composed of peat, sands and loamy sands (figure 3).The analysed ground water system was then discretized into a number of cells, becoming a discrete system instead of a continuous one, for which the heads and flows were computed. The finite difference grid was arranged into rows, columns and layers. Rows and columns cover the area under consideration in plan view, and the number of layers is assigned to main hydrostratigraphic units (i.e. aquifers and aquitards) [1], For the area of Przemkowsko-Przecławskie wetlands a two layer model was constructed with one layer representing shallow, uppermost geologic formations (peat, loamy sand, sands) in which a phreatic ground water level was observed, while the second layer represented a regional,sandy aquifer of a confined type (existing in the alluvial sand). The resistive layer, separating the upper and the lower aquifer (built of loams an sandy loams that average 7 m in thickness), was simulated by specifying proper vertical leakance term [1, 11] in the first model layer. A finite difference grid was superimposed on the geologic model . The grid consisted of 217 columns, 406 rows, and 2 layers, resulting in a total of 176204 cells. The horizontal dimensions of the grid cells were uniform (100 m by 100 m), and the vertical spacing varied adequate to the depths of the aquifers known from geological logs

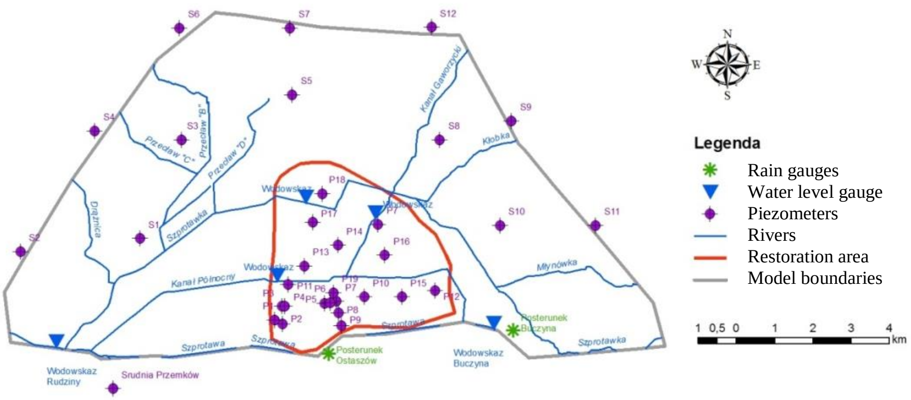
After the model identification and set up,the calibration process was performed as trial and error procedure, in order to estimate such parameter values, for which a reasonable match between modeled and observed ground water levels was achieved [1, 11]. Ground water levels used for calibration were measured in the network of piezometers and wells (figure 4) and the target parameter values were given in tables 1,2 and 3. These values were finally acceptable after the calibration process, by a positive estimation of model quality on the basis of so-called Nash-Sutcliffe efficiency [1] (table 4) and the correlation coefficient (R), mean error (ME), mean absolute error (MAE) and standard error (SE) (table 5). Then the model was exploited to simulate ground water levels for the proposed water management variants, with a decade time step, for the period 1965–1988.



P- precipitation
ETR- evapotranspiration
DR- river drainage
DB- lateral inflow
VL- vertical leakance of ground water

Sands, loamy sands, peat
Sandy loams
Sands
Glacial till

Rys. 3. Schemat hydrogeologiczny obiektu badań
Fig. 3. Hydrogeological scheme of the study site



Rys. 4. Sieć obserwacyjna
Fig. 4. Monitoring network

Tabela 1. Współczynnik filtracji pierwszej warstwy modelu w kierunku poziomym (średnie ważone)
Table 1. Horizontal hydraulic conductivity of the first model layer (weighted average)

Soil number	Soil type	Mean thickness [m]	Horizontal conductivity [m/s]			Weighted average [m/s]		
			min.	śr.	max.	min.	śr.	max.
1	Loamy sand	0.85	$5.8 \cdot 10^{-7}$	$2.1 \cdot 10^{-6}$	$5.8 \cdot 10^{-6}$			
2	Sandy loam	0.8	$1.2 \cdot 10^{-5}$	$2.3 \cdot 10^{-5}$	$3.5 \cdot 10^{-5}$	$2.5 \cdot 10^{-5}$	$3.9 \cdot 10^{-5}$	$5.5 \cdot 10^{-5}$
3	Sand	0.8	$6.2 \cdot 10^{-5}$	$9.7 \cdot 10^{-5}$	$1.3 \cdot 10^{-4}$			

