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RWS RIZA

Design of a water quality monitoring program for Stentsovsko-Zebrijanske Plavny, Danube Delta - Ukraine

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delft hydraulics
Design of a water quality monitoring program for Stentsovsko-Zebrijanske Plavny, Danube Delta - Ukraine

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TITLE:

ABSTRACT:
Final report on the future reserve Stentsovsko-Zebrijansky Plavny in the Danube Delta, Ukraine. The report describes the results of discussions during a two week visit of Marnix van der Vat to the area. In Chapter 2 the actual situation and the monitoring with respect to the hydrology and water quality is described. Indicative balances of water and nutrients for the area are presented. Furthermore an overview is given of the flora and fauna in the area, the actual socio-economic functions, the actual management and possible future management strategies.

Chapter 3 presents possibilities for a framework for analysis to evaluate future management strategies.

Models for the description of hydrology and water quality are emphasized. Steps towards the implementation of a framework of analysis are presented in paragraph 3.5. It is proposed to model the hydrology based on the water balance of the area and to estimate the distribution pattern of parameters such as flow velocity and water level from an additional survey, combined with the use of aerial photography. For water quality it is proposed to use the DELWAQ water quality model and combine this with the structural-functional approach towards the prediction of primary production as developed by OB-IBSS.

With respect to the monitoring programme, recommendations are presented in Chapter 4. The main recommendation is to intensify the monitoring by an increase of the frequency. Furthermore, a very important point is to include into the monitoring the functioning of the hydraulic structures in order to determine whether water losses are occurring. It is suggested to start the necessary maintenance of these structures based on the results of the monitoring.

REFERENCES:

REV | ORIGINATOR | DATE | REMARKS | REVIEWED BY | APPROVED BY
---|------------|------|---------|-------------|-------------
1.0 | Marnix van der Vat | 20-10-97 | | Marcel Marchand | Peter Glas

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A Mission report

B Required resources for the framework for analysis

C Equipment
1 Introduction

In its letter 25938 / IHP dated June 25th, 1997, RWS-RIZA commissioned DELFT HYDRAULICS to execute the project titled 'Design of a monitoring program for water quality of Stentsovsko-Zebriianske Plavny (Danube Delta, Ukraine)' as described in DELFT HYDRAULICS' proposal dated May 26th, 1997. The project is executed within the framework of RWS-RIZA's co-operation with the Danube Plavny Authority, Vilkove, (DPA).

This draft report describes the results of discussions with the staff of the Odessa Branch of the Institute of Biology of the Southern Seas (OB-IBSS) as well as staff of DPA during a two week visit to the Ukraine by Mr. M.P. van der Vat of DELFT HYDRAULICS. The contents of this report have been reviewed by OB-IBSS and DPA. A day-to-day report of activities during the visit is presented in Appendix A.

For the formulation of an integrated plan for the management of the Stentsovsko-Zebriianske Plavny marsh area additional knowledge and information is needed on the relationship between the water management, the water quality, the vegetation development and the occurrence of valuable faunistic elements, e.g. water birds. The water regime can be manipulated to a certain extent by means of the inlet structures. This enables the maintenance of the water levels of the area. The development of the vegetation can be influenced by specific measures like reed cutting, burning and changes in the water level. The development of the macrophytes in the lake is highly influenced by the water quality of the lake.

In order to gain insight in the functioning of the water system, more quantitative information is needed than is currently available. The aim of this project is advising DPA and OB-IBSS with respect to the development of a monitoring program for water quality management. More specifically, the advice focuses on:

- the evaluation of the existing monitoring program, the interpretation of existing data and the method of data collection (Chapter 2);
- drafting a proposal for the development of a hydrological/water quality model for the management of the study area (Chapter 3); and
- advice about additional monitoring and filing of data in a database (Chapter 4).

It is hoped that this report will form a contribution to the establishment of a sound management strategy for Stentsovsko Zebriianske Plavny in order to conserve and restore its natural values.

