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Modelling of sediment processes in Lake Žuvintas

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Lake Žuvintas is classified as a shallow eutrophic lake. Floating islands formed of aquatic vegetation are particularly characteristic of this lake. Silting processes of the lake have a negative impact on the water quality and environmental state. The turbidity of the lake and formation of a mud layer depend on some abiotic factors such as water inflow to the lake (discharge and water quality), meteorological parameters (wind, participation and temperature), variation of the lake water level, chemical composition of the bottom soil and the aquatic vegetation in the lake. Some measures of water management are proposed with the aim to improve the ecological state of Lake Žuvintas. These could be the regulation of the lake level with sluice regulators, improvement of the water quality of the river inflowing to the lake and cleaning the lake surface from water vegetation. Only mathematical modelling is used to predict the impact of sediment processes in the lake under different management scenarios. The aim of this research was the modelling of sedimentation processes in Lake Žuvintas during flood periods according to the scenarios of the lake management. For this purpose, the hydrodynamic model of the lake as the background for sediment transport modelling was constructed and calibrated. The two-dimensional modelling system MIKE 21 was used as a software.

Key words: Lake Žuvintas, hydrodynamics, sediment transport, MIKE 21 modelling system

INTRODUCTION

The sediment deposited in shallow lakes is often composed of organic matter. Decaying algal remains, zooplankton excretions, and land-derived material all contribute to organic matter deposited in lakes. Several abiotic factors (physical and climatic) influence the production, transport, deposition, and preservation of this organic matter, including the degree of lake stratification, water temperature, oxygen levels and nutrient supply. The turbidity of the lake and formation of a mud layer on the lake bottom have a huge influence on the amount and quality of organic matter in and environmental state of the lake. The decreasing lake depth has an almost inverse relationship to the amount of dissolved oxygen in its water. The composition of sediment deposition has a great influence on the water quality in shallow lakes. Thus, investigation of sedimentation processes is a significant point in evaluating the ecological state of lakes.

Aiming to improve the ecological state of shallow lakes, scenarios of water management could be proposed. The modelling of hydrodynamic and sediment transport processes of shallow lakes allows to forecast changes in lake turbidity and mud layer after implementation of water management measures. The application of a hydrodynamic and sediment transport model (LOEM) of Lake Okeechobee has been reported in (Jin Kang-Ren, Ji Zhen-Gang, 2005). This model simulates sediment resuspension and transport due to wind-driven current and waves. The LOEM is used to predict the impact of sediment processes in a lake under different management scenarios and environmental conditions (high / low lake stages and storm events / hurricanes). Another application of suspended sediment calculations has been reported from Lake Apopka (Bachmann et al, 2001). The high turbidity levels of Lake Apopka are primarily due to resuspended sediments rather than phytoplankton. A marsh flow-way is designed to filter the lake volume approximately two times a year. Using several different estimates of the rate of sediment formation in the lake, the model calculates that it would take 275 to 502 years to remove the sediments, so the lake could not attain clear water in a reasonable length of time.

The ecological state and water quality of lakes depend on the sedimentation processes (layer and deposition of mud). U. Cowgill (1988) analysed the chemical composition of the mud–water interface in shallow and eutrophic bodies of water. The spatial and temporal distribution of metal concentrations in sediment was investigated in the Gulf of Riga (Kulikova, Seisuma, 2005). Two expressive behaviours were observed for metals: sediment texture and bathymetry had a huge influence on metal distribution in sediments of a water body, and variations of some metals in three seasons (spring, summer and autumn) were significant.

Lake Žuvintas is a typical overgrowing lake with an area of 97 km^2. It is a very shallow lake (average depth 1.2 m) in which macrophyte biomass increases annually, sedimentation processes are intensive and eutrophication proceeds as well. There are numerous floating islands in the lake. According to the distribution of aquatic vegetation, the lake belongs to the beltwisecontinuous overgrowing type (Pranaitis, 2004). Lake Žuvintas belongs to the category of protected areas. Now this lake is established according to the Natura 2000 requirements. This lake has been investigated by many scientists. Some integrated projects were prepared with the aim to protect the nature of the Reserve. The results of complex expeditions (botanical, zoological, hydrological and hydrobiological research data) in 1979–1985 were published in (Заповедник..., 1993). Possible measures for improving the conditions of the Lake Žuvintas ecosystem are described in the PIN-Matra project "Management and restoration of Natura 2000 sites through an integrated river basin management plan of the Dovinė river, Lithuania (2003–2006)". The anthopogenic impact on the hydrological regime and water quality of Lake Žuvintas has been analysed (Gailiušis et al, 2003), changes in Lake Žuvintas entailed by hydrographic reconstructions have been analysed (Taminskas et al, 2005). K. Kilkus (2006) described the space distribution of hydrophysical–hydrochemical propeties in Lake Žuvintas. There is no much data concerning hydrodynamics and sedimentation processes in Lake Žuvintas.

