Introduction.

The hydropower module (hydropower potential module) is a qualitative characteristic of hydropower resources, reflecting the impact of various factors on hydropower production. It shows the amount of energy in kilowatts that can be obtained when using a runoff of 1 km^2 without regulation at a corresponding pressure of 1 m (Energy resources of the USSR, 1967).

The hydropower modules map gives an idea of the possibilities of using hydropower resources, taking into account the magnitude of water value, the degree of non-uniformity of runoff and the inevitability of energy losses during its use.

Method and/or Theory

To create maps of the hydropower modules distribution for the Pripyat basin rivers within Ukraine were:

1. hydropower modules are calculated based on the values of the total hydropower potentials of river sections (Obodovskyi et al., 2020 a);
2. using GIS-tools, the maps of hydropower modules distribution with isolines intervals through 0,5 $kW*km^{-2}$, 0,2 $kW*km^{-2}$ and 0,1 $kW*km^{-2}$ are created;
3. the accuracy of the constructed materials is estimated;
4. the most expedient variant for practical use is analyzed.

Results of investigations.

Creating maps of hydropower modules uses the same algorithm to create a water runoff map and are based on the same approaches as for creating water runoff maps. (Obodovskyi and Korniienko, 2020 b; Obodovskyi et al., 2017).

These maps were created using the program QGIS (QGIS, 2021) and were reduced to the following operations. For each river section of the research basin, the center of the catchment was determined and marked on the map as a point object (point layer), which included the values of the river's total potential within this section. Within the research basin, 396 points with calculated data were identified.

Next, the hydropower modules were calculated by entering the corresponding values in the point layer's attribute table. According to these data, using a deterministic surface interpolation method (the Natural Neighbor tool of spatial interpolation), a layer of raster data (continuous (or prediction) surface from sampled point values) was created (QGIS, 2021).

To graphically show the layer, we used the representation of data in the form of color map, which has the hydropower modules' corresponding values (Figure 1).

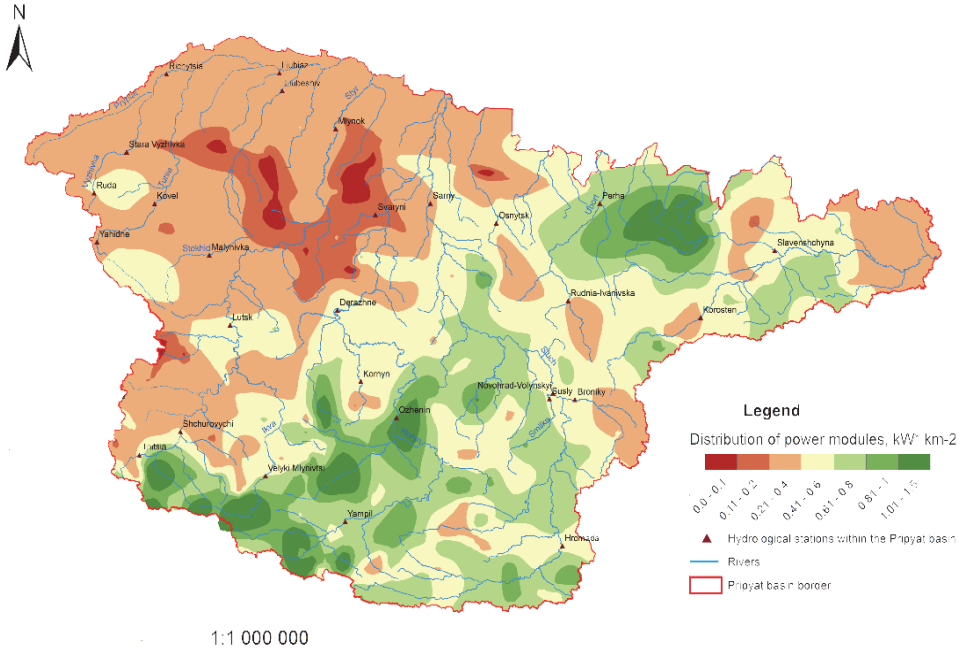


Figure 1 *The interpolation of hydropower modules distribution for the Pripyat basin rivers within Ukraine*

