Analysis of the possibilities for improvement of the water regime of Srebarna Maintained Reserve

Summary

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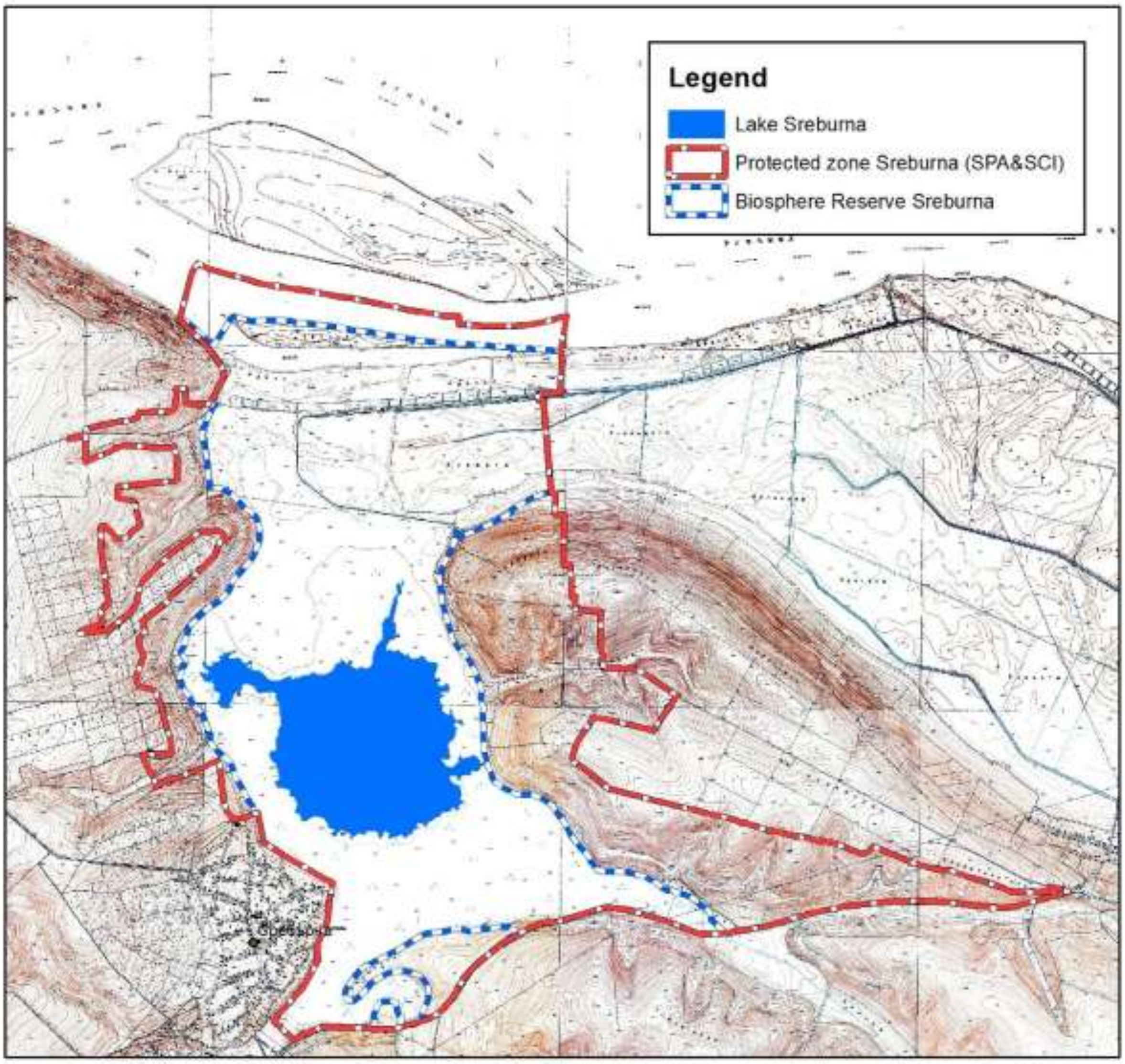
Introduction

Lake Srebarna is one of the most indicative examples of the policies pursued until now in the area of water management in Bulgaria. At the same time, the lake is also a popular example of the importance of the connection between a river and a riparian wetland area. In the past, the high waters of the Danube annually entered the lake. As the waters retreated, they removed nutrients, organic matter, and even whole islands of floating reed. With the construction of a protective dike between the lake and the Danube in 1948, the connection was broken. The territories between the lake and the Danube were claimed for agriculture and intensive forest cultures. A complex drainage system was also set up. As a result, the conditions in the lake changed abruptly; the succession was accelerated and so was the loss of biodiversity.