The aim of the present research was modelling of sedimentation processes in Lake Žuvintas during flood periods according to scenarios of the lake management. A hydrodynamic model of the lake as the backround for sediment transport modelling was constructed and calibrated. The two-dimensional MIKE 21 modelling system was used as a software.

MATERIALS AND METHODS

The two-dimensional numerical simulation system MIKE 21 was used for modelling hydrodynamic and sediment transport in Lake Žuvintas. The hydrodynamic module MIKE 21 HD is a general part of the numerical modelling system. It simulates unsteady two-dimensional flows in one-layer (vertically homogeneous) fluids. MIKE 21 HD uses Alternating Direction Implicit (ADI) techniques to integrate the equations for mass and momentum conservation in the space-time domain (MIKE 21..., 2005).

The main groups of initial data for modelling with MIKE 21 HD are as follows: the main parameters of the model (time step, simulation period, water body orientation, geographical longitude and latitude); bathymetry; boundary conditions (water level or discharge and flow direction); other acting forces (speed and direction of wind, additional sources and sinks, their discharges and flow velocities).

Results of the HD module are water levels, discharges or flow velocities in a specified area, cross-section or grid spacing.

The MT (Mud Transport) Module of the two-dimensional modelling system MIKE 21 was used with the objective to calculate mud transport processes in Lake Žuvintas (MIKE 21..., 2005). The mud transport modelling covers the processes of settling, deposition and erosion. Calculations are well suited for the primary grain size of diameters less than 60 μm.

The initial data for the MT model are the bathymetry of the lake and flow velocities (modelled by MIKE 21 HD), dispersion coefficients, mean settling velocity, critical velocities of deposition and erosion, erosion coefficient of the bed, initial concentration of sediments in the water area of the lake and in the boundary cross-sections.

Results of the MT model are the average concentration of suspended sediments in the vertical of the lake (g/m^3), deposition of sediment and erosion of the bed over the period (g/m^2), changes of the lake bed over the period (m).

The hydrological database (data of the inflow into Lake Žuvintas, outflow from the lake and water levels) is necessary for calculating the hydrodynamics and sediment transport processes.

The water levels in Lake Žuvintas have been measured since 1967. In the lakes Dusia and Žuvintas, belonging to the Dovinė river basin, sluice-regulator systems were constructed in 1972–1973. Therefore, water level measurement data of 1967–1971 characterize the natural lake regime, while later data characterize the regulated regime. The water levels of Lake Žuvintas are presented at 24-hour intervals and match the requirements of the model calibration.

Direct data on the inflow and overflow of Lake Žuvintas are not available. The runoff of the Dovinė was measured in 1951–1958 at the former Paežerėliai water measuring station (WMS) situated in the lower reaches and in 1969–1971 at the head from Lake Dusia (the Metelytės WMS). These runoff data are not sufficient for the analysis and determination of inflow into the lake. For this reason the river analogue Šešupė was chosen. The correlation of common years of runoff for the Šešupė river at Kalvarija WMS and the Dovinė at Paežerėliai WMS are close enough ($R = 0.92$), allowing to use the Šešupė runoff values and equations to determine the inflow into Lake Žuvintas. The link equation ($y = 1.27x - 0.737$) is used to calculate the runoff for the Dovinė at Paežerėliai WMS. The outflow from Lake Žuvintas was calculated using the balance method as a result of difference of inflow into the lake and water volume changes in the lake.

RESULTS

Hydrodynamic model of Lake Žuvintas

The hydrodynamic model of Lake Žuvintas was constructed to model the sediment processes in the lake. The bathymetry of Lake Žuvintas was prepared according to the digital map of 1986 (M 1:10 000) which was compiled by researchers of Institute of Geology and Geography. The lake was divided into a square grid spacing with the size of 10 m. A time step of 10 s was selected for the modeling. The boundary conditions were chosen as the inflow into the lake and the outflow from the lake (the Dovinė river discharge).

