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Assessment of anthropogenic changes natural hydrochemical pool Western Bug River

Keywords: Western Bug waterway, anthropogenic changes, natural hydrochemical pool, river revitalization

Abstract

The origins of the river Western Bug described which flows along the Polish-Ukrainian border, moves towards in Poland Bug (Western Bug) falls into the artificial lake Zehzhynske. Physiographic conditions of the general direction of the river flow given. Water regime of the Western Bug characterized. Forming of the chemical composition of water, water basin salinity in its natural state, chemical composition of river waters participating surface, groundwater and wastewater (anthropogenic) of water due to the change during the year as various kinds of influence are presented**.** Filtration properties of rocks varied presented. The degree of leaching of rocks, fracturing and chemical composition in the context of basin waters dedicated to the three intervals described. Anthropogenic impacts are discussed concerning the formation of hydro chemical characteristics as significant influence of economic activity (plowing, melioration, water intake, wastewater discharges, etc.). Concentration of major ions in water is given. Characterization of organic and biogenous nutrients is given also. Summarizing information it is postulated, that the Western Bug water is not as high quality and does not meet the requirements for surface water quality, operating in Poland. Most standard rates exceed nitrates, phosphates and zinc.

INTRODUCTION

The origins of the Western Bug is located near village Verkhobuzh Zolochiv district, Lviv region of Ukraine Podolia Upland. River Western Bug flows along the border between Poland and Ukraine from Ustyluh. In Poland Bug (Western Bug) flows into the artificial lake Zehzhynske (previously – the river Narew) Length of the river is 831 km (392 km in Ukraine), basin square is 39.4 thousand km². Main tributaries: Bialystok, Luga, Neretva (right), Poltva, Kamenka, Rata (left).

Physiographic conditions. General direction of the river flow is northwest. Places traced meanders and oxbow. Riverbed paved in the thickness of Quaternary formations, sometimes it crosses Cretaceous sediments. Width of the channel at low water is 25-70 m, depth 1.1-1.7 m, average velocity – 0.45-0.65 m/s. Relief basin of Western Bug is characterized as embedded in erosion-developed and flat plane-cavity formations. In addition, in areas close to the surface occurrences of carbonate rocks distributed at karst landforms are disseminated.

River regime. Water regime of Western Bug is characterized by high spring tide in abundant years, low summer-autumn low-flow in dry years, significant rain floods in the summer and sporadic rising of water level in the mainstream in winter. The highest water level in the river Western Bug occurs mainly in spring, in some years during the summer-autumn (1910, 1933, 1960, 1992, 1998) or winter (1957) floods. Flooding starts at the beginning in mid-February even at freezing. The maximum level is reached in mid-March. Raising level of intensity is 15-20 cm/day, abounding in river water up to 1.4 m/day [Kovalchuk, 2002; Knish, 2003].

Formation of the chemical composition of water. Year salinity of Western Bug basin in its natural state is about 400-500 mg/l. In all seasons ions HCO_3^- and Ca^{2+} prevail in the water. According to the O.O.Alekina classification river water of the Western Bug basin belong to the class of calcium hydrocarbon type II - $C_{II}Ca$, and the share of individual ions is: for anions HCO_3^- (63-64% - equiv.)> Cl^- (21-22% - equiv.)> SO_4^{2-} (15-16% - equiv.) for cations Ca^{2+} (63-66% equiv.)> $Na^+ + K^+$ (16-21%- equiv.)> Mg^{2+} (15-18% equiv.).

In the formation of the chemical composition of river surface waters, groundwater and wastewater (anthropogenic) waters are participating. According to Dr. M.R. Zabokrytska study [Zabokrytska, 2003] modern hydrochemical regime of the Western Bug river and its tributaries for major ions has a pronounced seasonal character, due to the change during the year as various kinds of power. In particular, during the spring flood, when increasing run-off, the water of the Western Bug concentrations of major ions and salinity of the water is minimal (499 mg/l). In low-flow periods, while reducing surface-slope runoff and increase underground power, water salinity increases – from 530 mg/l (summer-autumn low flow) to the maximum – 581 mg/l (winter time).

Surface water, formed by surface-slope runoff from the catchment basin depends primarily on the chemical composition of meteogenic water, which is a little choppy at the regional scale and composition of the soil. Soils in the study are represented mainly by spodosol black soil in the floodplain – sod, marsh light texture (loamy, sandy). In such soils in a humid climate formed wash mode that is not conducive to improving water salinity.