These changes prompted the first attempts at restoring the lake water regime. In 1963, 1979, and 1994 were implemented several projects that proved essential for the lake. Without these projects, Lake Srebarna would have probably lost its importance for the protection of aquatic ecosystems in Bulgaria. The projects were planned and carried out in the presence of a drainage system and arable land between the lake and the Danube. Due to this limitation, they did not accomplish the restoration of the dynamic connection between the river and the lake, nor the lasting maintenance of the water regime of the Reserve. After the arable lands to the north of the lake were added to the Reserve and the status of the protected area was established in 1999, this limitation was removed to a large extent. This opened a possibility of seeking entirely new solutions for the improvement of the water regime.

Lake Srebarna has a key role in the protection of riparian wetlands along the Danube in Bulgaria. Firstly, it is a largely preserved example of the primary ecosystem of the Danube wetlands. Secondly, despite the considerable changes (involving biodiversity loss) undergone by Srebarna, it remains the lake with the greatest potential for ecological restoration in the contemporary meaning of the word. Perhaps this is the only large Danube wetland area where sustainable management can be achieved in the near future with minimum human intervention and without the necessity of managing hydrotechnical facilities such as locks, canals, or protective dikes.

At present, a state administration body is responsible for the management of the protected areas, pursuing established practices. At the national level, considerable experience has been gained in the protection and restoration of wetland areas, including along the Danube. Now that the limitations in Srebarna Maintained Reserve are removed and the possibilities of funding for environmental projects are improved, we can no longer to neglect or delay the solution of the lake's main problems.

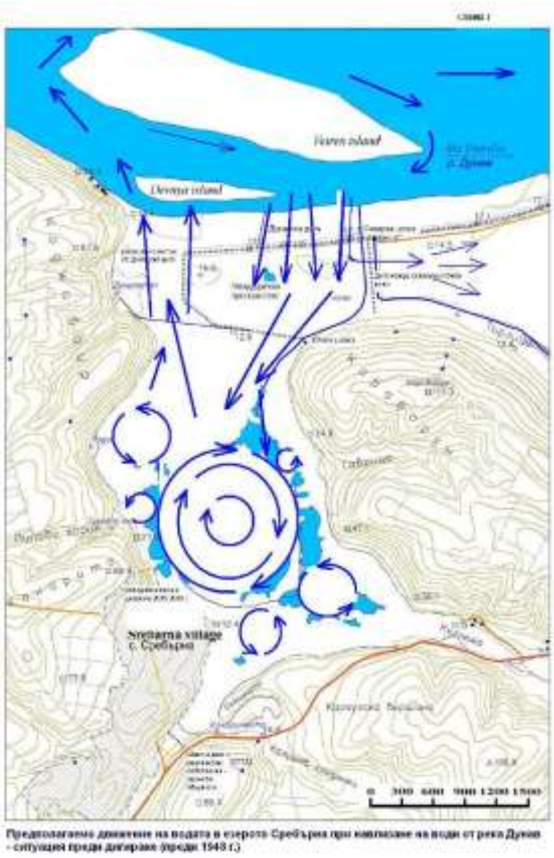


Srebarna Reserve situation

Factors determining the water regime of Lake Srebarna

Lake Srebarna was formed by a huge eddy (reverse current) as the Danube waters entered chiefly through the inlets in the eastern (lower) part of the Reserve, the turned in an opposite direction to the Danube current (clockwise) and re-entered the river through the inlets in the western (higher) part where they accumulated sediments.

Therefore the basic open water surface of Srebarna has an almost round shape, and the deepest parts used to be approximately in the middle. Naturally, during these spring floods were formed a number of additional currents and eddies, and part of the flood waters probably flowed downstream and flooded the lowland of Aydemir (at present comprising arable land).



Supposed water movements in Lake Srebarna during Danube floods – situation before diking (before 1948)

The hydraulics and direction of currents was also greatly affected by the two Danube islands located opposite Srebarna Lake – the smaller island of Devnya and the larger island of Vetren. In the development of Srebarna ecosystems, the anthropogenic changes mark several stages: natural state (until 1948); unnatural state (from 1949 until 1978); first restoration stage (from 1979 until 1994) and second restoration stage after 1994. In 1978, after a partial removal of the dike, the periodic entering of Danube waters during the spring high waters was restored. This had a considerable influence on the water balance and the hydrology characteristics of the lake. The prolonged drought between 1988 and 1994 brought about negative changes in the morphometric indicators of the lake such as reduction of the open water surface and the water volume. After the hydraulic system featuring a connecting canal between the Danube and Lake Srebarna was launched in 1994, conditions were created for regulating the water level, the flooded area and the water volume of the lake. In 1991-1993 hydrological research was carried out on the occasion of constructing a canal as a hydraulic connection between the lake and the Danube during high river waters. The studies reflect the negative changes in the hydrologic and morphometric indicators of the lake due to the drought.