Mr. Marnix van der Vat wants to thank the staff of OB-IBSS and DPA for the fruitful co-operation and for their generous hospitality.
2 Description of the area and problem identification

The description of the area is based on discussions with the staff of DPA and OB-IBSS and on the literature and data provided. In this chapter the actual monitoring program is described and the research results and opinions of the staff are presented. Each paragraph is based mainly on discussions with one person. If not indicated otherwise. The text presents his or her point of view.

In Chapter 3, a framework for analysis is presented based on the opinions of the authors. In Chapter 4 the authors present their recommendations for future monitoring.

2.1 Hydrology

The description of the hydrology, the monitoring program and the preliminary water balance are based on discussions with Mr. Vladimir Egorashchenko, Chief of Hydrology Department, Southern Ukrainian Water Management Institute. An approach to the analysis of the hydrology is presented in Chapter 3.1 based on the findings presented below. In Chapter 4.1 recommendations for future monitoring are presented.

2.1.1 The hydrological network

Figure 1 presents a map of the Stentsovsko-Zebrijanske Plavny area. The Plavny covers a surface area of 75 square kilometres. The major inflow of water occurs in the westernmost point of the area and comes from the Kylia branch of the Danube, through the Mezhkolahozyni channel. The inlet and outlet of water is regulated by the Tupikovy lock. In the north-west agricultural drainage water is pumped into the area and in the south near Sasik channel water from fish ponds is pumped into Zebrijanske Plavny. Since 1978, the Sasik-channel forms a hydrological division between the western part (Stentsovsko) and the eastern part (Zebrijanske) of the study area. Water can pass the channel through a siphon (Siphon 1). The eastern outlet of the area to the Black Sea is formed by two locks located near the village of Primorske in the dam separating the area from the sea since before the 1930s. Other major in- and outflow of water is caused by precipitation and evapotranspiration. The evapotranspiration exceeds the precipitation significantly resulting in a considerable net precipitation deficit.

Other possible flows of water, of which the significance is not yet certain, include infiltration through the dams causing water from both parts to flow to the Sasik channel and from the Zebrijanske part to flow to the Black Sea or vice versa. Furthermore the upwelling of groundwater originating from the Danube river might especially occur in the Zebrijanske part. Groundwater flow towards Zebrijanske Plavny is indicated by the occurrence of relatively cold water masses during the summer, with a much lower water temperature than their surroundings (according to Mrs. Galina Garkavaya, hydrochemist at OB-IBSS).

The current state of the various hydraulic structures results in water losses of unknown magnitude. If the water level in Mezhkolahozyni channel is lower than in Stentsovsko Plavny water flows into the channel, because Tupikovy lock cannot be closed completely.
Figure 1: Map of Stentsovsko-Zebrijanske Plavny

From visual inspection the inflow of Siphon 1 seemed much higher than its outflow. This might be caused by leakage of water from the tubes to Sasik channel. Siphon 2 has been constructed to make inlet of water from Sasik channel to Stentsovsko as well as Zebrijanske Plavny possible. Because in general the water level in Sasik channel is lower than in the Plavny, this siphon is not used. However, leakage of the tubes causes a small water flow to the channel. A much bigger flow occurs from Stentsovsko Plavny, where the tubes have not been closed. Water is flowing here with a significant discharge into Sasik channel. During high water in the Kilya branch of the Danube the inlet of water into the Mezhkolhoznyi channel is limited to protect downstream irrigation pumps from being flooded. This also reduces the amount of water available to Stentsovsko Zebrijanske Plavny.
The main water flow through the Plavny occurs through constructed channels with a depth of approximately two meters. Other open water has an average depth of approximately 0.5 meters. The main area of open water is the Zebrijanske Lake with an average depth of 1.5 meters. The remaining part of the Plavny consists of more or less closed reed vegetation.