Groundwater. Western Bug discharged numerous sources and Upper Quaternary aquifers in the river.

ECOGEOLOGY OF THE REGION

Aquifers in Quaternary sediments are widely distributed in the valleys and ravines. Groundwater confined to alluvial and glacial water and fine-, fine-grained sand, sandy loam, peat, less silty loam differences. Horizon thickness is from 0.5 to 25 meters or more, preferably 6-12 m, the maximum in the valley of the Western Bug horizon free-flow. The direction of movement of groundwater in the general contours the surface relief and can be traced from the watershed to the Western Bug River and its tributaries.

Filtration properties of rocks varied: water supply horizon within 1.5-10 m^2/day, filter coefficients vary from 0.001 to 8.10 m^2/day.

For salt composition groundwater study area belong to the hydrocarbon calcium, bicarbonate, calcium chloride, magnesium, calcium and characterized by low salinity (0.1-1.0 g/l), occasionally chloride calcium, sodium, calcium with mineralization up to 1.9 g/l . Water is quite soft. Their hardness ranges 0.64-3.29 mg-ekv./l.

Zone of aeration horizon is a natural filter. Horizon is available for domestic and anthropogenic contamination loads that exceed its natural opportunities to restore itself.

Water-bearing complex in the Upper Cretaceous, developed within the Volyn-Podolsk artesian basin, timed to Senon marl, chalk Turonian and Cenomanian sandstones. Overlain by Quaternary sediments clay varies, which serve roof top impermeable horizon in addition the lower terrain (valley year, beams, etc.). Top of the carbonate rocks eluvium to a depth of 0.1 to 20 m also serves as a relatively impermeable roof ("silting zone").

Aquifer in Cenomanian sediments distributed in the zone of leaching marl Senon over tier characterized by considerable thickness, large territorial spread and a large area that can be attributed to the pressure. In the valleys and ravines aquifer is unloaded numerous sources. The aquifer is observed in the range of depths from a few meters to 30-40 meters on the roof with an average thickness of 30-70 m.

The degree of leaching of rocks, fracturing them and chemical composition dedicated to them in the context of basin waters are three intervals.

The first interval bicarbonate-calcium waters of low salinity (0,25-0,6 g/l) is characterized by favorable to the movement of water filtration properties of rocks. It is in this interval is a main flow of quality for drinking-water purposes. In areas with values of water flow more than 250 m^2/day, explored and exploited groundwater intakes for centralized drinking water supply (Novovolynsk, Sokal, Zhvyrskyy, Bendyuzka, Mezhyrichanskyy, Boryatynskyy, Vanivskyy, Sosnivsky et al.).

The second interval extended deeper into the first 30-40 meters, and it confined water chloride-bicarbonate, sodium bicarbonate-chloride type of salinity of 1 g/l. In water there is high content of iodine (to 0.26 mg/l),ˈbromine (up to 0.20 mg/l) and fluorine (up to 3.5 mg/l).

Between these intervals there is a transitional zone with water, sodium bicarbonate-type mineralization 0.7-0.82 g/l. It leaching does not occur, and there is a process of cation substitution of calcium with sodium.

The third interval extended to a depth of 175-180 m and confined to light cracking marl thicker. Water sodium chloride mineralization is 1-3 g/l.

Anthropogenic impact. The formation of hydrochemical characteristics has significant influence economic activity (plowing, land reclamation and water intake, wastewater discharges, etc.).

In Western Bug basin three large reservoirs built: Zolochivske, Dobrotvorsk and Sokal.

Significant contamination of the river is in Busk after confluence into it Poltva River, which is actually a collector of municipal and industrial waste water of the Lviv city.

River flows near the mines 1, 2, 9 Novovolynsk Chervonograd mining and industrial area. Species heaps of coal mines may have increased activity and often contain elevated concentrations of Ti, Zr [Knish, 2003]. Besides coal mines on water status affect numerous artificial reservoirs, water-accumulation, and sludge.

According to the State Water Management Committee of Ukraine, in the basin of the Western Bug in 2001, wastewater discharges amounted to about 195 million m^3 and the ratio of clean and contaminated (inadequately treated and those who failed treatment) – 9:1 million m^3. In 2011, according to the State Administration of Environmental Protection in the Lviv region in Western Bug River Basin dropped 226.5 million m^3 return water are 44.63 million m^3 of untreated or inadequately treated (Regional Report, 2011).