The next step was to create isolines (linear objects) using Surface toolset's Contour (QGIS, 2021). Considering the hydropower modules is closely related to the runoff characteristic, similar intervals of hydropower module isolines were chosen for runoff maps (Obodovskyi and Korniienko, 2020 b).
Figures 2-4 show cartographic images of the hydropower modules distribution with isolines intervals through 0,5 kW*km^{-2}, 0,2 kW*km^{-2} and 0,1 kW*km^{-2}.
The map of hydropower modules distribution (Figure 2) with isolines through 0,5 kW*km^{-2} is not informative for a large part of the basin, in particular for the upper reaches of the Pripyat River and its sub-basins of tributaries Turiia, Stokhid and Styr, which are about 40 % of the Pripyat basin (within Ukraine).
For the remainder of the territory, the values ranged from 0,5 kW*km^{-2} to 1,5 kW*km^{-2}. Values of 1,0 and 1,5 kW*km^{-2} are typical only for the upper reaches of most tributaries of the Pripyat and for rivers flowing within the Slovechansko-Ovrutsky ridge. For the majority of the research basin, this map has values of 0,5 kW*km^{-2}. This distribution is not informative enough, as the calculated values of hydropower modules within this part of the basin are lower than 0,5 kW*km^{-2}.

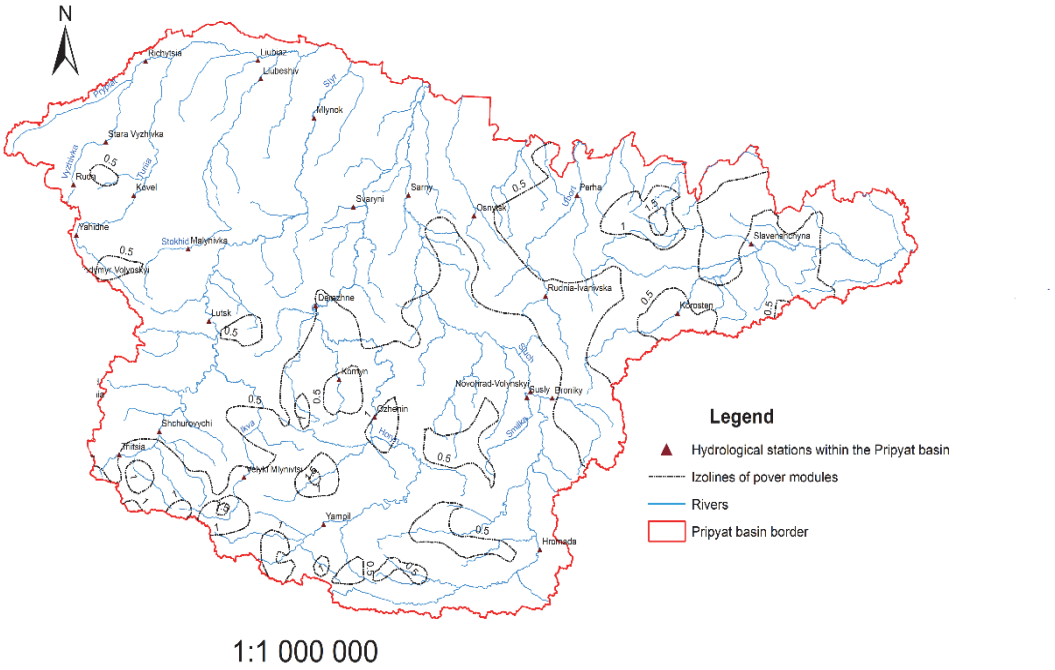


Figure 2 *Hydropower modules distribution for the Pripyat basin rivers within Ukraine with isolines interval thought 0,5 kW*km^{-2}*

The map of hydropower modules of the Pripyat Basin rivers within Ukraine with isolines through 0,2 kW*km^{-2} slightly increases the research area's coverage area, and their values range from 0,4 to 1,2 kW*km^{-2} (Figure 3).
However, there is a part of the Pripyat catchment area, located downstream of the hydrological station Richytsia and the lower reaches of its tributaries Stokhid and Styr, non-availability of isolines.
For the upper reaches of the Pripyat tributaries within the research basin, the modules values are 0,6-1,0 kW*km^{-2}, and for the rivers within the Slovechansko-Ovrutsky ridge – 0,8-1,2 kW*km^{-2}. Values of 0,2-0,4 kW*km^{-2} are typical for most of the territory. This distribution of isolines slightly increased the detail of determining the hydropower modules of rivers within the research area.