The calibration of the MIKE 21 hydrodynamic model was performed by varying the bed resistance (Manning number) and the eddy viscosity coefficient. A large part of Lake Žuvintas is covered by vegetation. This is the reason why different Manning numbers were chosen for

Table 1. **Inflow, outflow and water levels of Lake Žuvintas**

Date	Q_{inflow}, m^3/s	$Q_{outflow}$, m^3/s	H_{lake}, cm	Date	Q_{inflow}, m^3/s	$Q_{outflow}$, m^3/s	H_{lake}, cm
12 04 1996	13.33	4.96	152	05 02 2000	6.10	6.53	155
13 04 1996	15.02	8.93	159	06 02 2000	6.80	6.39	156
14 04 1996	15.80	8.80	166	07 02 2000	7.69	7.47	157
15 04 1996	20.58	20.91	170	08 02 2000	8.77	9.85	157
16 04 1996	21.66	16.07	176	09 02 2000	9.47	7.95	159
17 04 1996	21.51	19.14	178	10 02 2000	9.77	5.62	163
18 04 1996	21.20	20.89	178	11 02 2000	10.08	8.16	165
19 04 1996	19.73	20.48	176	12 02 2000	8.31	6.54	165

the areas of water and vegetation in the lake. This proposed values of the Manning number can range from 20 to 40 m$^{0.33}$/s (MIKE 21, 2005; Petr, 2003). We have chosen a Manning coefficient of 35.7 m$^{0.33}$/s for water areas and 20.0 m$^{0.33}$/s for the areas of vegetation. According to recommendations (MIKE 21, 2005), the eddy viscosity coefficient 1 m^2/s was chosen.

For calibration of the hydrodynamic model the spring flood period, in which the variation of Lake Žuvintas is considerable, is very important. The flood was analysed. The maximum value of the inflow calculated in 1996 was 21.66 m^3/s. It was the fourth greatest flood in the lake. In 2000, the flood was comparatively small. The greatest inflow to the lake was 10.08 m^3/s. For calibration of the model, an eight-day period was chosen. Data for calibration of the hydrodynamic model are presented in Table 1. The inflow into Lake Žuvintas and the outflow from it are used as the boundary conditions of the model.

During calibration of the hydrodynamic model, flow velocities and level variations in the lake were calculated. The flow structure during a great flood is shown in Fig. 1 (conditions in 1996, Table 1). In this case, flows in the lake occur in its western part only. The greatest flow velocities were determined in the vicinity of the Dovinė river flowing into the lake, however, 400 meters further from it the velocities were reduced to 4–5 cm /s. Flow velocities in the middle part of the lake are reduced to 1–2 cm/s. Flow velocities begin to grow when approaching the place where the Dovinė flows out of the lake, influenced by the great outflow rate. Besides, a less significant increase of flow velocity was noted between the isle and the south coast of the lake. A similar flow structure emerged under conditions of the flood in 2000. Great flow velocities in the place where the Dovinė joins the lake decreased to 3–4 cm at a distance of 400 meters. Velocities in the middle part of the lake were close to zero.

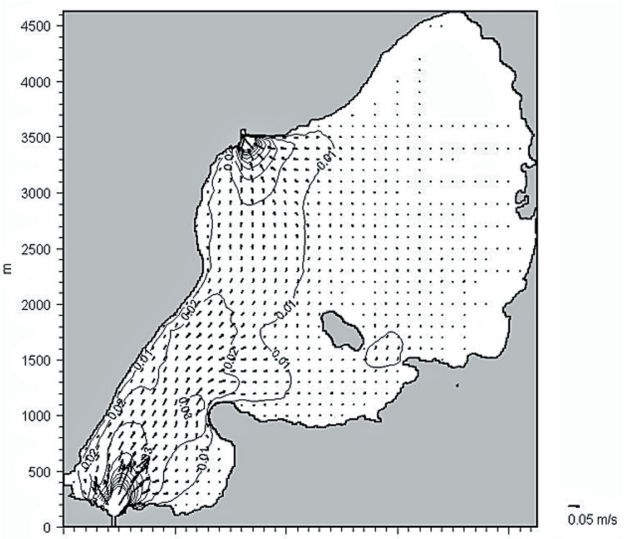

Fig. 1. Flow structure of Lake Žuvintas in 1996

The HD model calibration was carried out according to variations of water level in Lake Žuvintas. Water level changes, modelled for concrete initial conditions, were compared with the measured variations of the lake water level. During an eight-day period (April 12–19, 1996) the water level of the lake increased by 24 cm (Table 1). The modelled variation of water level is 26 cm. The correlation coefficient for measured and calculated variations of water level is 0.99. During the eight-day period of another flood (February 5–12, 2000) the lake level rose by 10 cm, and the calculated variation of water level was 11 cm. The measured water level variations of Lake Žuvintas coincide well with the variations of water level calculated using the model. These results show that the model MIKE 21 HD is suitable for modelling the hydrodynamics and sediment processes in Lake Žuvintas.