Of the 33 water users engaged in direct discharges of sewage, the Western Bug River and its tributaries, more than half – are enterprises of housing and communal services. After

treatment facilities listed companies in the river basin of water per year gets about 150 tons of salt, which is 97 % of total salts that come from sewage.

One factor that creates the potential threat of pollution of rivers surface waters Western Bug Basin is the reduction of forest cover, increasing the amount of land under cultivation. Their use and fertilization leading to changes in hydrological conditions, redistribution of runoff, weathering nature of the solid phase of soil and subsoil filtration capacity and the removal of water descending tributaries products destruction (weathering) solid phase [Klimenko, 1999].

Characterization of macrocomponent water composition. According to the State Hydrometeorological Service Minekoresources Ukraine [Zabokrytska, 2003] salinity waters of the Western Bug fluctuate near 439-608 mg/l. Water mineralization increases in low-flow periods, when the share of underground power supply increases and the total amount of water reduces and decreases during the spring floods (Fig. 1).

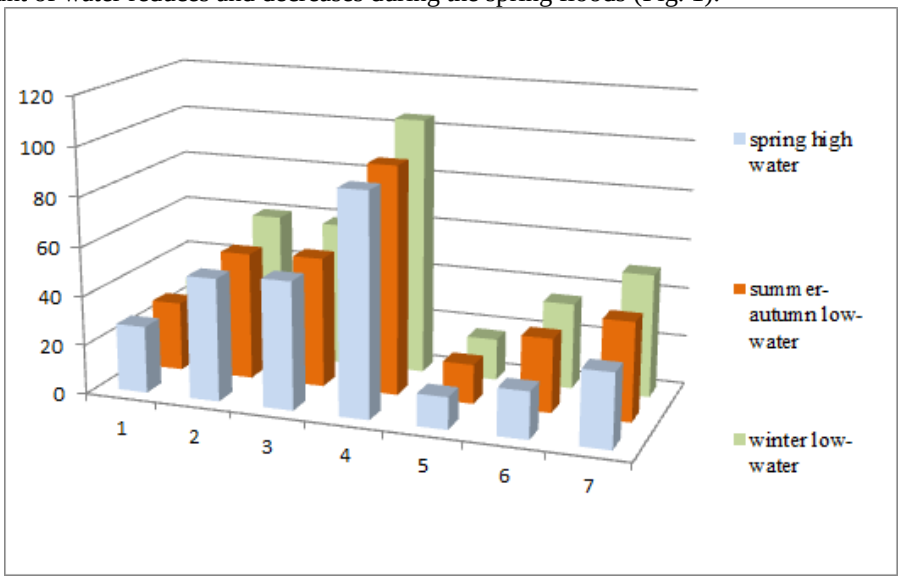

Fig. 1. Concentration of major ions in water. Western Bug River and its tributaries for the period 1989-2002: 1 – HCO_3^-, 2 – SO_4^{2-}, 3 – Cl^-, 4 – Ca^{2+}, 5 – Mg^{2+}, 6 – Na^+, 7 – K^+;; concentration of 2-6 in mg/l, 1 – in $n\times10^{-2}$ mg/l, 7 – in $n\times10^2$mg/l.

At any time of the year in the waters of the Western Bug ions HCO_3^- and Ca^{2+} dominate, which is determined by the influence of carbonate and gypsiferous rocks that make up the water pool intake. During spring floods, the proportion of sodium ions, and decreases the proportion of magnesium is increasing. During winter time the proportion of sulfate ion, magnesium and calcium increases. Share of chloride ions are the same in different seasons.

On the territory of Chervonograd mining and industrial area water quality of the river Western Bug is worsening. Particular, near the tailing dump (village Hirnyk) increases the number of solids (up to 595 mg/l), sodium (to 69.5mg/l), sulfates (to 107.8 mg/l), bromine (up to 0.67 mg/l).

On the boundary of Lviv and Volyn regions salinity of the Western Bug waters reache 680 mg/l, the content of chloride ions – 85 mg/l, sulphate ions – 120 mg/l.