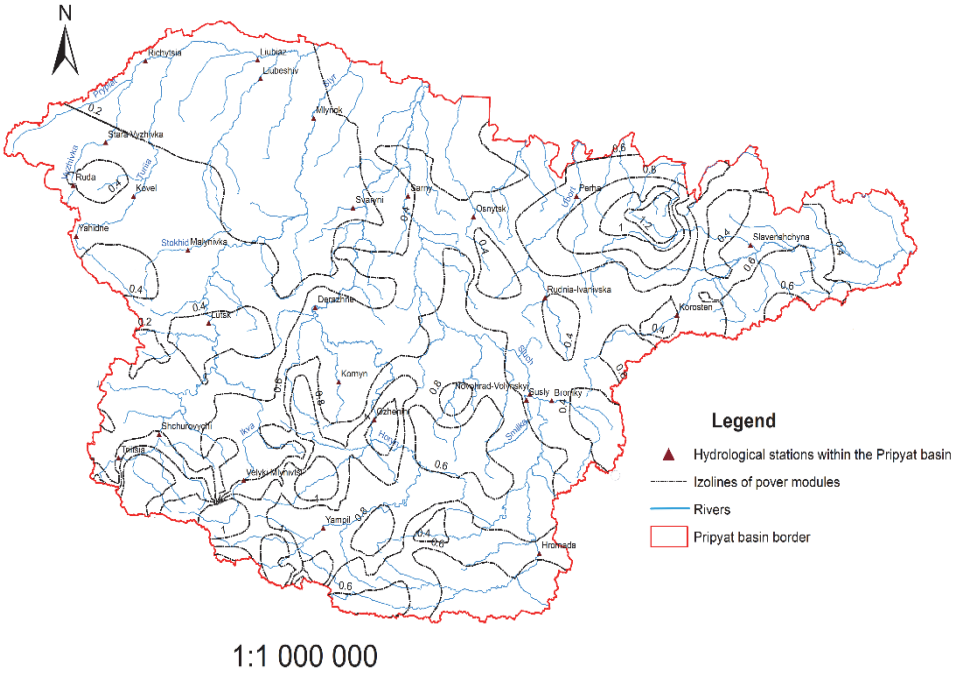


Figure 3 *Hydropower modules distribution for the Pripyat basin rivers within Ukraine with isolines interval thought 0,2 kW*km^{-2}*

By analogy with runoff maps, a map of hydropower modules of the Pripyat Basin rivers within Ukraine was created with isolines interval thought 0,1 kW*km^{-2} (Figure 4). Their values were distributed as follows: most of the territory covers the value of 0,2-0,4 kW*km^{-2}, the upper tributaries of the right-bank part of Pripyat basin within Ukraine – 0,6-1,2 kW*km^{-2}, the territory of the Slovechansko-Ovrutsky ridge – 0,8-1,6 kW*km^{-2}. Values of 0,1 and more than 1,2 kW*km^{-2} occur only locally and within small and, in part, medium rivers.