The lake catchment area (402 sq km) is drained by the rivers Srebrenska and Kalnezha, which have an inconstant water regime and almost dry up in summer and autumn.

With its hydrologic and morphometric characteristics, the lake can be classified as belonging to the smallest water bodies with an area of up to 10 sq km.

The protection of the territories around the Reserve is based on a dike system along the Danube river bank in the northern part of the Reserve and to the east of it. During very high waters of the Danube, the water enters the lake from the northwestern part of the Reserve outside the dike system. In this case the catchment area has no additional protection against flooding. In a situation like this, after the Danube waters subside, the water in the lake retreats through the place where they entered, as well as through the canal that connects the lake to the Danube after the locks are opened.

Map of hydrotechnical facilities in the northern part of the Reserve

The lake is a trap for sediments that enter the lake with the surface waters. These are waters from the Danube and from the rivers that flow into the lake. The sediment trap effect is largely aggravated by the way the constructed locks are managed. They are opened only during high waters of the Danube to convey water into the lake. No water is conveyed from the lake into the Danube except in very rare cases in the past. Erosion as a factor is limited. In reality eroded soil can enter the lake only from its high western shore. In the reserve there are no conditions for erosion and bank modification.

Water balance and water regime

After the construction of the Danube dike and its completion in 1952, the water balance of Lake Srebarna was changed. It lacks the component of surface waters from the Danube. At present, this element needs to be restored to the water balance as there is a new lake-river connection. However, over the past few years no surface waters from the Danube have entered the lake because the locks have not been opened and the Danube water level has not reached the critical elevations during which water can enter through the breached dike.

For the purpose of the feasibility study an analysis was carried out of the water levels of the Danube in the periods 1941-1991 and 1992-2011. Analysed were the monthly and annual water levels during high waters for the whole period. The data indicates that the water levels fluctuated between the elevations of 11.50 and 16,00 m a.s.l. This shows that there is a possibility for gravitational capturing of water masses at Lake Srebarna. According to the statistical analysis of the probability of the water levels, the levels that are characteristic and essential for a hydrological connection with probability 90%, 75%, 50%, and 20% are respectively 11.86 m, 12.63 m, 13.68 m, and 14.50 m. On the basis of this data were calculated the absolute elevations of the measured levels with according correction of distance between the actual water gauge at Silistra and the fictitious water gauge “Lake Srebarna”.

View from the Danube towards Srebarna (north to south). In the foreground: the canal between Devnya Island (the smaller of the two islands opposite Srebarna) and the bank. On the Danube bank there are some bare territories that used to be intensive poplar plantations until 2007. At present, these are part of the Reserve. On these territories is planned afforestation with local species and restoration of flooded forests (main natural habitat of the type 91E0). In the background: Lake Srebarna and Srebarna Village. Right-hand part of the middle ground: the area where at present during extremely high waters the lake is connected to the Danube. Left part of the middle ground: the so-called inter-dike area. These former arable lands are now part of the Reserve. In the past the hydraulic connection between the lake and the river took place here because the terrain is lower. In 1994 was constructed a connecting canal between the lake and the river that crossed the inter-dike area and the dikes by means of two locks (not very well seen on this picture). The water area in the middle of the inter-dike area is the remains of the excavation made to provide material for the dike.

Connecting canal between the Danube and Lake Srebarna (constructed in 1994). In the foreground: the so-called Northern lock; in the background: the Southern lock. Both were constructed at the dike surrounding the inter-dike area.

Connecting canal and Northern lock in the stretch by an arm of the Danube

Water gauge by the lake at the Southern lock

Duration of the water levels. This characteristic is important because it helps to approximately determine the water mass that can enter the reserve from the Danube. The key water levels for the already constructed facilities have elevations of 11.50, 11.88, and 12.33 m that correspond to measurements of 412 cm, 450 cm, and 500 cm (at Silistra water gauge stattion).

These water levels of the Danube have average annual durations of respectively 137 days (for the levels between elevations 11.33 and 11.88 m), 112 days (for the levels between elevations 11.88 and 12.33 m) and 81 days (for the levels above elevation 12.33 m).

