# DEVELOPMENT OF THE SHORE ZONE OF THE JEZIORSKO RESERVOIR (THE WARTA RIVER, CENTRAL POLAND)

*HALINA KACZMAREK**

**Halina Kaczmarek: Development of the shore zone of the Jeziorsko Reservoir (the Warta River, Central Poland) Geomorphologia Slovaca et Bohemica, 10, 2010, 1, 6 figs., 1 tab., 18 refs.**

The Jeziorsko Reservoir was artificially created between 1986 and 1992 on the Warta river (Central Poland, Fig. 1). It is characterised by cyclic high water level fluctuations, which reach up to 5 metres. At the maximum water level period its length equals 16 km, capacity amounts to 202.3 million $m^3$, and the shoreline length reaches 44.3 km. At the minimum water level period on the reservoir, from December to February, the reservoir area decreases from 42.3 to 19.6 $km^2$; i.e. 54 % of its area is periodically drained.

The shore zone of the reservoir develops in quaternary deposits (clays, sands, silts), locally in the Pliocene class. The reservoir shore zone is undergoing an intensive transformation phase. 64 % of the reservoir natural shores is active (BANACH and GROBELSKA 2003): 56 % are abrasive and 8 % accumulative. The abrasive shores develop with the contribution of mass movements. The sliding and slump of the material occurs here. Locally slides developed here.

In order to estimate the rate and direction of the changes occurring within the reservoir shore zone during the entire period of the reservoir exploitation a two-kilometre part of its eastern shore has been designated (Fig. 3). A comparative analysis of the photogrammetric (from 1991 and 2001) and cartographic materials has been carried out for the selected part. The analysis has been supplemented with the field measurements of the present tempo of the cliff edge retreat including the DGPS-description of its position. During the entire exploitation period of the Jeziorsko Reservoir, 1991 – 2009, in individual profiles the cliff edge has moved from 4.6 to 25.1 m i.e. from 0.26 up to 1.39 m annually, av. 1 m a year. In the first analysed period of the reservoir functioning, 1991-2004, the recession rate amounted from 0.35 to 1.63 m annually, whereas in 2004-2009 it oscillated from 0.26 up to 1.28 m. At present the rate of the cliff movement equals from 0.1 up to 0.3 m a year, locally it reaches 1 m a year.

**Key words:** water reservoir, fluctuations, shore zone, mass movements

## INTRODUCTION

The artificial water reservoir creation, both as a result of the river as well as lake up-lifting above the current maximum levels, evokes a qualitative and quantitative transformation of the factors and processes which shape its shore zone, initiating a new so called „reservoir" stage of its development. The shore withdrawal as a result of its abrasion and slope processes as well as its growth in the aftermath of the accumulation of the sediments transported within its grounds are the symptoms of the shore zone activity.

The shore zone is understood here as the area stretching from the above-water cliff edge or marking the maximum wave range of the accumulation form to the foot of the shore platform bend also known as the shore shallow. The zone is undergoing constant transformations as a result of a mutual interaction of the hydrodynamic reservoir and geodynamic processes occurring on the surrounding slopes. Both the rate and direction of the processes occurring within the shore zone are the resultant of the environmental features i.e. the geological structure, the morphometrics, the vegetation overgrowing the flooded slopes as well as the accompanying water line; occurring climatic conditions and the water management on the reservoir which determines the height of the water level fluctuations and their changeability in time.

The active, intensively developing reservoir shore zone not only makes the human activity difficult in its neighbourhood but also, which is often neglected, influences the physical-chemical parameters of the water collected in the reservoir, inter alia through the material supply from the abraded shore or the lack of littoral. Thus, the knowledge of both, the directions of the changes, formulation as well as their intensity is vital.

In the article the results of the research concerning the Jeziorsko Reservoir shore zone development will be presented. It is the second in terms of area and fourth in terms of capacity artificial water reservoir in Poland.