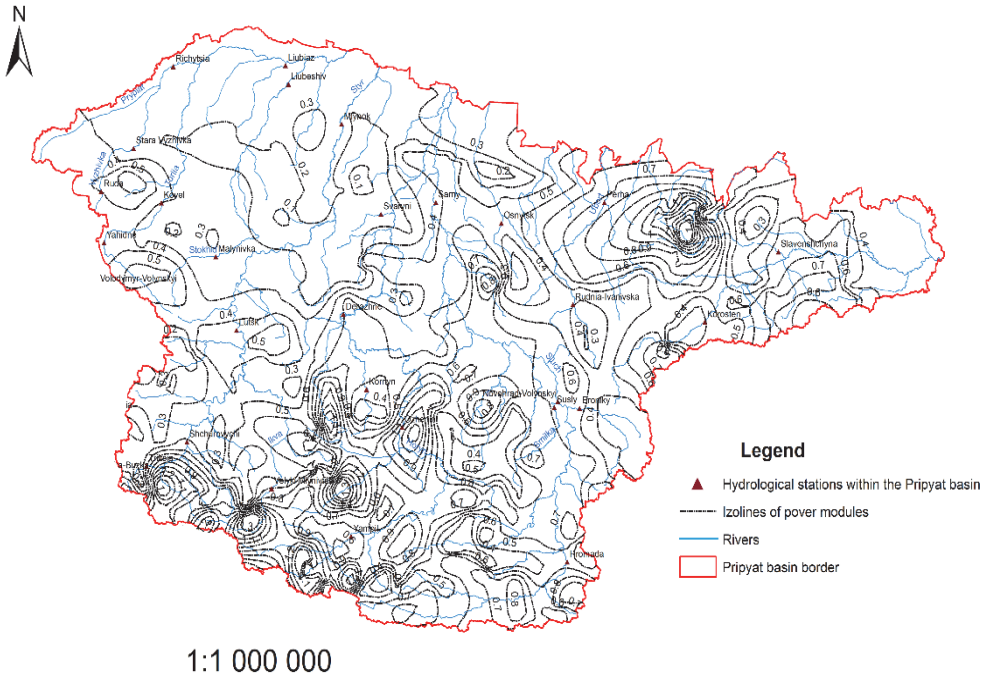
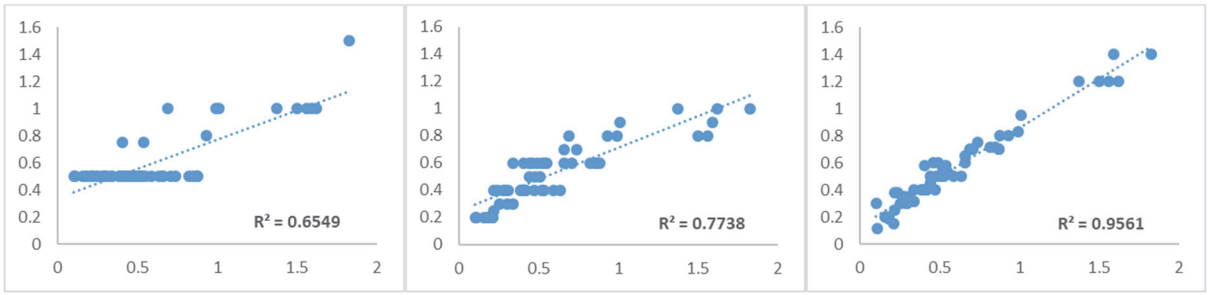


Figure 4 *Hydropower modules distribution for the Pripyat basin rivers within Ukraine with isolines interval thought 0,1 kW*km^{-2}*

To determine the most appropriate variant of cartographic variations in the distribution isolines of hydropower modules, a comparison of actual values (calculated) and values obtained with the obtained maps help was performed. For this purpose, out of 396 points, 55 points within the basin were selected (according to the principle of uniform location within the basin), and the connections between them were evaluated (Figure 5 a, b, c).



a *b* *c*

Figure 5 *Correlation between calculated values of hydropower modules (actual data) and with taken from the hydropower modules maps through 0,5 kW*km^{-2} (a), 0,2 kW*km^{-2} (b), 0,1 kW*km^{-2} (c) (manual data).*

Correlations have good relationships (except for Figure 5a), as evidenced by the coefficients of determination R^2 = 0,77 (Figure 5b) and R^2 = 0,96 (Figure 5c), as well as the corresponding correlation coefficients r = 0,88 and r = 0, 98. Based on this, the correlation between the calculated values of the power modules (actual) and with the taken from (manual) using hydropower modules distribution maps with the isolines intervals through 0,1 kW*km^{-2} has a better relationship (r → 1) and may be acceptable for practical use.

Conclusions

Based on the obtained maps and estimating the degree of connections (by correlation coefficients), the most optimal is the variation of the hydropower modules distribution map for the Pripyat basin rivers (within Ukraine) with isolines intervals thought 0.1 kW*km^{-2}. In this case, the map with an increase in the number of isolines contributes to clearer perception and determination of the hydropower modules values of rivers, for which there are no calculations.

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