The hydrological analyses of the fluctuations and duration of the levels of the Danube detailed above can be summarized as follows: at the assumed water gauge at Lake Srebarna and with the current hydrological regime of the Danube that has been strongly modified by anthropogenic activity, the annual gravitational entering of Danube waters in Lake Srebarna is possible only via artificial canals with bottom elevations lower than 11.50 m. This was also the base for the construction of the connecting canal in 1994 (the elevation of its bottom is 10.30 m a.s.l.). This shows that without management of the connecting canal it is not possible to ensure the annual gravitational entering of Danube waters into Lake Srebarna.

The analysis of the hydrological and hydrogeological conditions shows that Lake Srebarna, except by surface waters and Danube waters, is also fed by karst waters of the Lower Cretaceous aquifer. The accumulation of large sediment quantities (more than 1 m) in the cup of the lake probably limited the access of karst waters.
An important conclusion from the hydrogeological analysis is that infiltration is not a leading factor in the water balance. This means that the draining of the lake towards the Danube during dry periods is a very slow process. Evaporation and water loss through the locks are more important for the sinking of the lake level in summer than infiltration. Accordingly, the reverse process of infiltration of water from the Danube towards the lake during high waters practically has no importance for the water level in the lake.

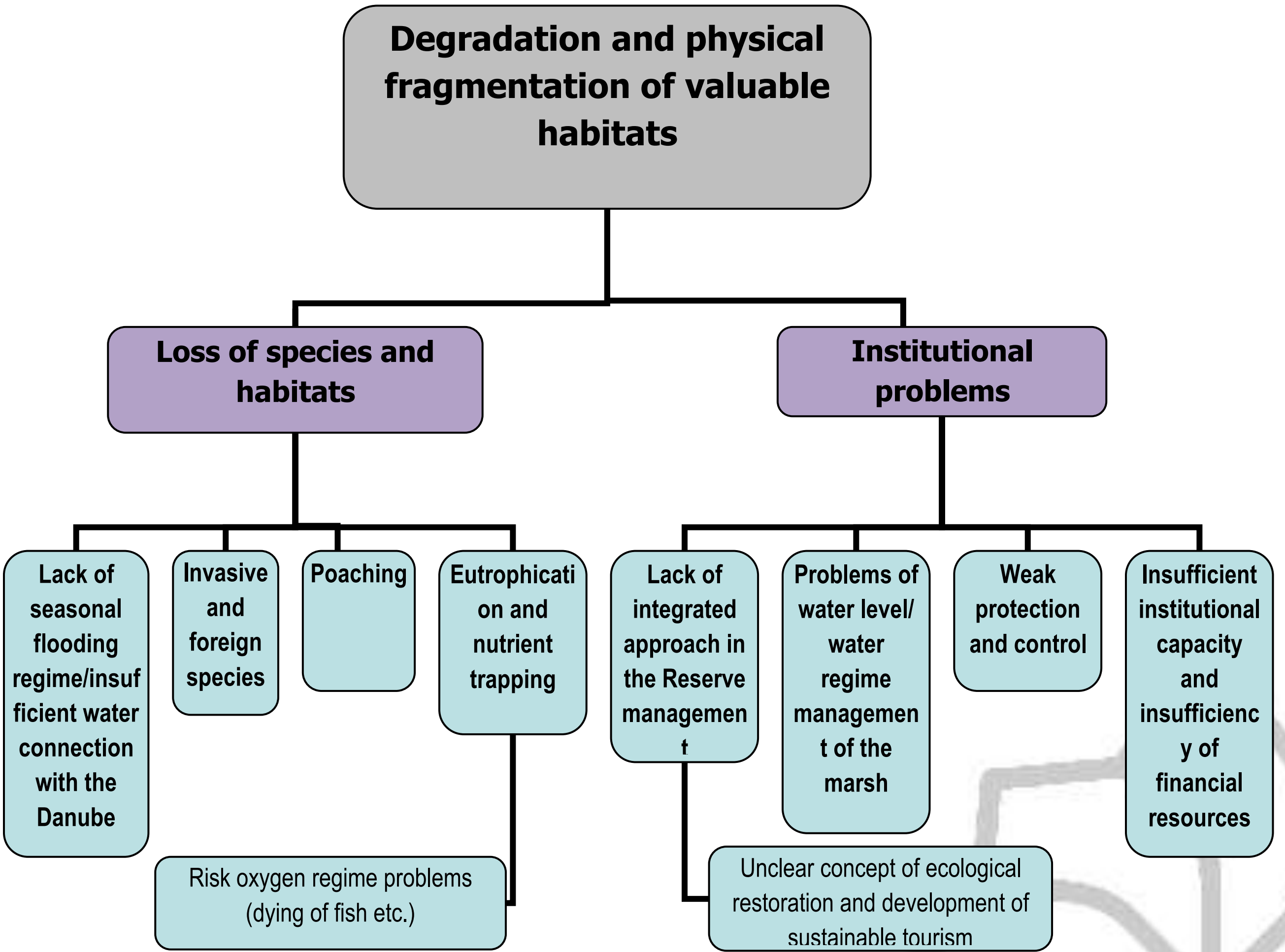
Northern canal lock

Problems in defining management goals for the lake water regime

As yet, the main goal of the ecological restoration and maintenance of the Reserve is still unclear – is it to achieve the seasonal spring flooding of Srebarna (partial or full), as was the existing situation before the diking of the Danube (before 1948), or is it rather to convey water into the lake and retain it at the highest possible level (similarly to dam management). At the moment there is a hybrid management model of the water regime with rather unclear goals. A certain degree of maintenance of the aquatic habitats is achieved, but the process of ecosystem degradation (due to eutrophication and accelerated succession) cannot be stopped. The current model resembles the management of a sediment trap. Therefore, it cannot be stable over time without sediment removal.Another main problem is the physical fragmentation of habitats that was caused in the reserve by the existing old dikes. Of particular interest is an area isolated by dikes that is near the Danube (comprising former vegetable gardens and orchards/ poplar plantations) with irregular rectangular shape and has great potential for restoration of conservationally important habitats.

There is physical fragmentation on a larger scale as well, leading to a process of gradual isolation of protected areas of the kind of Srebarna Maintained Reserve from other conservation core areas (isolation of habitats and species), not only on Bulgarian territory but also in neighbouring Romania.

Problem Tree (cause > effect) of the management of Srebarna Maintained Reserve



Although the data from the monitoring of Lake Srebarna by the Institute of Biodiversity and Ecosystem Research at the Bulgarian Academy of Sciences does not present an alarming picture of certain bird species, of the physicochemistry and the aquatic macrophyte flora, this should not be considered as reassuring – the data strongly depends on the basis for comparison, i.e. whether the state is compared to the situation before the main diking of the Danube (before 1948), or to the situation in the 1990s when the lake began to dry up.

Another standard factor that causes potential mistakes is the probability that a number of species and an amount of new biological data have been discovered as a result of the more active and thorough research conducted over the past few years.