* Polish Academy of Science, Institute of Geography, Department of Geomorphology and Hydrology of Lowland, Kopernika 19, 87 – 100 Toruń, Poland, e-mail: halina@geopan.torun.pl

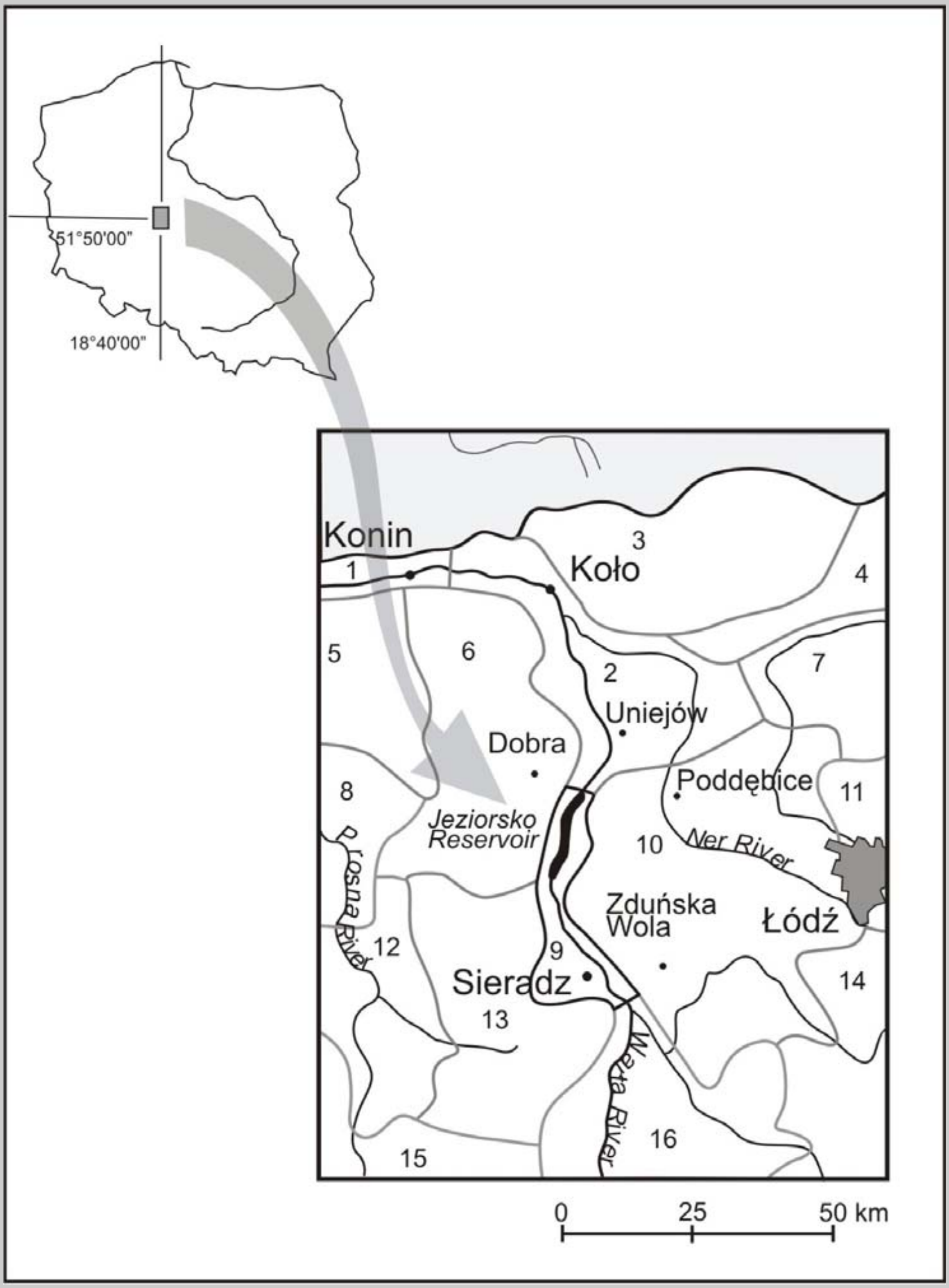



**Fig. 1** Localization of a study area according to physico-geographical division of Poland (base KONDRACKI 1994)
Regions: 1 — Konin Valley, 2 — Kolo Basin, 3 — Klodawa Plain, 4 — Kutno Plain, 5 — Ryhwald Plain, 6 — Turek Upland, 7 — Lowicz – Blonsk Plain, 8 — Kalis Upland, 9 — Sieradz Basin, 10 — Lask Upland, 11 — Łódź Hills, 12 — Grabow Basin, 13 — Zloczew Upland, 14 — Belchatow Upland, 15 — Wieruszow Upland, 16 — Szczercow Basin

## STUDY AREA

The Jeziorsko Reservoir has been created as the result of the damming of the Warta River. The dam locked the 9021.8 km$^2$ basin. Here the average annual discharge equals 49.8 m$^3$s$^{-1}$ (STACHÝ, ed. 1986). The preliminary reservoir filling commenced in 1986, yet the full up-lifting range was not achieved until 1992 (ORŁOWSKI 1999, SZEWCZYK 2007).