2.1.2 Monitoring program

A monitoring program for the determination of the water balance of Stentsovo-Zebrijanske Plavny has been started by OB-IBSS from April 1st, 1997, under the responsibility of Mr. Vladimir Egorashchenko. The programme includes the monitoring of water levels on both sites of four major structures:

- Tupikovy inlet structure (daily measurements, correlated with daily measurements up- and downstream in the Kylia Branch of the Danube and in the Mezhkolkhoznyi channel near the irrigation pumps);
- Siphon 1 under the Sasik channel connecting Stentsovo and Zebrijanske Plavny (monthly measurements, correlated with daily measurements several hundred meters further to the south in both Plavnys);
- Lock number 4 in Primorske (daily measurements); and
- Lock number 5, south of Primorske (monthly measurements, daily values to be extrapolated from lock number 4).

The operation of the shutters of the locks is recorded by the operating staff, but it seems that the Tupikovy lock is frequently being operated by unauthorised personnel. The discharge through these structures is determined monthly by measurement of velocity profiles. When enough data become available, rating curves can be prepared quantifying the relation between the water level upstream and downstream of the structure, the position of the shutter in case of the locks, and the discharge.

The water level in both parts of the system is monitored by gauges on either side of the Sasik channel in the south of the area to monitor the change in storage of water. Here also monthly measurements of precipitation and net precipitation (precipitation minus open water evaporation) are made.

Daily meteorological measurements, precipitation, wind velocity and dry and wet bulb temperature are being collected by other parties in the nearby villages of Vilkove and Primorske. These data are currently not available to OB-IBSS and DPA, but it is planned to use these data in combination with the monthly measurements for the quantification of precipitation and evaporation. Monthly evaporation will be calculated according to Dalton's Law (Mitsch and Gosselink, 1986) as adopted for local circumstances by the Ukrainian Hydrometeorological Institute:

\[ E = n * 0.2 * (1 + 0.56 * v) * (E_w - E_a), \]

with: \( E \) evaporation rate (mm/month);
\( n \) number of days per month (d);
\( v \) wind velocity (m/s);
\( E_w \) saturated vapour pressure at the actual water temperature (mbar); and
\( E_a \) actual vapour pressure (mbar).

The actual vapour pressure will be calculated from the measured wet bulb temperature. This equation has been calibrated for open water evaporation. Whether the total
evapotranspiration of a vegetated wetland is lower or higher than the open water evaporation remains undetermined (Mitsch and Gosselink, 1986). Therefore, the calculated open water evaporation will be used as an approximation for the total evapotranspiration.

The amount of drainage water pumped from the agricultural area into Stentsovsko-Zebrijanske Plavny can be calculated from the number of hours that the pumps have been working. These data are being collected by the local irrigation authority and are currently not available to OB-IBSS and DPA, but it is planned to use these data.

The relation between water level and volume will be determined for Stentsovsko and Zebrijanske Plavny separately from the geodetic map made in 1984. Because this map contains no data on the submerged topography additional measurements of the depth will be made along transects in the whole area.

Based on the above mentioned data OB-IBSS will prepare monthly water balances.

2.1.3 Preliminary water balance

Based on the preliminary results of the monitoring program from April till June 1997 and estimations of other discharges an indicative water balance has been constructed. Figure 2 presents a schematic overview of the considered flows of water. The indicative water balance is presented in Table 1 and Figure 3 (in m³/s) and 4 (in mm/day). As this water balance is based on incomplete data and estimations, the result should be interpreted with care as an indication of the possible quantity of the different inflows and outflows. Because the water level in both parts have not changed significantly during the monitoring period, it is assumed for the indicative water balance, that there has been no change in the storage of water.

Figure 2: Schematic presentation of the water flows into, between and out of Stentsovsko and Zebrijanske Plavny
Table 1: Indicative water balance for Stentsovsko-Zebrijanske Plavny for April - June 1997