Previous projects and solutions for reducing the effect of the modified water regime of Lake Srebarna

The 3 past attempts at restoring the hydraulic connection to the Danube by artificial canals and removing the western part of the dike (in 1963, 1979 and 1994) achieved partial success. The removed western part of the dike allows entrance of Danube waters only during extremely high water levels of the river that have come about only once in four or five years. The several so-called „garla" (micro depressions in the terrain) are overgrown with vegetation that additionally lowers their capacity. Moreover, the natural hydraulic system of water movement between the Danube and the marsh during spring waters is confused.

The following table lists all past important projects and solutions for reducing the effect of the changed water regime of Lake Srebarna

Contribution	Limitations
1. Construction of connecting canal of the Danube dike (Northern dike) that was constructed in 1948 <u>State of implementation</u>: The project was implemented in 1963 and soon after that the lock was closed. At present there are no direct results from this project.	
• Provision of water from the Danube	• Limited capacity of the canal and the lock • Impossibility to guarantee the protection of the arable land north of the lake from overmoistening and flooding

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2. Creating a hydraulic connection between the lake and the Danube by removing 600 m of the Northern dike in the northwestern part of the reserve. Construction of the so-called Southern dike for protection of arable lands in the area north and northeast of the lake.

State: Implemented in 1979

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- Allows entrance of high Danube waters into the lake
- Directly contributes to the restoration of target natural habitats
- Does not require funding for ongoing management and maintenance

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- The highest part of the watershed between the lake and the river is the area of the removed dike. Therefore a hydraulic connection in this area can happen only during very high water levels of the Danube that do not occur annually.
- The dynamic passing of water through this area is limited by the dense vegetation and the comparatively narrow front (width of the natural micro depressions of the terrain).

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3. Construction of a connecting canal between the lake and the river with locks on the Northern and Southern dike. Construction of the so-called Eastern dike that separates the arable lands north of the reserve (the so-called Inter-dike territory) and the lowland of Aydemir to the east.

State: Implemented in 1994

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- Allows an annual hydraulic connection between the river and the lake
- Allows a high level of control over the lake level, including complete draining of the lake during low waters of the Danube.

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- The capacity of the locks and the connecting canal does not allow a sufficient dynamic hydraulic connection between the lake and the river
- Financial and administrative problems in the operation and maintenance of the facilities
- Technical difficulties in the operation and maintenance of the facilities (clogging, blocking of the opening/ closing mechanisms etc.)
- Risk of complete draining of the water from the lake in case the facilities break down
- The problem of the lack of a functional

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<tr><td></td><td>migration corridor for the aquatic organisms has not been solved</td></tr>
<tr><td colspan="2">4. Construction of a second connecting canal with a lock in the western part of the reserve.