Characterization of organic and biogenic nutrients. According to the State Administration of Environmental Protection in the Lviv region indicator of biological oxygen consumption in the Western Bug River water in 2011 ranged from 2.59 to 6.55 mg/l with the highest content in town Sokal. Oil (petroleum) products found in 5 of 9 samples, the maximum concentration of which is fixed in town Kam'janka-Buska in the quantity of 0.13 mg/l.

Important parameters of water quality are the nitrogen compounds content. Typically nitrogen compounds in surface waters are of anthropogenic origin. Ammonium ion (NH_4^+) content in the Western Bug water, according to long-term studies [Zabokrytska, 2003] fluctuate from 1.51 to 5.65 mg/l, nitrite (NO_2^-) – from 0.07 to 0.28 mg/l, nitrate (NO_3^-) – 0.32 to 0.74 mg/l (Fig. 2).

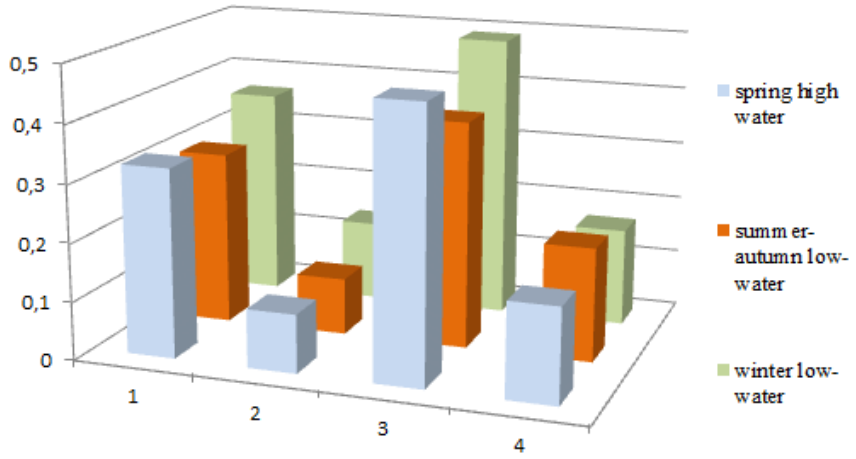

Fig. 2. The variability of biogenic compounds in water of Western Bug in different seasons. 1 – NH_4^+, 2 – NO_2^-, 3 – NO_3^-, 4 – PO_4^{3-}, the concentration – 1 in $n\times10^{-2}$ mg/l, 2 – 4 mg/l.

For nitrates clear seasonal periodicity found. Smallest nitrate concentration observed in the vegetational season, when dissolved nitrogen is rapidly consumed by higher aquatic vegetation in the photosynthesis process. During the winter low water they concentrations increased due to the minimal consumption of nitrate and degradation of organic matter and nitrogen transfer from organic forms in the mineral. In spring flood nitrate concentration again decreases.

Variability content of phosphate ions (PO_4^{3-}) is characterized by reciprocal variability of nitrate dependence. Phosphates contents are least during spring floods and winter time and the greatest during the autumn and winter time.

In 2011, according to the State Administration of Environmental Protection in the Lviv region (Regional Report, 2011) the concentration of ammonium ions (NH_4^+) in the

waters of Western Bug River ranged from 0.01 to 1.9 mg/l. The highest concentrations of ammonium ion recorded in Chervonograd mining-industrial area. Nitrate contents (NO_3^-) in the villages Horodyshche, Tudorkovychi, Skoromohy, Stary Dobrotvir reached and sometimes exceeded 0.97 mg/l and near the town Busk was 1.38 mg/l. Maximal concentration of phosphate ions recorded in the waters of the Western Bug River in the town Sokal (4.45 mg/l) and village Lytovezh (5.6 mg/l).

Thus, following the results of the State Environmental Protection Administration in Lviv region and the State Hydrometeorological Service Minecoresorces of Ukraine, water the Western Bug River on the content of major ions, nitrogen and phosphate ions does not exceed the applicable regulations in Ukraine parameters for drinking water.

According to the results [Klimenko, 2011], the water of Western Bug is not as high quality and does not meet the requirements for surface water quality operating in Poland. Most of standard rates exceeding nitrites, phosphates, zinc (Fig. 3).