Tabela 2. Wartości współczynników filtracji w kierunku pionowym (śr. ważone)
Table 2. Vertical hydraulic conductivity of the first model layer (weighted average)

Soil number	Soil type	śr. miąższość [m]	Vertical conductivity [m/s]			Weighted average [m/s]		
			min.	aver	max.	min.	aver	max.
1	Loamy sand	0.85	$5.8 \cdot 10^{-8}$	$3.5 \cdot 10^{-6}$	$4.1 \cdot 10^{-5}$			
2	Sandy loam	0.8	$2.2 \cdot 10^{-7}$	$4.2 \cdot 10^{-6}$	$6.7 \cdot 10^{-6}$	$4.5 \cdot 10^{-7}$	$3.6 \cdot 10^{-6}$	$1.9 \cdot 10^{-5}$
3	Sand	0.8	$1.1 \cdot 10^{-6}$	$3.1 \cdot 10^{-6}$	$7.1 \cdot 10^{-6}$			

Tabela 3. Przewodność hydrauliczna koryt cieków
Table 3. Hydraulic conductance of the river beds

Measurement number	Riverbed conductivity [m/s]			W[m]	L[m]	m_0[m]	Conductance [m^2/s]		
	min.	Aver.	max.				min.	aver	max.
1	$2.40 \cdot 10^{-7}$	$1.70 \cdot 10^{-6}$	$3.40 \cdot 10^{-6}$	5.5	100	1.1	$1.20 \cdot 10^{-4}$	$8.50 \cdot 10^{-4}$	$1.70 \cdot 10^{-3}$
2	$1.40 \cdot 10^{-7}$	$1.40 \cdot 10^{-6}$	$4.40 \cdot 10^{-6}$	4.5	100	0.7	$9.00 \cdot 10^{-5}$	$9.00 \cdot 10^{-4}$	$2.83 \cdot 10^{-3}$

Tabela 4. Jakość modelu według miary Nasha- Sutcliffa(dla kalibracji)
Table 4. Nash-Sutcliffe efficiency of the model (calibration)

Error	C1	C2	C3	C4	C5
value	0,12	0,71	0,72	0,72	0,83
optimum	0	1	1	1	1

Tabela 5. Jakość modelu dla okresu weryfikacji
Table 5. Model quality for validation period

Error	Piezometers																	
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
R	0.93	0.90	0.90	0.87	0.88	0.86	0.88	0.90	0.89	0.88	0.87	0.89	0.85	0.89	0.88	0.87	0.90	0.62
ME	0.11	0.18	0.20	0.14	0.15	0.16	0.14	0.22	0.16	0.17	0.16	0.10	0.17	0.16	0.15	0.17	0.17	0.23
MAE	0.15	0.23	0.25	0.18	0.20	0.21	0.22	0.31	0.25	0.19	0.22	0.18	0.18	0.13	0.21	0.26	0.30	0.31
SE	0.29	0.29	0.34	0.38	0.37	0.38	0.35	0.40	0.37	0.33	0.32	0.35	0.36	0.27	0.36	0.35	0.42	0.44

wells				
S1	S3	S5	S8	S10
0.87	0.8	0.75	0.69	0.68
0.19	0.18	0.24	0.19	0.17
0.26	0.28	0.34	0.27	0.23
0.34	0.32	0.43	0.35	0.36

2.3. Water management variants

The results of contemporary hydrological and phytosociological research proved a disturbance of Przemkowsko-Przeclawskie wetland habitats, and pointed at the need to change their hydrological conditions [2–5]. A diverse and untypical course of plant communities succession was observed on the wetlands area, probably caused by quantitative and qualitative changes of water feeding the wetland [8, 9]. As it was made evident, the contemporary need to restore more natural character of plant communities composition, and keeping them in good ecological status, requires changes of hydraulic structures operational parameters [9].

In the pristine state, a fluviogenic feeding type existed with the wetland area, which nowadays cannot be restored due to social and economic constrains [5–7]. In such a situation, the wetness of Przemkowsko Przeclawskie wetlands may be gradually increased by ground water feeding [2], leading to the formation of soligenious peatlands. In case the ground water feeding becomes insufficient, it is resolved to additionally use surface water reserves of the Szprotawa River, however, in previous ecohydrological studies it was pointed out, that surface water quality will not bring back primary plant communities composition due to being too eutrophic [5].