Analysis of hydrological regime of lake according to scenarios of lake management

Considerable variations of the hydrodynamical regime of Lake Žuvintas are possible only under flood conditions when the inflow and the outflow of the lake increase. Therefore, periods of 16–18 days (when the inflow and the outflow are maximal) were chosen for modelling the hydrodynamical regime of the lake. The hydrodynamical modelling of Lake Žuvintas was based on two scenarios elaborated by A. Povilaitis (2005). The first scenario (further called scenario 0) describes the current situation in the lake. The author performed the hydrological modelling of the Dovinė river basin using the SIMGRO model, referring to the hydrological, meteorological and other data of observations for the years 1994–2004. The daily discharges of Lake Žuvintas inflow and outflow were modelled for this period. They are used as boundary conditions for the MIKE 21 HD model.

The second scenario (further called scenario 1) describes the changed conditions of Lake Žuvintas outflow when the present sluice regulator was changed by an overflow dam with the highest crest 86.27 m. The daily discharges of Lake Žuvintas inflow and outflow are also modelled for the period 1994–2004 when the overflow dam was functioning and the since regulators of the lakes Dusia and Simnas were uncovered.

Scenarios of managing the hydrological regime of Lake Žuvintas have to be based on an analogy with natural level variation. Therefore, it was suggested to evaluate the spring flood character of the region's rivers according to their runoff volume and maximal discharges. Consequently, analysis of maximal inflow discharges of Lake Žuvintas in 1994–2004, estimated according to scenario 0, was done. It was established that flood with the largest inflow discharge occurred on 3–18 February, 2004. The maximal inflow discharge of this flood was 17.68 m^3/s, the maximal outflow discharge being 6.75 m^3/s, and 2.38 mill. m^3 of water was accumulated in the lake (Fig. 2a). The largest flood depending on the volume of runoff was in April 6–22, 1996 when 3.84 mill. m^3 of water was accumulated in Lake Žuvintas (Fig. 2b). A small flood occurred in January 22 – February 7, 2002. The largest inflow of this period was 6.10 m^3/s and the largest outflow 4.42 m^3/s (Fig. 2c); 1.57 mill. m^3 of water was accumulated in the lake.

The process of the described floods according to scenarios 0 and 1 differs insignificantly. Installation of the overflow dam could change at least the maximal flood of 3–18 February, 2004 (Fig. 2a): 1.73 mill. m^3 of water would be accumulated in the lake (37% less than according to scenario 0). In flood of April 6–22, 1996, the lake inflow in scenario 1 would be 20% larger than inflow in scenario 0. The lake outflow differs even more – it is 46% larger according to scenario 1 (Fig. 2b). The volume of water accumulated during the flood would drop by 29%. In the case of a small flood (of January 22 – February 7, 2002), the inflow and outflow of Lake Žuvintas according to scenario 1 is marginally smaller than the inflow and outflow according on scenario 0 – respectively by 10% and 7% (Fig. 2c), while the volume of the water accumulated during the flood would be by 25% less.

Analysis of mud transport in Lake Žuvintas

There is a description of some characteristics required for modelling mud transport. The average rate of sediment settling is 0.00048 m/s (MIKE 21..., 2005) because Lake Žuvintas is shallow and low flow rates are modelled. The rate of deposition of suspended sediments and the critical rate of erosion are set respectively at 0.1 and 0.3 m/s. The dispersion coefficients $D_x = D_y = 1.5$ m^2/s (MIKE 21..., 2005).

It is essential to determine the initial concentration of sediment turbidity in the lake and in the boundary cross-sections (the lake inflow and inflow turbidity) in the period under analysis for calculating the suspension distribution of Lake Žuvintas. There are no data on the lake turbidity for the periods of the analysed floods. Therefore, analysis of the many-year turbidity data was performed according to the database compiled by the researchers of Institute of Geology and Geography. The maximal values of turbidity were selected.

A substantial parameter in the research of mud transport in Lake Žuvintas is changes of the bed. These changes show what a layer of mud (m) can be settled during the periods of various floods when there are certain concentrations of the initial lake turbidity and its inflow and outflow turbidities.