<u>State</u>: Not implemented. Was considered as the second phase of the previous project</td></tr>
<tr><td>• Increases the capacity of the hydraulic connection between the river and the lake – covers the function of the already constructed connecting canal
• In certain hydrological conditions and with precise management this canal can be used predominantly to convey water into the lake, and the existing one – to convey water out of the lake. This could improve water circulation in the lake</td><td>• Disputable effectiveness of the second connecting canal regarding the provision of the water circulation in the lake
• The construction of opening/closing facilities for the second canal involves building another dike in the northwestern part of the reserve. This would lead to additional reduction of the hydraulic connection between the river and the lake
• The problems connected with the management of opening/closing facilities that were mentioned above
• A comparatively expensive solution</td></tr>
<tr><td colspan="2">5. Removal of sediments (sapropel mud) from the cup of the lake

<u>State</u>: Not implemented</td></tr>
<tr><td>• Direct and quick solution to the problem of the lake becoming shallow due to sediment accumulation
• In the long term it will reduce the sources of organic loading of the water body of the lake
• Possible increase of the inflow of ground waters into the lake cup (hypothesis of “underwater sources clogged by sediments)</td><td>• Increased human presence and disturbance
• Shock turbidation of the water for long periods and consequent eutrophication, hypoxy and other intoxications of the hydrobionts
• Necessity of management of the removed sediments
• A comparatively expensive solution</td></tr>
<tr><td colspan="2">6. Inserting a watertight barrier in the terrain between the lake and the Danube. Partial or complete restoration of the destroyed Danube dike.</td></tr>
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State: Conceptual phase	
• Reducing the infiltration loss from the lake cup to the Danube during low waters. • After the Danube water level sinks, it will allow to keep the elevation of the water level temporarily higher than the elevation of the terrain in the area of the destroyed dike	• Strong limitation of the dynamics of the lake water regime • Probably the reduction of water loss through infiltration will be inconsiderable • Increasing the effect of "dam-type management" with accelerated accumulation of sediments and raising the elevation of the lake bottom • Impossibility of long-term maintenance of the water height without other interventions
7. Biomass management. Removal of part of the plant biomass out of the reserve. State: In the past there was partial removal of plant biomass but the main aim was not environmental. Currently no biomass is being removed from the Reserve.	
• Direct treatment of some of the effects of the damaged water regime. Direct removal of biomass that would reduce the accumulation of organogenic sediments in the lake cup. • Reduced accumulation of non-degraded plant mass, preventing the reserve territories from becoming shallower (particularly in the area of the reed beds) • Possibility of direct management and maintenance of target habitats	• Increased human presence and disturbance • Risk of unsuccessful intervention and degradation of conservationally important natural habitats • If fire is used as a method of biomass management, there is a risk of abrupt nutrient loading of the water body and of destroying the structure of the floating reed associations. • Requires higher capacity of management and control • A comparatively expensive solution
8. Complete or partial removal of the Northern and Southern dike (opening of the so-called inter-dike territory), preserving and maintaining the functions of the connecting canal, the locks, and the Eastern dike. Formation of small hills or removal of the dike material from the reserve. State: Conceptual phase	

• Allows achieving a water regime that even with the current limiting factors (the Iron Gate Dams and the modified discharge of the Danube, incision of the river bed and drainage of the lowland of Aydemir) is as close as possible to the natural one before the interventions. Restoration of the dynamic hydraulic connection between the lake and river. • If the inter-dike territory is opened and the connecting canal is appropriately managed, it is possible to carry out removal of soluble and insoluble organic and inorganic matter from the lake to the Danube. This can bring about a reduction of the quantity of sediments in the lake, or at worse it will slow down the filling-up of the lake with sediments. • In the case of positive results, this approach can lead to reduction or removal of the necessity of additional interventions (removal of sediments, of plant biomass, etc.). • Improvement of the conditions for migration of hydrobionts from and to the lake • Limiting the access of people and predators in the northern area of the Reserve • Possibility of the formation of new bird colonies and restoration of forest habitats • Comparatively low price	• The effect is slow • Requires higher capacity of management and control • Requires specialized monitoring of sediments, water quality, nature habitats and key animal species to determine the need for additional action • In the variant of complete removal of the dikes, after the retreat of the Danube high waters, the maximum level of the lake will be up to 50 cm lower than the current one under the same conditions. This may affect (though perhaps insignificantly) the minimum level of the lake during low waters. If the dikes are partially or gradually removed, no conditions may be expected for a change in the minimum water level in comparison to the current conditions. • Increases the risk of pollutants entering from the Danube.