The Jeziorsko Reservoir lies within the Sieradz Basin and occupies the meridionally running section of the Warta valley (**Fig. 1**). The direct surrounding of the basin includes up to 150 m a. s. l. - quaternary uplands (BANACH and GROBELSKA 2003). The territory

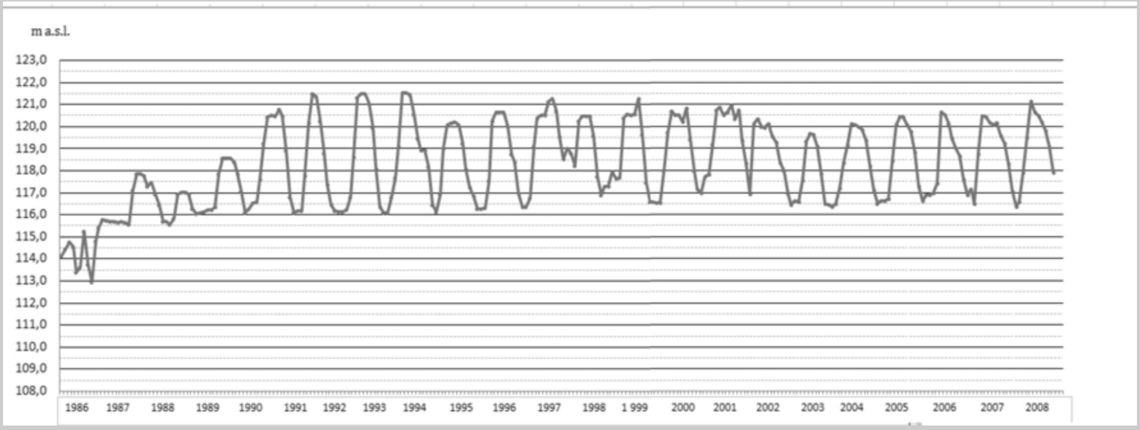



**Fig. 2** Water level on Jeziorsko Reservoir in 1987 – 2008y

lies in the edge zone of the Łódź Basin and the Przedsudecka Monocline (KLATKOWA and ZAŁOBA 1992). Here the oldest formations include severely crushed upper-cretaceous marls which remain 5 – 40 m, locally 2 – 3 m, underneath. The cretaceous formations constitute a direct basis for the Pleistocene formations that cover the area. They mainly include glacial and fluvioglacial sediments of the Warta Stage Saale Glaciation. Their thickness reaches 20 m. The forms remain under older fluvioglacial formations or directly on the clay of the maximum range of the stage. The formations are frequently glaciotectonically deformed. Only the maximum stage local clays occur directly on the surface of the territory (KLATKOWA and ZAŁOBA 1992, ZAŁOBA 1996).

The flat moraine upland in the reservoir surrounding is divided by two river valleys. First, running from southern-east to northern-west, is called the vistulian Pra-Warta valley (BARANOWSKI and MAŃKOWSKA 1972). It is currently used by the Pichna River, which branches from the Jeziorsko Reservoir, and the Teleszyna River in the further section of the valley. At present it constitutes a depression area protected by dams. The decline is crossed by the meridionally running contemporary Warta valley. The vistulian valley is filled with sand and river silts creating approx. 4 – 7 m high slats in the direct neighbourhood of the Warta River. The bottom of the second, younger, valley used by the Warta and currently occupied by the Jeziorsko Reservoir is filled with holocene formations. The forms mainly include sands and av. 2 metre-thick river alluvial soils locally changing into aggregate muds. The edge of the Warta valley, which embraced the reservoir before its formation, had an erosion character on its significant sections. It is cut by numerous erosion-denudation valleys partly used by little streams. Once landslides occured here locally as well. The reservoir shore zone consists mainly of boulder clays and Saale Glaciation fluvioglacial sediments as well as the vistulian river silts. Locally they are accompanied with glaciolimnic sediments, clay slope washes and active slide colluviums. At low water levels on the reservoir the Warta slope washes are washed away by the waves. The process occurs at the top and middle part of the reservoir (BANACH and GROBELSKA 2003).

The Jeziorsko Reservoir is characterised by high water level fluctuations which are the result of the reservoir flood protection and retention functions. Permanent, approx. five-metre high, water level fluctuations occur on the reservoir in every annual cycle (**Fig. 2**). Maximum levels are recorded in the spring-summertime, when the reservoir filling takes place, and minimal ones occur in the autumn-wintertime, after the reservoir gradual emptying which lasts from July until the end of November. From the half of April till the end of June, a stable up-lifting level, no higher than normal (120.5 m above sea level) is kept on the reservoir. Such a situation is favourable for the maintenance of the stable home conditions for water birds in the reservoir upper section.