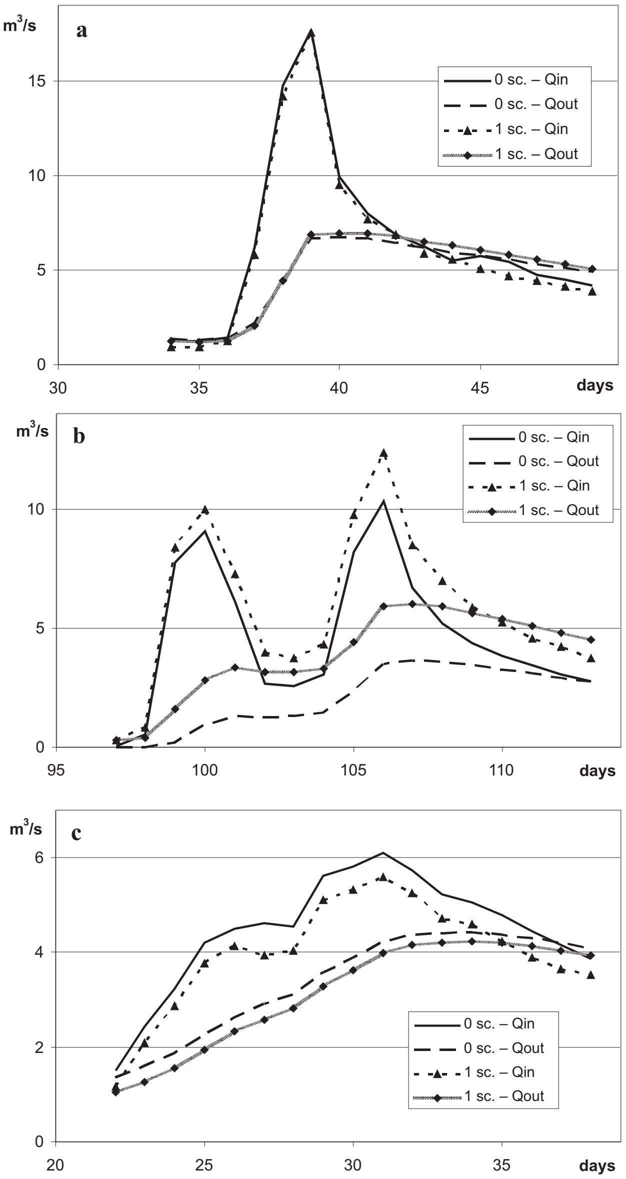

Fig. 2. Inflow and outflow of Lake Žuvintas according to scenarios 0 and 1 for periods: a) 03 02 – 18 02 2004, b) 07 04 – 23 04 1996; c) 22 01 – 07 02 2002

For modelling the suspended sediment distribution during the period of February 3–18, 2004, it was determined that the lake inflow turbidity was 27 g/m^3, the lake outflow turbidity being 8 g/m^3 and the lake initial turbidity 22 g/m^3. These parameters are used for modelling mud distribution according to both scenarios 0 and 1 (Fig. 3). Additionally, for the calculation, the turbidity parameters were reduced two times (inflow turbidity 13 g/m^3, outflow turbidity 4 g/m^3, initial turbidity 11 g/m^3). In the above period, the average mud layer of 4.03 cm could be accumulated in Lake Žuvintas according to scenario 0, 4.00 cm according to scenario 1 and 1.79 cm according to scenario 0 when turbidity parameters are two times smaller.

Changes of the mud layer during the flood of 2004 were calculated in the cross-section A–B (Fig. 3) of Lake Žuvintas. In the beginning of the cross-section A–B, near the place of lake inflow, the bed erosion proceeds (the

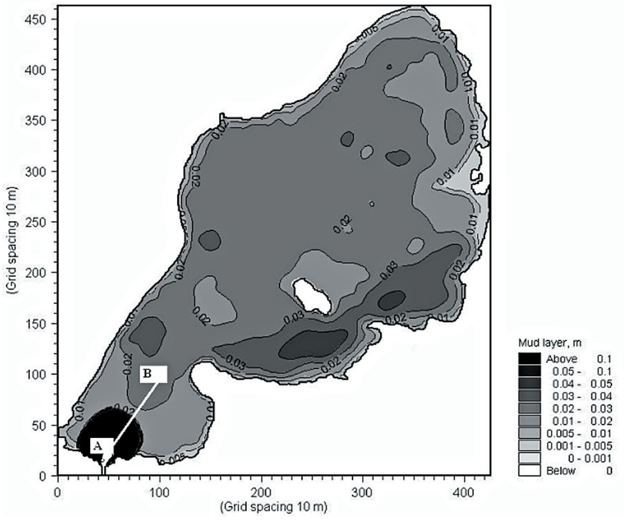

Fig. 3. Lake Žuvintas bed changes according to scenario 0 in the period of flood (03 02 – 18 02 2004). Lake inflow turbidity is 27 g/m³, lake outflow turbidity 8 g/m³ and lake initial turbidity 22 g/m³