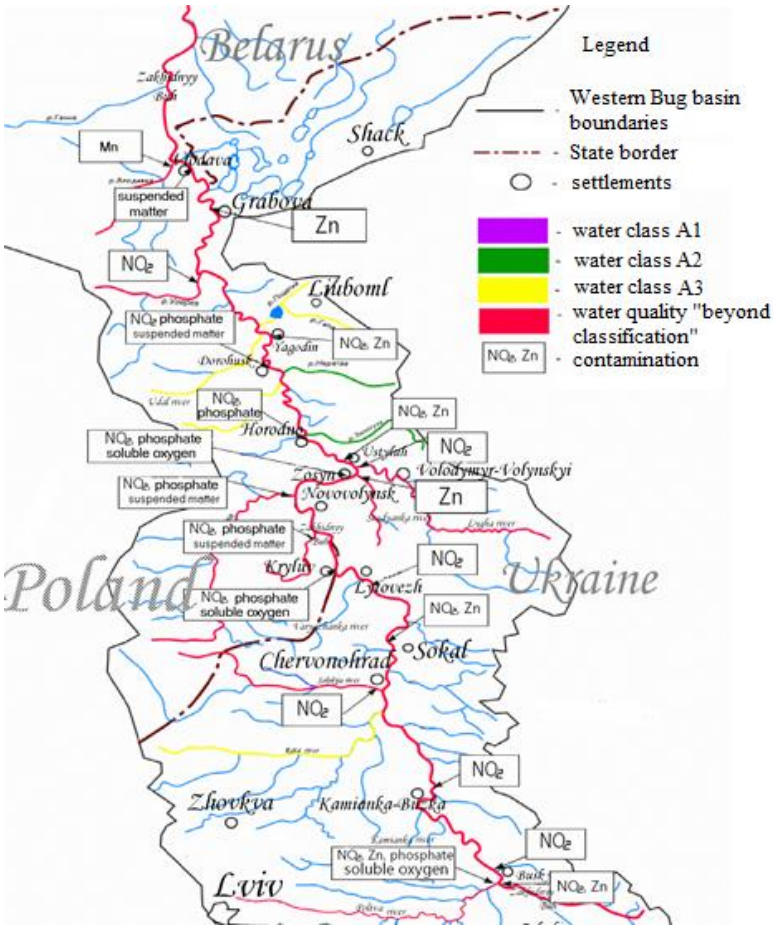

Fig. 3. Zoning scheme of the Western Bug in accordance with the quality of surface waters of Poland [after Klimenko, 2011].

Status of national and cross-border monitoring of river water basin of the Western Bug. The states – transfrontier monitoring participants of West Bug water quality – are Ukraine, Poland and Belarus, among which there is close cooperation. Specifically, under the TACIS in 1997-2001, it was made the first international project for such monitoring. The second project (2004-2006) was aimed at implementing an organizational structure for integrated and sustainable management of the river basin.

It should be noted that in accordance with the Helsinki Convention "On Protection and Rational Use of Transboundary Watercourses and International Lakes" and the monitoring program in Poland at the Ukrainian-Polish section of the Western Bug it was defined two points of transboundary monitoring water quality (respectively, of Ustilug – Zosin; Yagodin – Dorohusk). In addition, as the part of the national network for monitoring water quality basin are items that are located directly on the border areas of the Western Bug and its tributaries – and he Solokiya Kopayivka rivers and may also be involved in cross-border monitoring system. Thus, in the Ukrainian part of the Western Bug basin interagency extensive network monitoring is created [Zabokrytska, 2005]. However, there are a number of issues concerning the functional content of its activities, which decision in the near future would significantly increase the effectiveness of both national and transboundary water monitoring. Required synchronization timing observations expanding the list of hydrometric measurements and standardization of analytical determinations methods of chemical components in the laboratories of national monitoring various departments and implementation clearer and more effective exchange of information at national level are in demand.

WESTERN BUG MAPS AREAS FLOODING SIMULATION

Simulation maps areas subject to flooding (flow inundation map). According to the geological material given the simulation maps areas subject to flooding in the Western Bug River vicinity were carried out in programming medium ArcGIS with the use of the add HEC-GeoRAS 10.0 and program HEC-RAS 4.1.0 from the site http://www.hec.usace.army.mil/

The idea of the study was to obtain maps of the region utilizing the satellite data and predict possible flooding in the area using historical data about the rise of the water level in extremely high water years to make the prognosis with the help of satellites possible taking into account more precise obtaining of the surface topography in this known in geologically insight region. Methodo;ogy of experiment gies us also the possibility to understand the ecogeophysical idea of obtained results

The study, which took place was carried out in the following stages illustarted with the obtained maps:

1. The downloading satellite altitude data Shuttle Radar Topography Mission (SRTM) within the territory of the Western Bug River from the site http://earthexplorer.usgs.gov/
2. Converting data into high-rise flat local coordinate system CK63 Zone 2.
3. Creating catchment and network water flows from high-altitude data. The result of the allocation of catchment basin is seen in the picture (Fig.4).