The Jeziorsko Reservoir occupies the entire flat plain of the Warta. Depending on the water level the reservoir length varies from 16 to 7 km given the 2.5 km width; the average depth equals 1.7 up to 5.2 m. After SZEWCZYK (2007) at maximum water level the reservoir area reaches 42.3 km$^2$, whereas its capacity comes to 202.3 mln m$^3$. At minimum levels the area reaches 19.6 km$^2$ (at absolute minimum 17.6 km$^2$) and the capacity equals merely 36.4 mln m$^3$ (at absolute minimum 30.2 mln m$^3$).

This causes that, at allowed minimum water levels, over half of the basin area is periodically uncovered.

## METHODS

The author together with M. Banach commenced the Jeziorsko Reservoir shore zone research in 1999; i.e. 7 years after the beginning of the reservoir exploitation (BANACH and GROBELSKA 2003). The one-time works included the shore zone mapping, on the basis of the 1:50 000 scale topographic maps, combined with the creation of the geomorphic profiles of the periodically uncovered part of the shore platform. The author referred back to the research in 2008, broadening its scope.

During the mapping five dynamic shore types have been distinguished: abrasive (including landslides), accumulative, neutral, erosive and artificially reinforced (BANACH and GROBELSKA 2003).In their location one has paid attention to their apparent relation with the shore geologic structure and lithology, the morphology of the flooded slope and the shoreline topography (**Tab. 1**).

A detailed study concerning the dynamics and direction of the changes which have taken part within the Jeziorsko reservoir shore zone, since its formation up to now, has been carried out on the selected 2-kilometre shore fragment (**Fig. 3**).

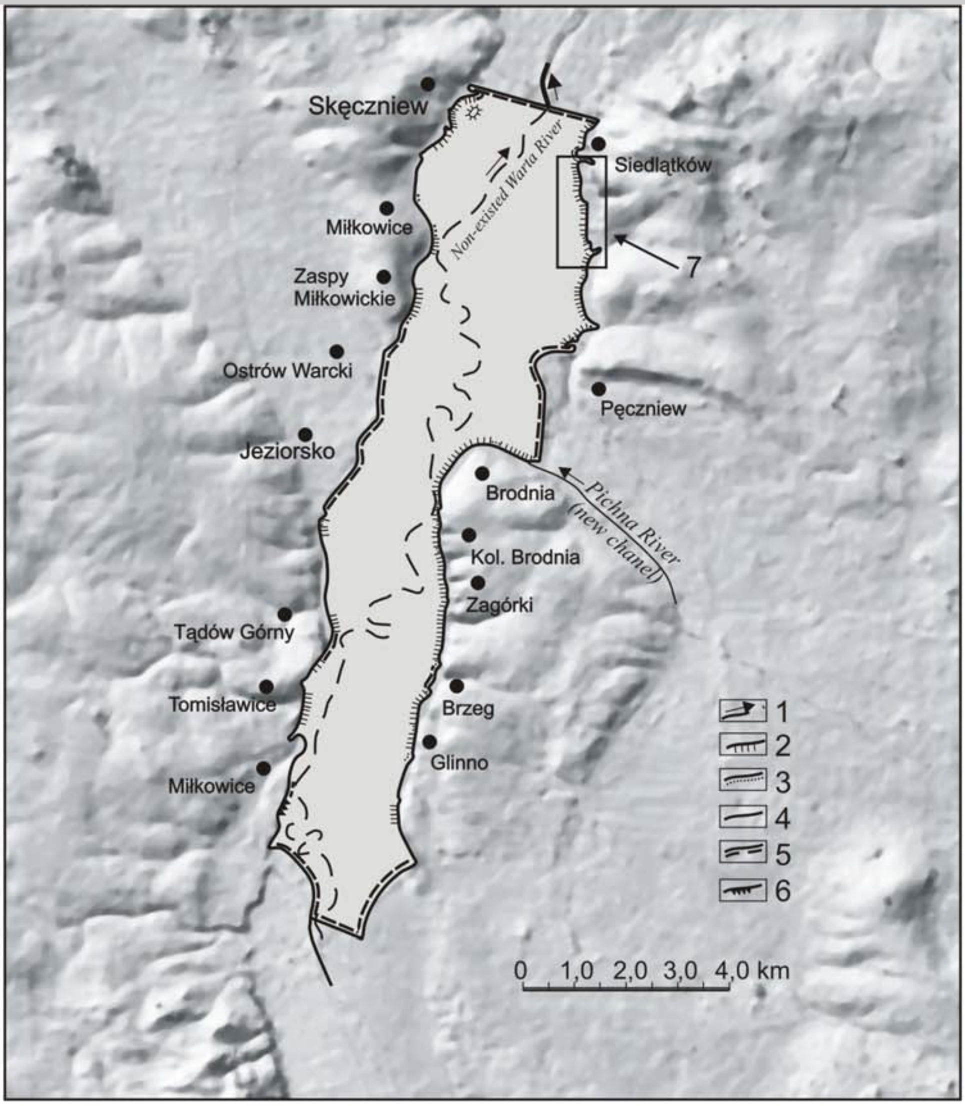
For the sample shore fragment the analysis of the archive photogrammetric materials and the geodetic measurements have been performed. In the analysis 1:27 000-scale (from 1991) and 1:26 000 – scale (from 2004) air photos have been used. First of the used photo series was taken merely a month after the first filling of the reservoir. This allowed to reconstruct the initial condition of the Jeziorsko reservoir shore zone, and in particular the location of the higher cliff edge. In March 2009 the Trimble DGPS-measurements of the present cliff edge location was carried out. The above materials have been drawn up by means of ArcGIS programme which allowed to achieve the 0,3 – metre horizontal accuracy of the measurements (KACZMAREK and TYSZKOWSKI 2009). Furthermore, in order to obtain data concerning the abrasion rate on the selected shore fragment, in 2008 the author installed the monitoring network. This enables to carry out, every three months, the seasonal direct measurements of the shore recession speed.