<table>
<thead>
<tr>
<th>Post on balance</th>
<th>discharge m³/s</th>
<th>discharge mm/d</th>
<th>source of data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflows to Stentsovsko</td>
<td>3.3</td>
<td>4.5</td>
<td>from monitoring</td>
</tr>
<tr>
<td>Tupikovy</td>
<td>2.0</td>
<td>2.3</td>
<td>estimation of 150 mm</td>
</tr>
<tr>
<td>Precipitation</td>
<td>0.8</td>
<td>1.6</td>
<td>from previous years</td>
</tr>
<tr>
<td>Drainage water</td>
<td>0.5</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>Outflows from Stentsovko</td>
<td>2.4</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>1.2</td>
<td>2.8</td>
<td>estimation of 250 mm</td>
</tr>
<tr>
<td>Siphon 1</td>
<td>1.2</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Inflows to Zebrijanske</td>
<td>1.7</td>
<td>3.0</td>
<td>from monitoring</td>
</tr>
<tr>
<td>Siphon 1</td>
<td>1.2</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Precipitation</td>
<td>0.5</td>
<td>1.6</td>
<td>estimation of 150 mm</td>
</tr>
<tr>
<td>Outflows from Zebrijanske</td>
<td>1.5</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Lock number 4</td>
<td>0.4</td>
<td>0.5</td>
<td>from monitoring</td>
</tr>
<tr>
<td>Lock number 5</td>
<td>0.2</td>
<td>0.2</td>
<td>from monitoring</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>0.9</td>
<td>2.8</td>
<td></td>
</tr>
</tbody>
</table>

![Water balances of Stentsovsko-Zebrijanske Plavny](image)

Figure 3: Indicative water balances of respectively the whole Stentsovsko-Zebrijanske Plavny, Stentsovsko, being the western part, and Zebrijanske, being the eastern part (from left to right) in m³/s.
Figure 4: Indicative water balances of respectively the whole Stentsovsko-Zebrijske Plavny, Stentsovsko, being the western part, and Zebrijske, being the eastern part (from left to right) in mm/day.

Infiltration of water through the dams and upwelling of infiltrated water from the Danube might result in additional flows of water. However, these flows have a diffuse character and are very difficult to measure. A first approximation of the order of magnitude of these flows has been obtained by application of Darcy's law:

$$Q = K \cdot A \cdot \frac{h}{L},$$

with:  
- $Q$: discharge ($m^3/d$);  
- $K$: saturated hydraulic conductivity ($m/d$);  
- $A$: cross-sectional area ($m^2$);  
- $h$: difference in water table or piezometric surface ($m$); and  
- $L$: distance over which $h$ occurs ($m$).

Using a value of 0.1 m/d for the saturated conductivity, assuming that the dams and the substrate have a clay texture, no significant infiltration seems to occur. However, preferential flow through areas with a higher conductivity may yield significant flows.

The presented water balances clearly show a discrepancy between the in- and outflow, especially for the Stentsovsko part; inflow exceeds outflow by almost 50% of the outflow. This can be caused by the inaccuracy of the estimates of the discharges or by the omission of a significant outflow. Most likely the discrepancy is caused by loss of water from the siphons under Sasik channel.

Based on a total volume of 18.6 Mm$^3$ of water for Stentsovsko Zebrijske Plavny (Titar, 1997), the above presented water balance would mean that the system has an average hydraulic residence time of approximately two to five months.
2.2 Water quality

The information in this chapter is based on discussions with Dr. Boris Alexandrov, Mrs. Galina Garkavaya, regarding hydrochemistry, Dr. Galina Minicheva, regarding primary production, and Dr. Sergey Dyatlov, regarding biotoxicity. An approach to the analysis of the water quality is presented in Chapters 3.2 and 3.3 based on the findings presented below. In Chapter 4.2 recommendations for future monitoring are presented.

2.2.1 Monitoring program

Since 1994 each year three expeditions have been made by OB-IBSS on request of DPA to Stentsovsko Zebrijanske Plavny for monitoring of the water quality: one in June, one in August and one in October.

The quality of water flows is sampled at three locations:

- Tupikovy inlet;
- the siphon under the Sasik channel; and
- lock number 4 in Primorske.

The quality of the Danube water in the Kylia branch is sampled monthly. Irregular monitoring of the quality of drainage water pumped from agricultural areas has been executed by OB-IBSS and the local irrigation authority.

The water quality inside the reserve is described by samples taken at eleven locations, with different site characteristics, such as open water or dense reed stands, distance from inlet and depth (see Figure 1).