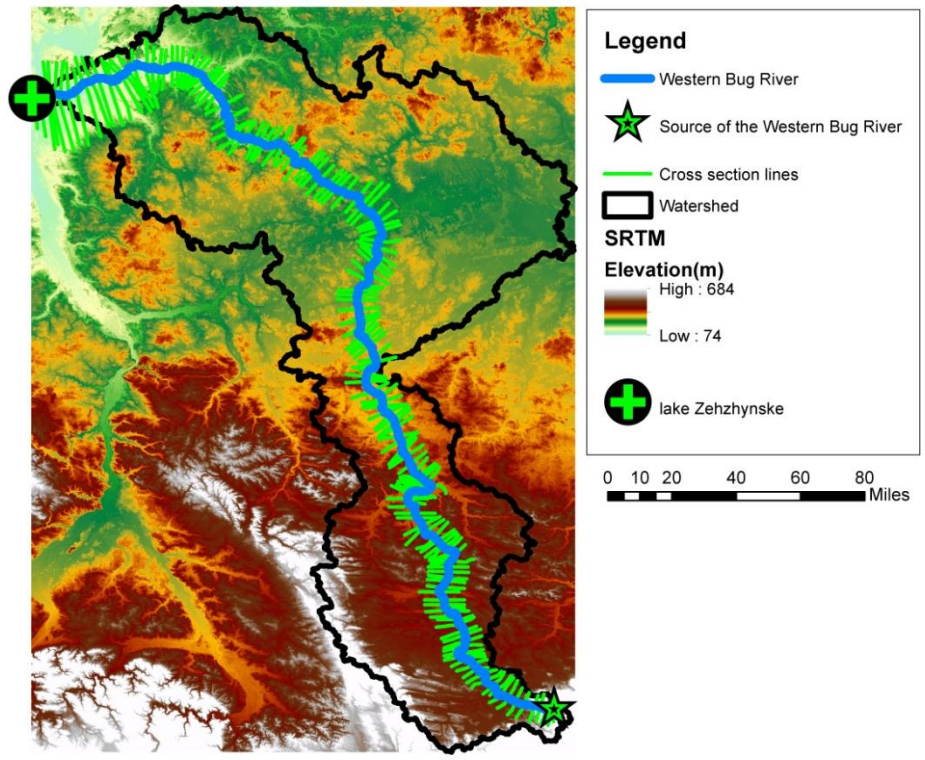

Fig.4 Catchment basin of the Western Bug River and Cross section lines

In the picture we see Western Bug River - the main riverflow Western Bug. Cross section lines - lines of transverse profiles modeled. Watershed - catchment Western Bug River before the confluence with Lake Zehzhynske. Catchment area according to our model was 39 471 km^2. SRTM - high-altitude satellite data SRTM in meters above sea level. As a result of the imposition of riverbed on high data it is possible to build cross-sections of the river.

4. To determine the areas of flooding, determining the forecast level rise of water, construction of cross profiles was maintained.

5. The next step is the process of transferring data from an application ArcGIS using software application HEC-GeoRAS 10.0 into the internal format of the HEC-RAS 4.1.0.

6. Data analysis and modeling of water flow in the program HEC-RAS 4.1.0 is the default values of water consumption in m^3/s. We have taken two options. 1 embodiment was the annual spring-summer flood and option 2 extremely great flood, which met last 100 years.