## RESULTS AND INTERPRETATION

The total length of the Jeziorsko reservoir shores at the maximum water level amounts to 44.3 km, of which 32.1 % (14.2 km) is artificial and thus unsusceptible to the wave wash. The mapping carried out in 1991 showed that about 2/3 of the natural reservoir shores is active, i.e. it has got abrasive (56 %) or accumulative (7.0 %) character. The highly active shore zone as the result of its intensive transformation under the influence of the wind wave abrasion, is favoured by the meridional course of the reservoir (the extention index 6.2), a little variety of the shoreline (1.9), a significant exposure (exposure index 881), high annual water level amplitudes (up to 5 m) as well as a great lithologic and morphologic variety of the shores (BANACH and GROBELSKA 2003). In the spatial layout an evident domination of the abrasive shore along the right windswept, and at the same time higher, part of the reser-

| Type of shore | Summary (total) | | Right | | Left | |
|---|---|---|---|---|---|---|
| | km | % (% without artificial) | km | % (% without artificial) | km | % (% without artificial) |
| **total** | **44.3** | **100.0** | **20.9** | **100.0** | **23.4** | **100.0** |
| abrasive | 17.0 | 38.4 (56.5) | 5.1 | 24.4 (38.3) | 11.9 | 50.9 (70.8) |
| *landslide* | *0.4* | *0.9 (1.3)* | - | - | *0.4* | *1.7 (2.4)* |
| accumulative | 2.1 | 4.7 (7.0) | 0.6 | 2.9 (4.51) | 1.5 | 6.4 (8.9) |
| neutral | 10.8 | 24.4 (35.9) | 7.4 | 35.4 (55.6) | 3.4 | 14.5 (20.2) |
| erosive | 0.2 | 0.4 (0.7) | 0.2 | 0.9 (1.5) | - | - |
| artificial | 14.2 | 32.1 | 7.6 | 36.4 | 6.6 | 28.2 |
| | | | | | | |
| *abrasive + accumulative* | *19.1* | *43.1 (63.5)* | *5.7* | *27.3 (42.8)* | *13.4* | *57.3 (79.7)* |
| *active (abrasive + accumulative + erosion)* | *19.3* | *43.5 (64.2)* | *5.9* | *28.2 (44.3)* | *13.4* | *57.3 (79,7)* |