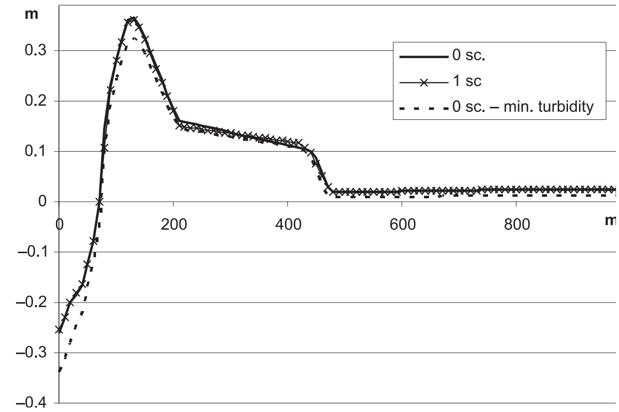

Fig. 4. Change of mud layer during the flood (03 02 – 18 02 2004) in the cross-section A–B

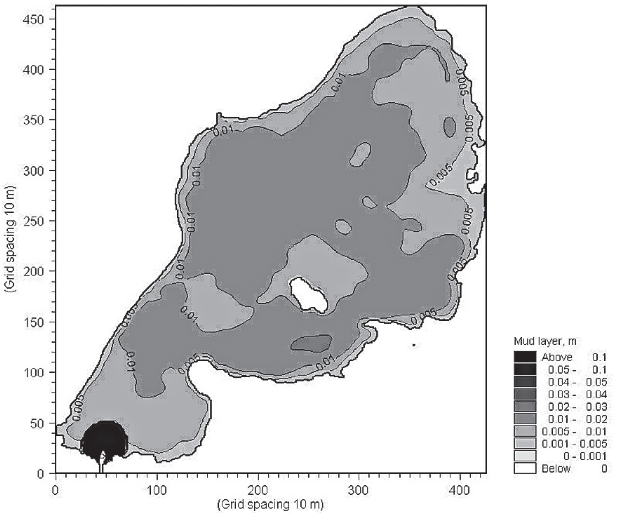

Fig. 5. Lake Žuvintas bed changes according to scenario 0 during the period of flood (06 04 – 22 04 1996). Lake inflow turbidity is 20 g/m³, lake outflow turbidity 4 g/m³ and lake initial turbidity 10 g/m³

large inflow discharge degrades the bed of the lake) (Fig. 4). Only 60 m away the accumulation processes start. The bed changes according to scenarios 0 and 1 are similar. The largest layer of mud would be 36 cm according to scenarios 0 and 1 and 32 cm according to scenario 0, when turbidity parameters are two times smaller. The influence of the initial lake turbidity is significant in the cross-section A–B from 500 to 1000 m. When the initial lake turbidity is 22 g/m³, this part of the lake would be covered with a 2 cm mud layer of, and when the initial lake turbidity is 11 g/m³ the layer of mud would be 1 cm.

For modelling the distribution of suspended sediments in the period April 6–22, 1996 it has been determined that the lake inflow turbidity is 20 g/m³, the outflow turbidity being 4 g/m³ and the initial turbidity 10 g/m³. The accumulated mud thickness according to scenario 0 is presented in Fig. 5. The inflow area of Lake Žuvintas is most strongly influenced. A layer of suspended sediments over 10 cm thick is formed in the water area 260 m away from Lake Žuvintas inflow point. In the other parts of the lake, the accumulated mud layer reduces to 1–2 cm. The processes of mud accumulation are similar according to scenario 1 in the flood of 1996.

Also the mud transport is modelled according to scenario 0 when the turbidity parameters are changed to maximal (the lake inflow turbidity – 27 g/m³, the lake outflow turbidity 8 g/m³, the initial lake turbidity 22 g/m³). During the period of April 6–22, 1996, an average mud layer of 2.05 cm would be accumulated in Lake Žuvintas according to scenario 0, 2.27 cm according to scenario 1, and 3.72 according to scenario 0, when the turbidity parameters are maximal.