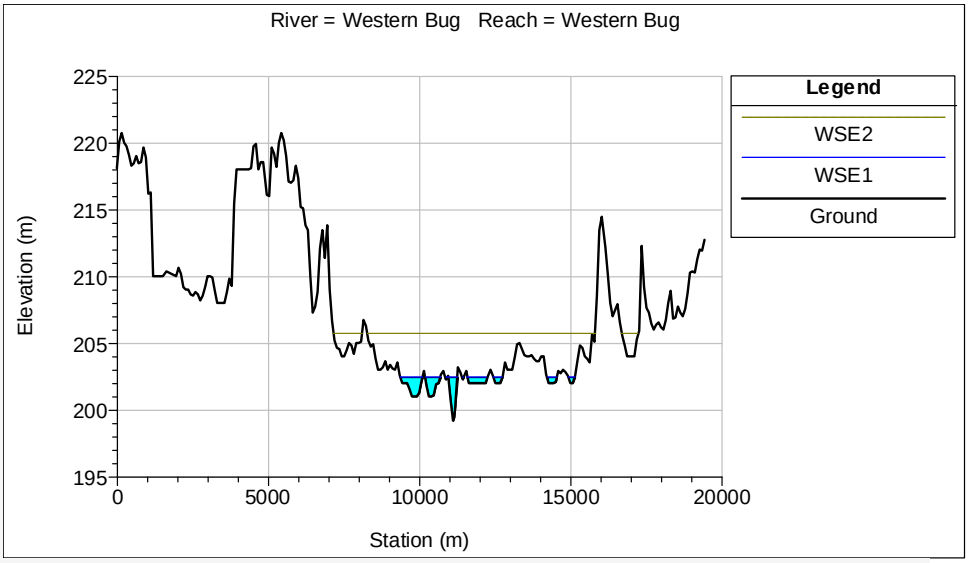

Fig.5 Ground - profile of the river bottom. WSE 1 - Water surface elevation of (normal spring-summer flood). WSE 2 - Water surface elevation of (projected rise in the water level in the river as a result of flooding once every 100 years).

On the Fig.5we see the ground of the river and two modeled rises of water level of the river, which are devoted to the annual and prognosis rise according to maximum in 100 years.

7. View images of transverse profile, which is at a distance of 518,023 km from the Western Bug River leakage gives us, an idea of the possible rise of water level (Fig.6).

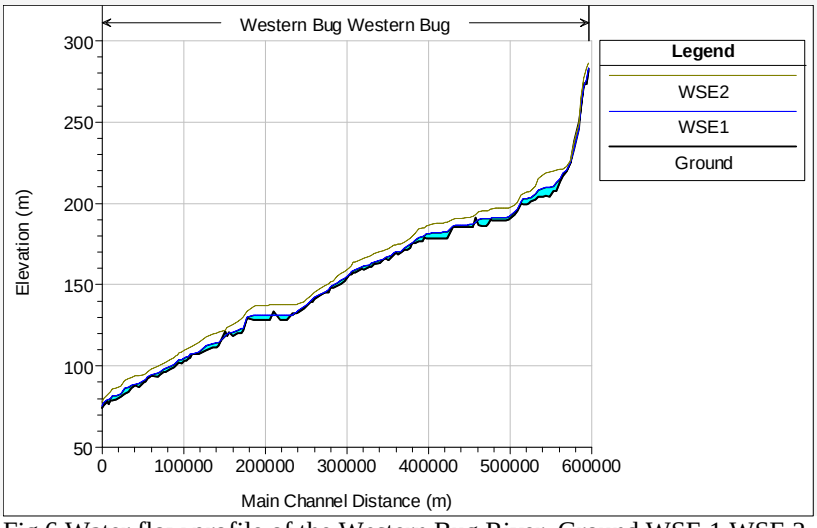

Fig.6 Water flow profile of the Western Bug River. Ground,WSE 1,WSE 2 – as on Fig.5.

Finely we give obtained ssimulation results in the area of town Ustilug on the border between Poland and Ukraine.