Through allowing to use surface water feeding it can be expected, that within Przemowsko-Przecławskie wetlands a mixed, heterogenous hydrological feeding type will be shaped, similar to examples from the Lower Biebrza River in Poland, which is covered by fluviogenic wetlands with partial soligenious feeding.

Basing on existing analyses of water balance for the catchment of the Szprotawa River at Buczyna gauge [2–6] and on the actual inventory of hydraulic structures at the Lower Silesia voivodship [9] six water management variants were elaborated, which should contribute to restoration of hydrological conditions within Przemkowsko-Przecławskie Wetlands. The choice of the "best" variant was dependent on ground water system modeling, and comparing the results with the use of hydrological criteria [1].

The variant named as „0" described the actual physical status of the wetlands hydrological system and was assumed to be the reference one. Variants „1" and „2" involved actions directed at the increase of ground water feeding. Variant no 1 simulated a slow down of ground water outflow by hydraulic structures (fig. 5), while variant no 2 involved all actions considered in no .1 and additionally the ground water pumping station was switched off (fig. 5) [2, 8].

According to existing ecohydrological analyses variants 1 and 2 will provide ground water feeding of an appropriate quality [8], however the magnitude of the soligenious feeding may not be sufficient to increase the wetness of habitats [3, 4]. In this situation, variants „3", „4" and „5" were assumed, which are an attempt to partially regain fluviogenic feeding type (surface water flooding). In those variants it is allowed to use characteristic surface water reserves of the Szprotawa River: the lowest of the low long term reserve for the period 1965–1988 (scenario 3), the mean of the low reserves for the period 1965–1988 (scenario 4) and the highest of the low reserves (scenario 5). The reserves were determined by analysing the water balance of the Szprotawa River [3–5]. They were calculated by subtracting the needs of the fishponds. located close to the wetlands, and the indispensable flow from the mean decade discharges of the Szprotawa River. The reserves were supplied to the Northern Channel by an existing sluice in the dyke of the Szprotawa River (figure 5).

In each of the water management variants a different operating parameters of hydraulic structures were applied. For the existing sluice in the dyke of the Szprotawa River, and for the pumping station proper discharge rates were applied, and for the weirs the maximum or minimum water levels were set (table 6).

The results of modeling for all the variants were compared with the use of hydrological criteria. The application of hydrological criteria was directed at the estimation of habitat wetness, that would contribute to the development of swampy ecosystems. With the use of those criteria characteristic ground water levels were described in the valley of the Biebrza River [13–16] which is treated as reference area, because of the existence of intact, natural and well-preserved wetlands. Following hydrological characteristics were analysed:

- Mean ground water levels (MML),
- Inundation frequency (IF),
- Mean ground water level amplitudes MdH,
- Mean low ground water levels (MLL).

Tabela 6. Podstawowe parametry urządzeń wodnych
Table 6. Basic operational parameters of hydraulic structures

Variant	Water damming by weirs	Discharge of the pumping station [m^3/s]	Sluice discharge [m^3/s]
0	Min	$Q_{max} = 0{,}02\ m^3/s$	0
1	Max.	$Q_{max} = 0{,}02\ m^3/s$	0
2	Max.	$Q = 0\ m^3/s$	0
3	–	$Q = 0\ m^3/s$	LL
4	–	$Q = 0\ m^3/s$	ML
5	–	$Q = 0\ m^3/s$	HL

(LL – the lowest of the low reserves, ML – mean of the low reserves, HL – the highest of the low reserves)

Those characteristics were calculated for the area of Przemkowsko- Przecławskie Wetlands with the use of ground water flow model, and then they were compared with threshold values [15] determined for the Biebrza Valley, considered to be reference wetland site (table 7).

Hydrological characteristics of potential swampy habitats were observed on the areas covered by reed rushes, reed canary grass, tall sedge communities and peat-moss communities in the Biebrza River Valley. Those communities are characterized by mean water stages occurring at or over the surface of the land and by mean low water stages at depths not higher than 0,6 m, and also by inundation frequency not exceeding 30%. Potential heterogenity of hydrological alimentation of swampy habitats was considered by introducing ground water amplitude, that distinguishes swampy habitats of a low amplitude ($SdH < 0{,}7m$) and a high amplitude of ground water table ($SdH \geq 0{,}7m$) [15].

The habitats for which mean ground water levels ranged from 0 to 0,3 m below land surface, and inundation frequency varied from 10 to 30% were considered to be „wet" habitats. In the reference site – the Biebrza Valley, this type of habitats includes mainly king-cup (Caltha) and herbaceous communities.