Recommendations about the preparation of a new management plan of Srebarna Maintained Reserve

Recommendations were drawn up about the preparation of a new management plan of Srebarna Maintained Reserve and planning of future projects for protection and restoration of the ecosystems of the Reserve. Considered were only some of the water regime problems that had not found a long-term solution until then.

- Preparation of analyses for improvement of the water regime of Lake Srebarna that, along with the changes in the biota, will also consider the following:
    - Hydrological and hydrogeological analysis of Lake Srebarna and the adjoining stretch of the Danube;
    - Projects for drainage of the lowlands of Srebarna and Aydemir and its effect on the water regime of Srebarna Reserve;
    - Projects and solutions for improvement of the water regime of Lake Srebarna and their effect;
    - Past policies, goals and operating practices of management of the water regime of Srebarna.
- In connection to the preparation of a new management plan it is necessary to redefine the goals of water regime management of Lake Srebarna and their interconnection
- Preparation of terms of reference for a feasibility study of complex restoration of the water regime of Srebarna Reserve
- Carrying out a feasibility study of the complex restoration of the water regime of Srebarna Reserve. Within this study or as a subsequent phase it is necessary to prepare:
    - A water regime management plan;
    - Instruction manual for management of the hydrotechnical facilities;
    - A new or updated instruction manual for maintenance of the hydrotechnical facilities;
- Ensuring the implementation of the new plan after its assessment and coordination

- Until a new plan and implementation programme are approved, it is necessary to take urgent measures to restore the functions of the connecting canal and the other main hydrotechnical facilities. This includes assessment of their state and if necessary, repairs of the connecting canal in the area between the Danube and the Northern lock (the most critical stretch), the connecting canal in its remaining part, the Northern lock, the Southern lock, the Eastern dike, the protective dike and lock by the village of Srebarna

- Preparation and implementation of a specialized programme for monitoring of Srebarna Reserve in connection to the water regime management. Until now a number monitoring and individual studies of the lake were carried out, including studies on its water regime problems. Therefore it is necessary to analyse the available information and to summarize it for the purposes of the new water regime management plan and monitoring programme.

- Preparation of a new monitoring programme adapted to the needs of a new water regime management plan of Srebarna.

- The monitoring programme is to be completely optimized so that the main part of its implementation does not require the employment of narrow specialists or the allocation of additional funding, except the usual funding for administration of the Reserve. The chief components that need to be included in the programme are the following:

  - Monitoring of the water level of Lake Srebarna and if necessary – of the Danube
  - Monitoring of sediments
  - Monitoring of the water quality of basic indicators
  - Monitoring of biomass and the distribution of key habitats
  - Monitoring of key indicator species and conservationally important species