**Tab. 1** Base on BANACH and GROBELSKA 2003, changed




| No | Metres | | | % | | | Metres/year | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1991-2004 | 2004-2009 | 1991-2009 | 1991-2004 | 2004-2009 | 1991-2009 | 1991-2004 | 2004-2009 | 1991-2009 |
| 1 | 16,9 | 2,3 | 19,2 | 88,0 | 12,0 | 100,0 | 1,30 | 0,46 | 1,07 |
| 2 | 16,9 | 2,5 | 19,4 | 87,1 | 12,9 | 100,0 | 1,30 | 0,50 | 1,08 |
| 3 | 21,2 | 1,8 | 23,0 | 92,2 | 7,8 | 100,0 | 1,63 | 0,36 | 1,28 |
| 4 | 17,4 | 1,2 | 18,6 | 93,5 | 6,5 | 100,0 | 1,34 | 0,24 | 1,03 |
| 5 | 18,0 | 2,6 | 20,6 | 87,4 | 12,6 | 100,0 | 1,38 | 0,52 | 1,14 |
| 6 | 10,4 | 1,5 | 11,9 | 87,4 | 12,6 | 100,0 | 0,80 | 0,30 | 0,66 |
| 7 | 20,0 | 2,1 | 22,1 | 90,5 | 9,5 | 100,0 | 1,54 | 0,42 | 1,23 |
| 8 | 18,9 | 0,8 | 19,7 | 95,9 | 4,1 | 100,0 | 1,45 | 0,16 | 1,09 |
| 9 | 22,9 | 1,0 | 23,9 | 95,8 | 4,2 | 100,0 | 1,76 | 0,20 | 1,33 |
| 10 | 20,8 | 1,8 | 22,6 | 92,0 | 8,0 | 100,0 | 1,60 | 0,36 | 1,26 |
| 11 | 4,6 | 0,0 | 4,6 | 100,0 | 0,0 | 100,0 | 0,35 | 0,00 | 0,26 |
| 12 | 9,8 | 2,1 | 11,9 | 82,4 | 17,6 | 100,0 | 0,75 | 0,42 | 0,66 |
| 13 | 16,4 | 2,4 | 18,8 | 87,2 | 12,8 | 100,0 | 1,26 | 0,48 | 1,04 |
| 14 | 18,0 | 3,2 | 21,2 | 84,9 | 15,1 | 100,0 | 1,38 | 0,64 | 1,18 |
| 15 | 17,2 | 5,2 | 22,4 | 76,8 | 23,2 | 100,0 | 1,32 | 1,04 | 1,24 |
| 16 | 16,5 | 3,9 | 20,4 | 80,9 | 19,1 | 100,0 | 1,27 | 0,78 | 1,13 |
| 17 | 13,1 | 2,2 | 15,3 | 85,6 | 14,4 | 100,0 | 1,01 | 0,44 | 0,85 |
| 18 | 8,6 | 0,5 | 9,1 | 94,5 | 5,5 | 100,0 | 0,66 | 0,10 | 0,51 |
| 19 | 12,6 | 1,0 | 13,6 | 92,6 | 7,4 | 100,0 | 0,97 | 0,20 | 0,76 |
| 20 | 7,2 | 2,2 | 9,4 | 76,6 | 23,4 | 100,0 | 0,55 | 0,44 | 0,52 |
| 21 | 17,9 | 7,2 | 25,1 | 71,3 | 28,7 | 100,0 | 1,38 | 1,44 | 1,39 |

**Fig. 3** Shore zone of Jeziorsko Reservoir – typology (base BANACH and GROBELSKA 2003, changed) and speed of cliff movements

1 – non-existed river, 2 – abrasive bank, 3 – accumulative bank, 4 – neutral bank, 5 – artificial bank, 6 – eroded bank, 7 – detailed study area. Table contain detailed measurements dates in study area

voir shore draws attention. The abrasive shore constitutes over 70 % of the natural shore (**Tab. 1**)! The heights occurring along the right shore of the cliffs oscillate from about 10 m in the northern, up to 7.5 in the middle and merely 1 metre in the southern part of the reservoir. Long, a few hundred-metre abrasive sections are separated by means of a few dozen-metre long accumulative shore fragments. The opposite left, western shore is low, and little varied in terms of heights. About 40 % of its natural shore undergoes abrasion. The maximum height of the active cliffs does not exceed 2 metres here.

For further research, as mentioned, a fragment of the right high shore situated in the northern part of the reservoir has been selected (**Fig. 3**). The shore occurring here has got an abrasive character and the accompanying cliff has got a varied height, from a few dozen centimetres up to 10 metres, i.e. the maximum height occurring on the reservoir. Here, the shore develops within strongly glaciotectonically disturbed glacial and fluvioglacial forms of the Saale Glaciation. In their neighbourhood numerous a few dozen-centimetre in diameter boulders and the incorporated blocks of the Neogene sediments with brown coal, sands and clays occur. Depending on the dominant sediment type within a given cliff fragment its development takes place with the contribution of various slope processes. Along the fragments of the cliff built of more stable and dense clays the falling of the rock blocks can be observed (**Fig. 4**). Yet, along the sections built of less compact clay sands and sandy clays, which are frequently overlayered with a few dozen-centimetre thick well-washed fine and medium-grained sands, the material slump is dominant (**Fig. 5**).