Tabela 7. Wartości progowe charakterystyk hydrologicznych dla wydzielenia siedlisk obszarów mokradeł
Table 7. Threshold values of hydrological characteristics for different wetland habitats

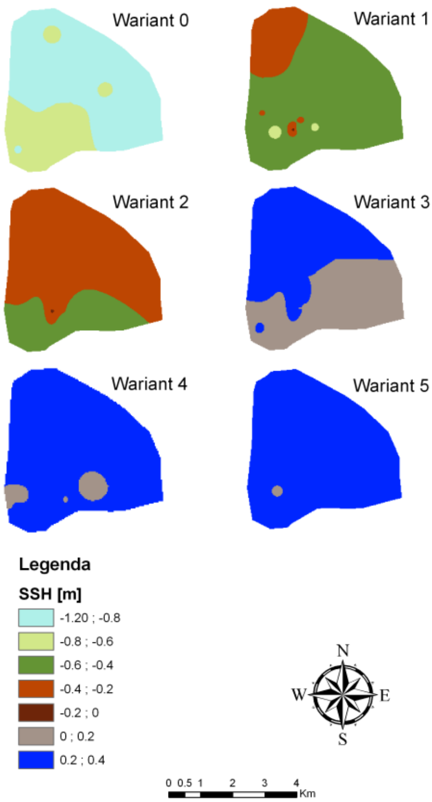
<table>
<tr><th>Habitat type</th><th>MML [m]</th><th>IF %</th><th>MdH [m]</th><th>MLL [m]</th></tr>
<tr><td>Swampy habitats of a low ground water amplitude</td><td rowspan="2">>0</td><td rowspan="2">>30</td><td>< 0,7</td><td rowspan="2">> -0,6</td></tr>
<tr><td>Swampy habitats of a high ground water amplitude</td><td>> 0,7</td></tr>
<tr><td>Wet habitats</td><td>< -0,3 ; 0></td><td><10 ; 30></td><td>–</td><td>–</td></tr>
<tr><td>Moist habitats</td><td>< -0,6 ; -0,3></td><td><10</td><td>–</td><td>–</td></tr>
</table>

The third distinguished category of habitats requires the combination of water management and extensive agricultural use for successful restoration. They were determined to be „moist” habitats, for which the mean depth of the ground water table during the vegetation season ranges from 0,3 to 0,6 m, and the inundation frequency does not exceed several days [13, 18].

Rys. 5. Urządzenia wodne na obiekcie badań
Fig. 5. Hydraulic structures on the research area

3. Results and discussion

Restoration variants on the Przemowsko-Przecławskie wetlands area were analysed with the use of ground water flow model in order to find out to which degree controlled water table management can provide for the re-formation of a swampy ecosystem. The main aim of the analyses was to determine the surfaces of potentially swampy habitats, that would be present on the restoration area after the change of water management principles. Figure 6 shows mean, long-term ground water levels for the analysed restoration variants, achieved through modeling of ground water flow, with decade time step for the period 1965–1988.



Rys. 6. Średnie stany wód gruntowych wg proponowanych wariantów
Fig. 6. Mean ground water levels for the proposed variants

For the variant that describes the actual status of the hydrographic system, mean ground water levels ranged from 0,6 to 0,8 m below the land elevation. The slow down of ground water outflow (variant 1) and restriction of ground water abstraction (variant 2) caused that the depth to mean ground water table ranged from 0,2 to 0,6 m. The supply of surface water reserves enabled to reach ground water heads at or over the land elevation

In the next stage, inundation frequency was analysed. In case it ranges from 25 to 50% or more, a swampy habitat may develop, but since it reaches below 25%, a potential for wet or moist habitat is created (figure 7).

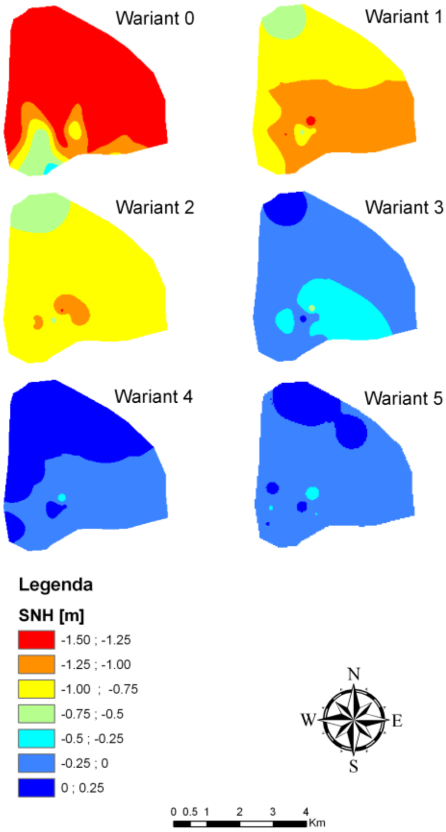
Rys. 7. Częstotliwości zalewu wg proponowanych wariantów
Fig. 7. Inundation frequencies for the proposed variants