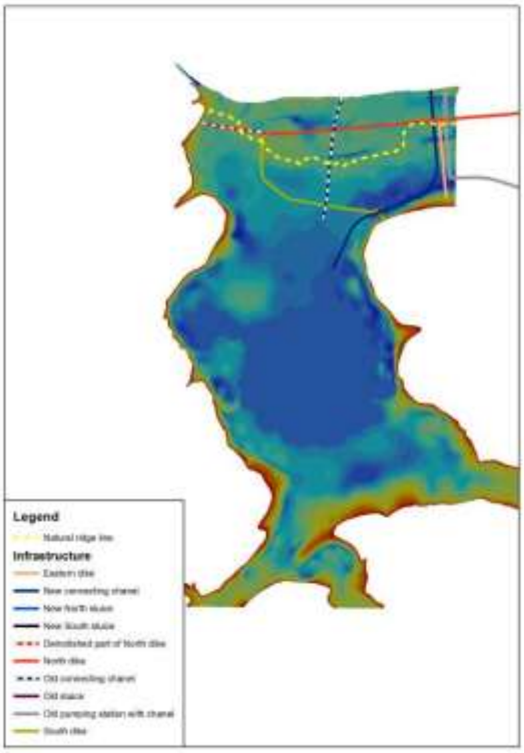
- Implementation of basic monitoring

Technical proposals for improvement of the water regime

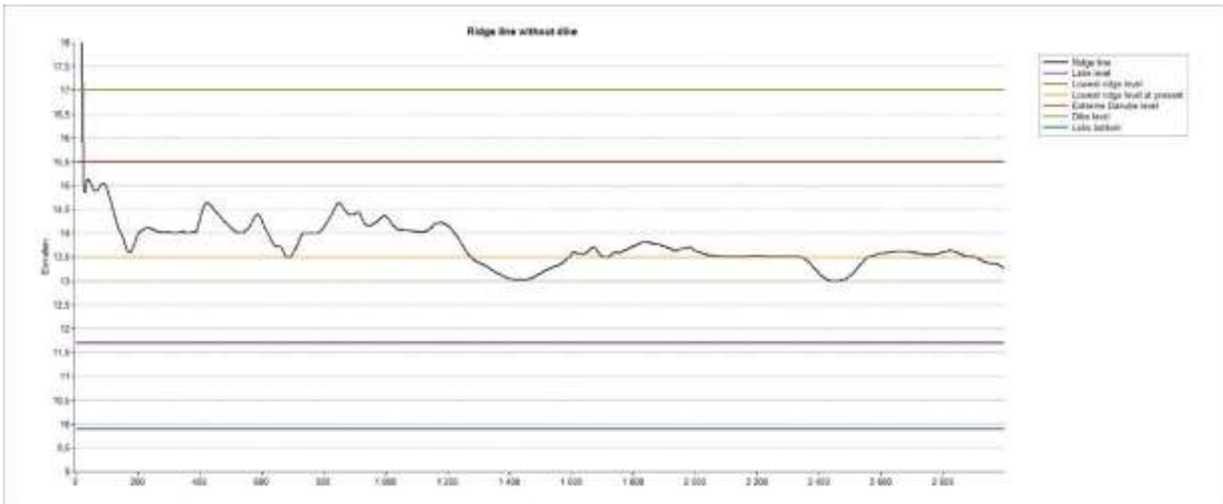
The developed technical solutions rely on increasing the circulation of water between the lake and the river, the final aim being to achieve maximum movement of water from the lake to the river without lowering the lake level. Two technical interventions are proposed:

- Increasing the capacity of water movement through the northwestern part of the Reserve. This includes digging a trench as a connection between the lake and the river at elevation 12.00 m in the western end of the Reserve. The trench has a width of the bottom 100.0 m, a slope of 0.25 0/00; м=1.5, and measures 680 m in length;
- Removal of the Northern and Southern dike. The soil will be used to fill up the ditches within the reserve. Part of the soil can be used to form islands within the reserve.

Geodesic survey and referring the data to the National Reference System



Surface model of the Reserve



Ridge profile between Lake Srebarna and the Danube. At present, the connection between the Danube and Srebarna is through the stretch from 0 m to 800 m (a stretch of breached dike), theoretically at levels above 13.50 m a.s.l. (in practice at levels above 14.00 m a.s.l.).

The remaining part of the natural ridge after the 800th meter is locked within the inter-dike area and does not function. Theoretically here, after removing the dikes, the connection between the river and the lake can take place at elevation 13.00 m a.s.l., which is almost an annual event.

The proposed solutions can be considered as conservative because they envisage preserving the existing locks and the connecting canal, and at the same time they do not include construction of new complex locks and other hydrotechnical facilities that require qualified staff for their management.

By combining these technical interventions, three variants are proposed for improving the water regime. These are as follows:

Variant 1 includes:

- Digging a trench as a connection between the river and the lake at elevation 12.00 m in the western part of the Reserve. The trench has a width of the bottom of 100.0 m and a length of 680 m
- Preserving the existing locks and canal
- Preserving the Northern and Southern dike

Indicative value 575,586 BGN.

Variant 2 includes:

- Digging a trench as a connection between the river and the lake (as in the first variant) at elevation 12.00 m in the western part of the Reserve. The trench has a width of the bottom of 100.0 m and a length of 680 m
- Preserving the existing locks and canal
- Removing the Northern and Southern dike, and using the soil to fill up the ditches within the reserve. Part of the soil can be used to form islands within the reserve

Indicative value 1,731,902 BGN. This is the maximum sum for the variant including the complete removal of the dike and transportation of the material. Considerably cheaper scenarios are also possible – these include cutting the dikes and keeping the material in place within the reserve.

Variant 3 includes:

- Preserving the existing locks and canal
- Removing the Northern and Southern dike, using the soil to fill up the ditches within the Reserve. Part of the soil can be used to form islands within the Reserve

Indicative value 1,160,316 BGN. This is the maximum sum for the variant including the complete removal of the dike and transportation of the material. Considerably cheaper scenarios are also possible – these include cutting the dikes and keeping the material in place within the reserve. In this case the value of the activities will be reduced by up to 50% of the proposed sum.

Of the three variants, the most appropriate is the third. It is to be paired with a new scheme of management of the locks and the introduction of a system of monitoring of the water regime, including sediments. This approach can help to achieve conditions that are maximally close to the natural ones, and at the same time there will remain the opportunity of controlled management of the water regime.