Furthermore, in the selected shore fragment, within the 8-metre high cliff, in the region of the occurrence of strongly glaciotectonically disturbed Neogene forms incorporated in the glacial sediments, the rotary slide has developed (**Fig. 6**). At present it reaches 30 m in width and 15 metre in length. The cubature of the land slide colluvia CZARNECKI and GOŹDZIK (2008) estimated at 700 $m^3$.

For the selected shore fragment, on the basis of the analysis of the air photos, a reconstruction of the top part of the cliff edge course, after the first filling of the reservoir; i.e. in 1991 and in 2004, 13 years later, was performed. Direct DGPS-field measurements enabled to determine the location of the abovementioned edge in 2009, and the monitoring network readings determined its dynamics. The juxtaposition of the obtained results indicates a high intensity of the shore zone transforma-

**Fig. 4** Abrasive cliff near Siedlątków, Jeziorsko Reservoir

**Fig. 5** Scree banks, Jeziorsko Reservoir

tion (**Fig. 3**). In the entire period of the Jeziorsko Reservoir functioning, 1991-2002, in the individual profiles the cliff edge moved from 4.6 up to 25.1 m; i.e. from 0.26 do 1.39 metre a year., av. 1m a year. In the time layout a slightly bigger recession rate of the shore in the first years of the reservoir functioning that nowadays is indicated. It equalled 0.35 up to 1.63 metre a year, whereas in 2004 – 2009 it oscillated from 0.26 up to 1.28 m. At present, the cliff movement rate amounts to from 0.1 up to 0.3 m a year, locally it reaches 1 metre a

**Fig. 6** Landslide, Jeziorsko Reservoir

year! In the spatial layout the peninsulas and convex shore fragments, which are more exposed and thus subject to abrasion, are characterised by a considerably bigger recession rate. The smallest movement took part, however, within the bay and along the concave shore fragments.

During the interpretation of the above data one should be aware of a very high time and spatial changeability of the described process. This is a characteristic feature of the shore zones of the reservoirs with high, a few-metre, irregular water level fluctuations, to which the Jeziorsko reservoir belongs. On such reservoirs one often observes a periodic, lasting even a couple of years, shore zone stabilization, followed by its re-activity (BANACH and SPANILÁ 2000, HABIDOV et. al. 1999).

The seeming shore zone stabilization here is mainly connected with the occurrence of a high irregularity of the water levels. Both maximum and minimum water level on the reservoir in the individual years reaches different values and ordinates. In the case of the Jeziorsko reservoir the differences are respectively: 1.92 m between minimum levels and 1.96 m between maximum levels! Not in each exploitation cycle, therefore, the water level in the reservoir reaches the cliff base, which simultaneously makes its abrasion impossible. At lower water levels, however, the wash and transformation of the material accumulated earlier on the surface of the surrounding shore platform takes place. This leads to the growth of its inclination and at the same time growth of the height of the waves which reach the cliff base. This creates favourable conditions for the shore abrasion in the next phase of the water height on the reservoir.

## CONCLUSION

The Jeziorsko Reservoir shore zone is currently undergoing an intensive development phase. The abrasive shores, which constitute over 50 % of the length of the natural shores, develop with the contribution of mass movements. The falling-off and slump of the material are dominant here. Locally, in the strongly glaciotectonically disturbed regions of the clay forms active mass movements occur. The rate of the cliff edge retreat along the north-eastern shore fragment equals av. from 0.26 up to 1.28 metre annually in the entire period of the reservoir functioning and it indicates a slight decreasing tendency.

A frequent constraint on the research concerning the artificial reservoir shore zone development, in particular the dynamics and directions of the changes occurring within its surrounding, is the possibility of the time and spatial change reconstruction. Thus, combining the analysis of the photogrammetric archive materials with the direct field measurements seems to be a very good solution.

## *ACKNOWLEDGMENTS*

*The work has been done under financial support of Ministry of Science and Higher Education of Poland. Project No. N N306 0330 33.*

## REFERENCES

BANACH, M., GROBELSKA, H. (2003). Stan dynamiki brzegów zbiornika Jeziorsko [The dynamics of Jeziorsko Reservoir shore zone]. *Słupskie Prace Geograficzne*, 1, 91 – 106.