The change of the mud thickness is calculated during the flood of 1996 in the cross-section A–B of Lake Žuvintas (Fig. 6). The thickest mud layer would be accumulated in the 300 m section from the lake inflow according to scenario 1 because the inflow into the lake according to this scenario is the largest. According to scenario 0 the mud layer would be less in this section. The maximal values of the mud layer in the cross-section A–B are 24 cm according to scenario 0 and 30 cm according to scenario 1. When the turbidity parameters are changed to maximal, the mud layer would increase by 2–6 cm in the 300 m section versus scenario 0 results when the turbidity parameters are less. The influence of the initial lake turbidity is significant in the cross-section A–B from 380 to 1000 m. When the initial lake turbidity is 11 g/m³ (scenarios 0 and 1), this part of the lake would be covered with a mud layer of up to 1 cm, and when the turbidity is 22 g/m³ (scenario 0 with maximal turbidity parameters), the mud thickness would be 2 cm.

For the period January 22 – February 7, 2002, the mud transport was modelled according to scenarios 0 and 1 (the lake inflow turbidity is 5 g/m³, outflow turbidity 2 g/m³, the initial lake turbidity 3 g/m³). The thickness of mud over 10 cm forms in a water area 200 m away from Lake Žuvintas inflow point. In the other parts of the lake, the layer of the accumulated mud reduces to several milimetres. Similar processes of mud accumulation proceed according to scenario 1. During a small flood, the aver-

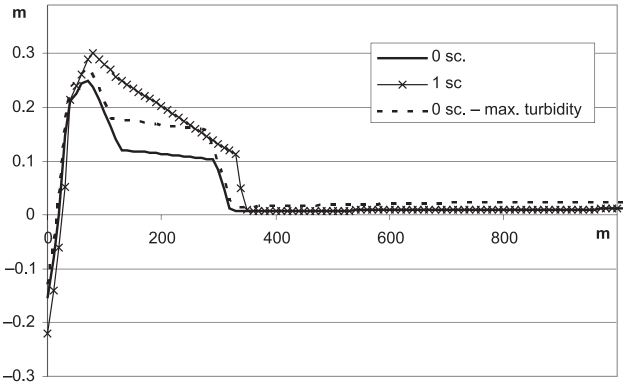

Fig. 6. Change of mud layer during the flood (06 04 – 22 04 1996) in the cross-section A–B

age mud layer of 0.13 cm would be accumulated in Lake Žuvintas according to scenario 0 and 0.12 cm according to scenario 1.

Analysis of Lake Žuvintas mud transport according to scenarios 0 and 1 under various flood conditions revealed two zones of the lake:

1. The water area which is 400 m away from the lake inflow point. The main force determining the mud accumulation processes in this area is the lake inflow turbidity. If the concentration of lake inflow turbidity is higher, a thicker layer of mud is accumulated in the water area.

2. The rest of the lake. In this area, mud transport processes depend on the initial lake turbidity. The lake turbidity depends on the natural conditions: in case of great rainfalls it increases considerably because outwashes from the banks to the lake are possible. Besides, strong winds also influence the hydrodynamical regime of this shallow lake. The appearance of flows influences the bed of the lake and changes its turbidity. With a high initial turbidity of the lake, after some time changes in the bed can occur: in the whole lake, except the first zone, a mud layer of 1–2 cm can be formed. When the initial turbidity is low, mud accumulation processes hardly happen in the lake.

Changes of the bed in the outflow zone of Lake Žuvintas will depend on the bathymetry of the lake in the overflow dam installation area, the flow structure and the initial turbidity. According to data of lake sedimentation, the measured turbidity is low in the outflow zone of the lake (limit values are 0.4–12 g/m^3, average values being 2–4 g/m^3). In the periods of different floods, low flow velocities are modelled in the area of the outflow zone of the lake. Therefore, the results of modelling of mud transport do not show larger zones of accumulated mud or erosion of the bed. If the lake bathymetry is changed considerably with projecting the overflow dam according to scenario 1, changes of the bed could be calculated additionally modelling the mud transport in Lake Žuvintas.

Comparison of the results of mud transport in Lake Žuvintas according to scenario 0 (present conditions of Lake Žuvintas management) and scenario 1 (an overflow dam with the maximal crest altitude 86.28 m) shows that the installation of the overflow dam will not have a significant influence on the mud accumulation processes in the lake. The lake inflow and outflow do not differ much according to both scenarios, so under the same conditions of the lake inflow turbidity, a similar layer of mud will be accumulated in the lake (Figs. 4 and 6).