The hydrochemistry of the water is described by the following parameters:

- temperature
- oxygen concentration
- percentage oxygen saturation
- pH
- hydrogen sulphide concentration
- biological oxygen demand in five days
- organic carbon concentration
- ammonium concentration
- nitrite concentration
- nitrate concentration
- organic nitrogen concentration
- phosphate concentration
- organic phosphate concentration
- dissolved silicium concentration
- total suspended matter concentration
- concentration of salt and its ionic composition

It should be noted that the determination method of organic nitrogen and phosphorus used by OB-IBSS, differs from the methodology commonly used in Western-Europe: subtracting the inorganic fraction from Kjeldahl-nitrogen and total-phosphorus). Instead of destruction
of the unfiltered sample, oxidation of the filtered sample with persulphate (K$_2$S$_2$O$_8$) is used by OB-IBSS. This will result in lower estimates of the total nutrient content because:

- the particulate fraction of the nutrient, as well organic as inorganic adsorbed, is not taken into account, because the filtered sample is used; en
- not all organic nutrients will be measured because of the use of oxidation with persulphate instead of destruction.

For the calculation of primary production of submerged vegetation the biomass and active surface through which metabolism takes place is determined for each species. These data are used for a structural-functional evaluation of the autotrophic vegetation (Minicheva, 1996 and 1997). This method is discussed in more detail in Chapter 3.3.1.

The biotoxicity of the water is measured by means of biotesting on *Ceriodaphnia affinis*. Measures of toxicity are the acute and chronic mortality of the *C. affinis* population and its reproductivity. Measurements have been made for water and sediment.

### 2.2.2 External influences

The inlet of Danube water at Tupikovy and the pumping of drainage water are the major external sources of nutrients and toxic substances, especially pesticides. The drainage water consists of water from agricultural fields, especially irrigated rice fields; little domestic waste water is added, because the villages have no sewage system. Drainage pumps are located at several locations along the northern border of the reserve. The Danube can be regarded as the major source of nutrients (in inorganic form) and the drainage water as the major source of pesticides and salt. It has been mentioned by Mrs. Garkavaya, that a possible source of nitrogen in Zebrijanske might be infiltration of the dam from fields to the south.

Because no accurate water balance is available yet, only very tentative nutrient balances can be made. Monthly balances will be constructed by multiplication of the discharges with the measured concentrations of nutrients. The high temporal variability of the concentrations and the discharge compared with the monitoring frequency, however, creates a significant level of uncertainty to these balances.

Balances for total nitrogen and total phosphorus have been constructed based on the indicative water balance presented above and on water quality measurements. Two different values for the concentrations of total nitrogen and phosphorus have been used:

- the estimated average concentration as measured during monitoring expeditions by OB-IBSS since 1994 (resulting balances presented in Table 2 and Figures 5 and 6); and
- concentrations measured in the laboratory of RWS-RIZA from samples taken April 17th, 1997 (resulting balances presented in Table 3 and Figures 7 and 8).

The value of these balances is limited, because they are based on inconsistent data for different periods and only on one measurement for the water quality. The contribution of atmospheric deposition had to be estimated, because no data are available. Deposition rates have been taken from Johnston (1991) as 0.5 gN/m$^2$/y and 0.05 gP/m$^2$/y. The balances based on the data from OB-IBSS cannot be compared completely with the ones based on data from RWS-RIZA, because the determination of the organic nutrient contents differs significantly (see above). The nitrogen balance based on the data from OB-IBSS might
Table 2: Estimated nitrogen and phosphorus balances, based on chemical analysis by OB-IBSS

<table>
<thead>
<tr>
<th></th>
<th>Concentration (mgN/l)</th>
<th>Concentration (mgP/l)</th>
<th>kgN/ha/y</th>
<th>kgP/ha/y</th>
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Retention rate

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</table>

Figure 5: Estimated nitrogen balance, based on chemical analysis by OB-IBSS

especially be biased by the high concentration of organic nitrogen in the drainage water measured in June 1995.
Figure 6: Estimated phosphorus balance, based on chemical analysis by OB-IBSS