BANACH, M., SPANILÁ, T.(2000). Geodynamic Evolution of Water Reservoir Banks. *Acta Montana*, ser. A, 15, 116, Institute of Rock Structure and Mechanics, Academy of Sciences of the Czech Republic, 45 – 66.

BARANOWSKI, J., MAŃKOWSKA, A. (1972). *Mapa geologiczna Polski w skali 1:200 000, 47-M-34-I (Kalisz)*. Państwowy Instytut Geologiczny, Warszawa.

BURACZYŃSKI, Z. (1986). Geology and engineer researches (on Jeziorsko Reservoir) (in Polish). *Gospodarka Wodna*, 8, 185 – 187.

CZARNECKI, L., GOŹDZIK, J. (2008). Landslides in Łodz Region (in Polish). In Jokiel, P. ed. *Extreme phenomena and exceptional events in Central Poland*. Folia Geographica Physica, 8, 165 – 183.

GROBELSKA, H. (2006). *Evolution of the Pakość Reservoir shore zone (Gniezno Lakeland)* (in Polish). Geographical Studies, 205, Warszawa.

GRZESIAK, M., DOMAŃSKA, W., eds. (2007). *Environmental Protection. Information's and statistically study*. Central Statistical Office of Poland, Warszawa, 97 p.

HABIDOV, A. S., ŻINDARIEV, L. A., SAVKIN, V. M. (1999). Evoljucija beregov vodochranilišč usłovijach dlinnopieriodnych koliebanij urovnia vody. In Kašmienskaja, O. V., ed. *Berega morej i vnutrennych vodojemov. Aktualnye problemy geologii, geomorfologii i dinamiki.* Izdatielstvo SO RAN, Naučno-

Izdatelskij Centr OIGGM, Novosibirsk, 114 – 124.

HELLSTEN, S. (2000). *Environmental factors and aquatic macrophytes in the littoral zone of regulated lakes. Causes, consequences and possibilities to alleviate harmful effects*. Acta Universitatis Ouluensis, Scientiae Rerum Naturalium, A, 348, Oulu, 46 p.

KACZMAREK, H., TYSZKOWSKI, S. (2009). The use of the aerial and ground photogrammetry in the Jeziorsko Reservoir shore zone monitoring (the Warta River, Central Poland). *Geomorphologia Slovaca et Bohemica*, 9, 2, 7 – 12.

KAJAK, Z. (1998). *Hydrology – limnology. Ecosystems of inland waters* (in Polish). Polish Scientific Publishers, Warszawa.

KLATKOWA, H., ZAŁOBA, M. (1992). *Szczegółowa mapa geologiczna Polski [Comments for Detailed Geological Map of Poland] 1:50 000, arkusz Warta*. Państwowy Instytut Geologiczny, Warszawa.

KONDRACKI, J. (1994). *Geografia Polski. Mezoregiony fizycznogeograficzne Geography of Poland. [Physical Geography Mezoregions]*. Wydawnictwo Naukowe PWN SA, Warszawa, 340 p.

ORŁOWSKI, W. (1999). Techniczna charakterystyka zbiornika retencyjnego Jeziorsko na Warcie [Enginery description of Jeziorsko Reservoir on the Warta River]. *Konferencja Naukowo-Techniczna „Eksploatacja i oddziaływanie dużych zbiorników nizinnych (na przykładzie zbiornika wodnego Jeziorsko)". (Uniejów, Poland, 20-21 May 1999)*, 7 – 17.

OVČINNIKOV, G. I. (2003). *The dynamics of shore zone of Angara River reservoirs* (in Russian). Manuscript, Siberian Branch, Russian Academy of Sciences, Irkutsk. Decree-low of Environmental Ministry Act 23.12.1998 y (in Polish), 166: 1219.

STACHÝ, J., ed. (1986) *Atlas hydrologiczny Polski [Hydrological Atlas of Poland]*. Wyd. Instytutu Meteorologii i Gospodarki Wodnej, Warszawa.

SZEWCZYK, G. (2007). *Zbiornik Jeziorsko*. Regionalny Zarząd Gospodarki Wodnej, Poznań.

ZAŁOBA, M. (1996). Ślady oscylacji lądolodu warciańskiego we wschodniej części międzyrzecza Warty I Prosny [Traces of the Wartian ice sheet oscillation in the eastern part of the region between the Warta and Prosna Rivers]. *Acta Geographica Lodziensia*, 71, 275 – 287.