Inundation frequency did not exceed 25% in the scenario describing the actual status of the hydrographic system and also in the variants assuming the increase of ground water feeding (1 and 2) The areas of the frequency higher than 50% appeared as a result of supplying surface water reserves.

In the next stage of analyses the ground water table amplitudes were taken into consideration (fig. 8). Their values distinguish swampy habitats in respect of hydrological alimentation heterogenity.

Rys. 8. Średnie amplitudy zwierciadła wody gruntowej wg proponowanych wariantów
Fig. 8. Mean ground water amplitudes for the proposed variants

Ground water amplitudes ranged from 1,25 m to 0,5 m when the ground water outflow was attempted to be slowed down and coupled with the supply of the lowest surface water reserves (LLQ res.). After the supply of MLQ (mean low) or HLQ (the highest of the low) reserves there appear such wetland areas, on which the amplitude decreases to the range:0,25–0,5 m. Fig 9 presents mean low ground water levels for the analysed variants.

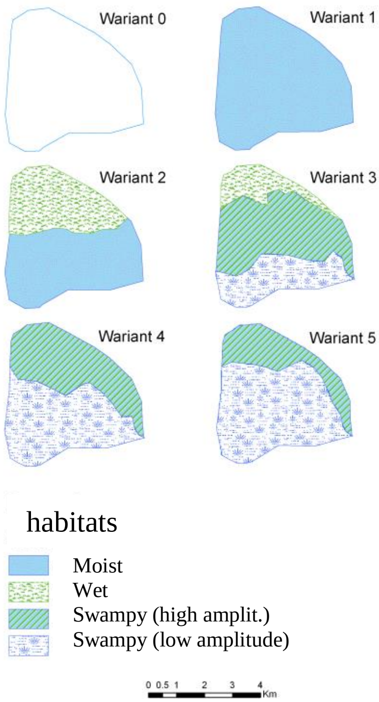


Rys. 9. Średnie niskie stany wód gruntowych wg proponowanych wariantów
Fig. 9. Mean low ground water levels for the proposed variants

The analysis of hydrological conditions for swampy habitats should take into account mean low ground water levels according to experts' opinion, but the low levels are not considered for moist and wet habitats.

As a result of the slow down of ground water outflow and the restriction of pumping station discharge rate (variant 2) mean low ground water levels ranged within 0,75 to 1,5 m below land elevation. Aconsiderable increase of mean low ground water levels appeared by using surface water reserves, causing that they maintained at depths < 0,5 m.

In the final stage of analyses, the calculated characteristic ground water levels were compared with threshold values from table 7.



Rys. 10. Rozmieszczenie siedlisk na obszarze renaturyzowanym
Fig. 10. Habitats composition of the restoration site

It could be concluded that the proposed variants lead to a gradual re-formation of wetland habitats. Wet and moist habitats appeared as a result of ground water outflow slow down by hydraulic structures combined with the restriction of pumping rate. Applying surface water reserves increases hydrological feeding to such a degree that swampy processes may be fairly initiated.

4. Conclusions

In the „zero" variant mean ground water levels ranged from 1,20 to 0,6 m below land surface, inundation frequencies were lower than 25% while mean ground water amplitudes oscillated between 0,75 and 1,50 m and mean low ground water levels maintained at 1,25 to 1,5 m below the surface. Comparing these values to applied criteria we can conclude, that taking no actions, such as water damming, restriction of pumping, applying surface water reserves, we cannot increase the area wetness, sufficient for swampy, wet or moist habitats.

In the first variant, mean ground water levels are increased to 0,2–0,6 m but still the inundation frequency is lower than 25%, mean ground water amplitudes are in fact lowered to 0,75–1,25 m, so are mean low ground water levels (0,75–1,25 m below surface). These values were reached when the outflow was slowed down, but the pumping station was still switched on and no surface water reserves were delivered. In this way proper conditions for moist habitats were developed.