Table 3: Estimated nitrogen and phosphorus balances, based on chemical analysis by RIZA

<table>
<thead>
<tr>
<th>Post on balance</th>
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<th>Budget</th>
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<td>mgP/l</td>
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<td>-</td>
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<td>Evapotranspiration</td>
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</tr>
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<td>Lock number 5</td>
<td>2.1</td>
<td>0.11</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>0.0</td>
<td>0.00</td>
</tr>
<tr>
<td>Retention rate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.2.3 Internal situation and processes

The occurrence of low oxygen concentrations and related high concentrations of hydrogen sulphide is being regarded as the major water quality problem of the Stentsovsko Zebrijanske Plavny. Low oxygen concentrations are caused by the decay of organic matter produced locally by submerged vegetation and reeds. This situation occurs mainly in parts of the area with stagnant waters and closed reed vegetation. The situation in Stentsovsko is worse than in Zebrijanske. Furthermore, the occurrence of hydrogen sulphide is connected with the constructed channels, which have been dug into the substrate of sulphate rich,
marine clays. In these relatively deep channels stratification occurs in the summer, with low oxygen concentrations in the lower layer.

Low oxygen concentrations are said to be caused by stagnation of water in reed beds and by oxygen consumption by (roots of) dead reed. A correlation has been demonstrated between the local hydrodynamic situation and the primary productivity (excluding reed), with a higher productivity in stagnant areas (Minicheva, 1997). Low oxygen concentrations are demonstrated to occur mainly in deeper areas (more than one meter) and in areas with less than 25% open water. In these areas the production is concentrated in the pelagic zone, especially by green algae, while in areas with sufficient flow of water the production is dominated by macrophytobenthos, such as Chara (i.e. in Zebrijanske Lake). The total pelagic and benthic primary production has been calculated by OB-IBSS from measurements of the diurnal amplitude of the oxygen concentration as 1.62 - 2.38 mgC/l/d, qualifying the water as polyhypertrophic. The individual measured values range from 0 to 5.25 mgC/l/d. It appears that water quality problems occur generally when the production exceeds 2.4 mgC/l/d. The primary production found in Stentsovsko Zebrijanske Plavny is nearly two times higher than in the nearby wetlands near the Dniepr.

In general the water quality is better in the central parts of Stentsovsko and Zebrijanske Plavny than the water quality near Siphon 1. This is caused by the low water flows near the siphon due to dense reed stands near the outlet.

Another problem is the internal loading of the system with nutrients and toxic substances from the sediments where they have previously accumulated. Explosive fluxes from sediment to water of mineral phosphate might especially occur in case of low oxygen concentrations, when precipitated phosphate minerals become unstable. The occurrence of secondary pollution by toxic substances is demonstrated by an increase of biotoxicity within the Plavny as compared to the inflowing water from the Danube and the drainage pumps.

OB-IBSS intends to incorporate into its future investigations also the occurrence of phenols, because it is mentioned in literature, that the root felts of the reed vegetation can produce phenols. This is another potential water quality problem of which the extent remains to be determined.

The water flowing from Stentsovsko Zebrijanske Plavny has higher concentrations of nutrients than the water in the Black Sea. According to Dr. Dyatlov this causes temporary blooming of algae in the coastal zone.

OB-IBSS has prepared characteristics of the biodiversity of pelagic and benthic organisms in Stentsovsko Zebrijanske Plavny. 147 species of algae are found, 98 species of zooplankton and 36 species of macrozoobenthos. The Shannon biodiversity index has been determined, showing the highest biodiversity for Stentsovsko Plavny with a value of 2.5. Because of the oxygen problems the zoobenthos is dominated by larvae of insects which form up to 75% of the specimen and up to 95% of the biomass of the zoobenthos.