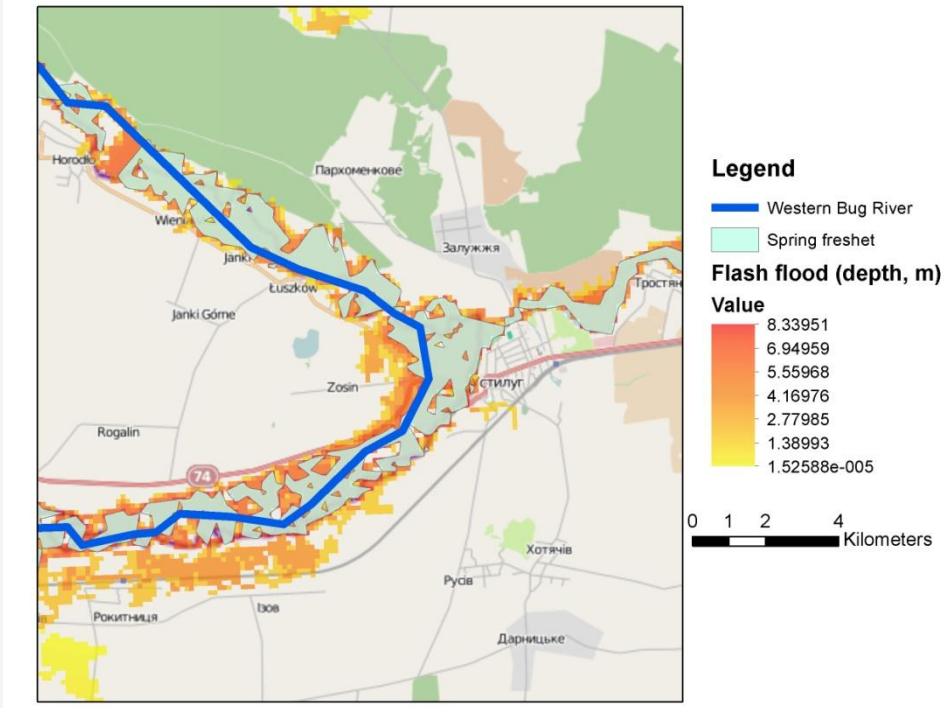

Fig.7 Zone of flooding during spring floods

On the figure we see: Western Bug River – the river, Spring freshet – flooding zone during spring floods, Flash flood (depth, m) – extreme flood inundation zone and magnitude of flooding in meters.

From the above given above results it can be concluded that satellite data and their processing allow creating flooding risk maps, which are in demand for the future management decisions and provided action to counter floods.

CLOSING REMARKS

1. In the formation of the chemical composition of the Western Bug waters participating surface-slope water runoff groundwater and Upper Quaternary aquifers, sewage various enterprises participate. Abundance of inadequately treated sewage creates environmental threats in the basin of the Western Bug. Specifically, in 2011, according to the State Administration of Environmental Protection in the Lviv region in Western Bug River Basin it was dropped 226.5 million m^3 return water, part 44.63 million m^3 was untreated or inadequately treated.

2. Salinity of Western Bug basin rivers in their natural state, are about 400-500 mg/l. In all seasons ions HCO_3^- and Ca^{2+} prevail in the water. According to the classification O.O.Alekina river basin waters of the Western Bug belong to the class of calcium hydro-

carbon type II - C_{II}^{Ca} and the share of individual ions is: for anions HCO_3^- (63-64% - equiv.)> Cl^- (21-22% - equiv.)> SO_4^{2-}(15-16% - equiv.) for cations Ca^{2+} (63-66% - equiv.)> $Na^+ + K^+$ (16-21% - eq.)> Mg^{2+} (15-18% - equiv.).

3. The content of the individual chemistry components of the water has a distinct seasonal zoning. In particular, during the spring floods increase the proportion of sodium ions and decrease the proportion of magnesium. During winter time the proportion of sulfate ions, magnesium and calcium increases. Smallest nitrate concentration observed in summer and in spring flood and during the winter low water concentrations increases. Phosphates are the least during spring floods and winter time and the greatest during the autumn and winter time.

4. According to the result of the State Environmental Protection Administration in Lviv region and the State Hydrometeorological Service Minecoresources, Ukraine the Western Bug River water over the content of major ions, nitrogen and phosphate ion concentrations not exceeding standard for drinking water existing in Ukraine. As the alternative result studies of water the Western Bug River is not as high quality and does not meet the requirements for surface water quality, operating in Poland. Most standard rates are exceeding nitrite concentrations, phosphates, zinc.

5. Despite the organization of points interstate water monitoring, collaboration services, environmental protection in both countries, are required synchronize timing observations, expanding the list of hydrometric measurements unification of analytical determinations methods of chemical components in the national monitoring laboratories of various departments in implementation of clearer and more effective exchange of information at the international level and the system studies of hydrological, chemical and other parameters of the Western Bug, studying various stressful factors, modeling the likely changes and other environmental conditions of the Basin, the development of a clear plan of various services action of the two countries in emergency events cases. This is extremely in time necessity Ukrainian-Polish project, the results of which implementation will lay a scientific basis for management of natural and man-made environment administration of Western Bug Basin.

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