The second variant leads also to mean ground water levels between 0,2–0,6 m below land surface. Similar to variant 1, the inundation frequency was lower than 25%, ground water amplitudes ranged between 0,75–1,25 m, but mean ground water levels were slightly higher, amounting from 1,00 to 0,75 m. Such values of hydrological characteristics prove, that slow down of the outflow coupled with switching off pumping station didn't significantly change the wetness of the restored wetlands. However, the comparison between modeling results of variant no. 2 and threshold values directs at moist but also wet habitats on the largest part of the wetland.

In variant no. 3 a considerable change of mean ground water levels was observed, as they reached values >0, also inundation frequency amounted to more than 50%, but again ground water amplitudes remained within 0,75–1,25 m. There were higher low ground water levels, ranging from 0 to 0,5 m below land elevation. The increasing values of hydrological characteristics in this variant resulted from additional supply of the lowest surface water reserves, leading to appearance of swampy habitats of a high ground water amplitude.

Mean ground water levels amounting to 0,2–0,4 m above the land in variants 4 and 5, along with inundation frequencies ranging from 50 to 100%, amplitudes between 0 and 0,25 m and mean low ground water levels from -0,25 (below) to +0,25 (over surface) are considered to be sufficient for the development of swampy habitats, on condition, that the outflow is slowed down, the pumping is restricted and mean or high surface water reserves are provided.

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Modelowanie warunków wodnych na potrzeby renaturyzacji Bagien Przemkowsko-Przecławskich

Streszczenie

Przekształcenie środowiska naturalnego obszarów mokradeł spowodowało konieczność podjęcia działań na rzecz ich ochrony i renaturyzacji. Szacuje się, że w środkowej i zachodniej części kontynentu europejskiego ponad 80% (Borger, 1992, Smits i in., 2001), a na świecie ponad połowa terenów mo-

kradłowych została osuszona lub przeobrażona w takim stopniu, że przestała pełnić swoje pierwotne funkcje w krajobrazie.

Jako obiekt badań wybrano Bagna Przemkowsko-Przecławskie, o łącznej powierzchni równej 3050 ha, położone w południowo-zachodniej Polsce na Dolnym Śląsku. Według przeprowadzanych badań florystycznych (Szlachetka, 2005) zbiorowiska roślinne Bagien Przemkowsko-Przecławskich wykazują obecnie stadia regeneracyjne po długotrwałym odwodnieniu, świadczące o współczesnej degradacji przyrodniczej tego obiektu.

W celu odtworzenia walorów środowiska Bagien Przemkowsko-Przecławskich ustanowiono w 1997 roku Przemkowski Park Krajobrazowy, uwzględniając w sposób szczególny ochronę środowiska przyrodniczego w planach gospodarowania wodą oraz w prowadzeniu gospodarki łąkowo-pastwiskowej (Grootjans i in., 2007). Celem oceny możliwości odtworzenia warunków wodnych oraz szaty roślinnej, skonstruowano model przepływu wód podziemnych dla obiektu Bagna Przemkowsko-Przecławskie, wykorzystując program komputerowy MODFLOW. Za jego pomocą symulowano położenie zwierciadła wód gruntowych dla 6-ciu wariantów gospodarowania wodą, opracowanych na podstawie rozpoznania aktualnego stanu siedlisk i elementów sieci wodnej bagien. Obliczenia realizowano z dekadowym krokiem czasowym dla wielolecia 1965–1988. Stany wód gruntowych, obliczone za pomocą modelu, porównywano z przyjętymi kryteriami hydrologicznymi, opisującymi stan uwilgotnienia siedlisk mokradłowych. Kryteria te zawierały wartości progowe charakterystycznych stanów wody, opracowane na podstawie monitoringu siedlisk referencyjnych w dolinie rzeki Biebrzy w północno-wschodniej Polsce.

Poszczególne warianty obliczeniowe były zróżnicowane pod względem parametrów pracy urządzeń wodnych, takich jak: wysokości piętrzenia wody przez zastawki i jazy, wydatek przepompowni melioracyjnej oraz przerzut wód powierzchniowych do obszaru renaturyzowanego.

Analiza wyników modelowania wykazała, że dla odtworzenia siedlisk bagiennych na obiekcie badań potrzebne jest nie tylko wykorzystanie istniejącego zasilania podziemnego, ale także niezbędne jest doprowadzenie rezerw wód powierzchniowych.