The retention rates as estimated from the nutrient balances are similar for the balances based on data from OB-IBSS and the ones based on data from RWS-RIZA (approximately 42 kgN/ha/y and 0.75 kgP/ha/y). However, the underlying data are quite different and the calculated retention rates have different origins. Therefore, the reliability of these values is very limited, although the values are not unrealistic as compared to the range described for wetlands by Johnston (1991).
2.3 Vegetation and fauna

The information in this chapter is based on discussions with Dr. Michael Zhmud and on a draft management plan prepared by him (Zhmud, 1996). An approach to the analysis of vegetation and fauna is presented in Chapter 3.4 based on the findings presented below.

Most of the area is occupied by a mosaic of shallow open water and reed vegetation (*Phragmites australis*) (Zhmud, 1996). The density of the reed stands ranges from open water with reed at the edges (Zebrijanske Lake) through a mosaic of reed and open water to closed stands of reed. From a helicopter survey by OB-IBSS the amount of open water has been estimated as 38% for Stentsovsko Plavny and 29% for Zebrijanske Plavny.

The mosaic landscape is the highest valued habitat for birds. The area of closed stands of reed is increasing. This indicates that the production of organic matter exceeds the mineralization within the area.

Both flora and fauna of the Stentsovsko Zebrijanske Plavny have a unique composition, with large numbers of species listed in the Ukrainian Red Data Book of endangered species or other international lists of this kind. Birds form the most outstanding group with a recorded number of species of approximately 240 of which 43 are listed in the Red Data Book. Most species depend directly or indirectly on the vegetation structure, the water quality and the hydrology of the area. For a more complete description of the flora and fauna is referred to Titar (1997) and Zhmud (1996).

2.4 Socio-economic functions

The following (potential) functions of the Stentsovsko Zebrijanske Plavny can be distinguished or are influenced by its water management:

- conservation of biodiversity by providing habitats for endangered species either by permanent settling, for specific functions such as feeding or breeding or as resting place while migrating;
- fishing;
- hunting of waterfowl and trapping of muskrats;
- harvest of reed to be used as building material or for the production of paper;
- collection of frogs for export to France;
- protection of surrounding buildings against inconvenience caused by high groundwater levels;
- recreation;
- nature education;
- grazing of reed by cows and sheep owned by local inhabitants;
- disposal of drainage water from surrounding irrigated areas; and
- natural purification of pollutants from inflowing water.

2.5 Actual management authorities and practices

The area of Stentsovsko Zebrijanske Plavny is owned by the Ukrainian state and is under the local forestry authority of Izmail, which plays no active role in its management. In the near future the area will be incorporated into the nature reserve Danuskie Plavny and will be handed over to DPA (Titar, 1997).
Water management, like regulation and maintenance of structures, falls under the responsibility of the Managing Department for Protection Dams and Constructions of the Near-Danube Irrigation System. DPA is in charge of the daily operation of the locks on the seaside and the Tupikovsky lock is operated by the Irrigation Management in consultation with DPA. The drainage pumps are operated by the Irrigation Management.

In general, the actual water management can be characterised as trying to get the highest possible amount of water into the system and keeping it there. This is accomplished by the inlet of Danube water in the spring, when the water level is highest, while the downstream locks are opened only if the water level inside the wetland exceeds the upper limit set by the level of the dikes and the surrounding buildings. There is no intake of water from the Black Sea. The effectiveness of this management is reduced by the malfunctioning of structures.

Since 1996 the level of the seaside locks is lowered 25 centimetres during six weeks in July and August to lower the water level in Zebrijanske Plavny to stimulate the mineralization of organic matter and to reduce the growth of reed. The duration and magnitude of lowering of the water table seems to be too limited to achieve this goal. However, longer and/or more extreme lowering of the water table would have adverse effects on hunting.

Throughout the year uncontrolled grazing by cattle takes place. 5% of the reed is harvested each year in winter, while 20 - 30% of the reed is burned down to get rid of dead grass and reeds (Titar, 1997).

**2.6 Problem identification**

The major problem in Stentsovsko Zebrijanske Plavny is considered by most concerned to be the decrease in area of the mosaic landscape of reed and open water and increasing abundance of dense stands of reed, which are less favourable as habitats for birds and cause stagnation of the water leading to water quality problems such as low oxygen concentrations, blooming of green algae and disappearance of macrophytobenthos, like Chara.