CONCLUSIONS

1. The calibration of the hydrodynamic model MIKE 21 HD is necessary in order to model hydrodynamic processes and sediment transport in Lake Žuvintas. Data on Lake Žuvintas inflow and outflow are needed for calibration. Direct measurement data of the inflow are not enough. Therefore, information on the inflow was estimated using data of a river analogue – the Šešupė (WMS Kalvarija).

2. The calibration of the hydrodynamic model was carried out for spring floods of 1996 and 2000. The coefficient of correlation between the measured and the calculated water levels of Lake Žuvintas is 0.99. Therefore, the model MIKE 21 HD is suitable for modelling hydrodynamic and sediment transport in Lake Žuvintas according to various scenarios of its management.

3. The hydrodynamic modelling of Lake Žuvintas was performed according to two scenarios: scenario 0 describes the present conditions in the lake, while scenario 1 describes the changed conditions of the lake outflow, with the present sluice-regulator being converted to an overflow dam. When the modelled variations of the water level of Lake Žuvintas were analysed during three floods, it was determined that an installation of an overflow dam in the Dovinė river would reduce water level variations in the lake by 5–7 cm. The character of the water level variations is similar according to both scenarios, only the maximal values differ. The lake flow structures are similar according to both scenarios.

4. Under various flood conditions, mud transport in Lake Žuvintas was analysed according to scenarios 0 and 1, and two zones of the lake were distinguished: 1) the water area 400 m away from the lake inflow point, 2) and the rest of the lake. In the first zone, mud transport processes depend on the lake inflow turbidity and discharge, while in the second zone these processes depend on the initial lake turbidity.

5. In the periods of great floods (analogue – the year 2004), an average mud layer of 4.11 cm would be accumulated in Lake Žuvintas according to scenario 0, and 4.03 cm according to scenario 1. In periods of average floods (analogue – the year 1996), an average mud layer of 2.05 cm would be accumulated in the lake according to scenario 0, and 2.27 cm according to scenario 1. In periods of small floods (analogue – the year 2002), an average mud layer of 0.13 cm would be accumulated in the lake according to scenario 0, and 0.12 cm according to scenario 1.

6. Comparison of data on mud transport in Lake Žuvintas according to scenario 0 (present conditions of Lake Žuvintas management) and scenario 1 (an overflow dam with the maximal crest altitude 86.28 m) shows that the installation of the overflow dam will not have a significant influence on mud accumulation processes in the lake. In order to reduce mud accumulation in Lake Žuvintas, the inflow water quality should be ameliorated and the anti-erosive implements should be used in the basin of the lake.

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ŽUVINTO EŽERO NEŠMENŲ PROCESŲ MODELIAVIMAS

Santrauka

Žuvinto ežeras priklauso seklių eutrofinių ežerų klasei. Ežero seklėjimo procesai turi didelę įtaką vandens kokybei bei ekosistemos būklei. Susikaupiantis dumblo sluoksnio storis bei nešmenų sudėtis ežere priklauso nuo abiotinių veiksnių: prietakos į ežerą (vandens debitas, drumstumas ir cheminė sudėtis), meteorologinių rodiklių (krituliai, vėjas ir temperatūra), ežero vandens lygio svyravimo, dugno grunto savybių bei ežero augmenijos plotų. Norint pagerinti Žuvinto ežero ekologinę būklę yra siūlomos tam tikros vandentvarkos priemonės, kaip Dovinės upės baseino šliuzų reguliavimas, įtekančių į ežerą upelių vandens kokybės gerinimas, ežero valymas pašalinant dalį vandens augmenijos. Siekiant įvertinti šių priemonių efektyvumą, būtina žinoti, kaip pasikeis ežero sedimentacijos procesai pakitus abiotiniams veiksniams, t. y. įvykdžius vandentvarkos priemones. Šį uždavinį galima išspręsti tik matematinio modeliavimo metodais.

Straipsnio tikslas – Žuvinto ežero hidrodinaminių ir nešmenų procesų modelio sukūrimas bei šio modelio taikymas įvertinant vandentvarkos priemonių įtaką ežero dumblėjimui. Ežero hidrodinaminis modelis yra sukalibruotas remiantis Dovinės ir Šešupės upių baseinų hidrologinių duomenų baze. Modeliui sudaryti panaudota dvimatė skaitmeninio modeliavimo sistema MIKE 21.

Raktažodžiai: Žuvinto ežeras, hidrodinamika, nešmenų pernaša, modeliavimo sistema MIKE 21