The water quality itself is considered to be a second problem. High concentrations of nutrients and pesticides in incoming water together with the release of these pollutants from the sediment cause problems such as blooming of algae and increased toxicity by pesticides. Furthermore, low oxygen and high hydrogen-sulphide concentrations pose a threat to aquatic populations such as fish. Low oxygen concentrations are caused mainly by stagnation of water in reed beds and oxygen consumption by dead (roots of) reed.

**2.7 Possible future management strategies**

In his contribution, Iedema (1997) proposes general objectives and options for ecological development of Stentsovsko Zebrijanske Plavny.

**Objectives for ecological development**

With respect to the ecological development of Stentsovsko Zebrijanske Plavny the following general objectives can be distinguished:

1. Contribution to the biodiversity of the (Ukrainian) Danube Delta:
• diversity in habitats in de Danube Delta (Stentovské Zebrijanske Plavny as a part of the Delta);
• diversity in species on international, national and Delta level (priority above the local level);

2. Contribution to naturalness:
• aiming at natural processes, dynamics and water quality;
• aiming at minimal management efforts after restoration;

3. Preserving characteristics of the original situation.

These general objectives need to be discussed among the involved Oekrainsian parties. For the development plan for Stentovské Zebrijanske Plavny, these objectives could be further elaborated.

A preliminary evaluation based on concise information from DPA and OB-IBSS leads to the following analysis:

1. biodiversity
• the contribution of Stentovské Zebrijanske Plavny to the habitat diversity in the Danube Delta lies in the mosaic vegetation pattern and the presence of mesotrophic water (which obviously is linked to the filtering function of the vegetation);
• the contribution of Stentovské Zebrijanske Plavny to the species diversity (international, national, Delta) lies especially in its rich waterfowl;

2. naturalness
• the hydrology of the Stentovské Zebrijanske Plavny is not natural: river influence has been diminished, the Stentovské Zebrijanske Plavny has been divided in two parts by canal Sasik, the water level is maintained high as long as possible, the connection with the Black sea has been blocked;
• the water quality of the Stentovské Zebrijanske Plavny is influenced because in summer eutrophic and saline irrigation water is drained into SZP;

3. characteristics
• the characteristics of the Stentovské Zebrijanske Plavny lies in its biodiversity, functioning in the periphery of the Danube and specific human use;
• the human use of the reed beds in the Stentovské Zebrijanske Plavny - burning, grazing, harvesting- has been diminished strongly.

This analysis may lead to the following concrete objectives for the development of the Stentovské Zebrijanske Plavny:
1. the development and maintenance of a mosaic vegetation structure and the presence of mesotrophic water as habitat for a high diversity and productivity of waterfowl;
2. enlarging the river influence and dynamics and restoration of the contact zone between SZP and the Black Sea;
3. improving the water quality of the incoming water (Danube and drainage water); and
4. develop opportunities for human use of the reedbeds.

These objectives are not necessarily compatible. But if a ranking in priority between objectives is decided upon, discussions about compatibility of objectives are less complex. Finally, based on the effects of different development options, DPA has to make its own choice.

Additional long term objectives can be formulated with respect to the functioning of the Stentovské Zebrijanske Plavny as a part of the Danube Delta:
• creation of buffer zones around the Stentsovsko Zebrijeanske Plavny; and
• development of an ecological corridor to the island Jermakov and the Romanian part of
  the Delta.

Options for ecological development
The main tools for development are water management, vegetation management and land
use. With respect to the objectives one can think of several options for the water
management of the Stentsovsko Zebrijeanske Plavny, which reflect the natural variation in
discharges of the Danube and the influence of the Black Sea:

• the marginal wetland: inlet and outlet sluices are always open, so the water
dynamics in Stentsovsko-Zebrijeanske Plavny reflect the dynamics of the Danube
and the Black Sea and precipitation and evaporation; not only within a year but also
between years. Fluctuations in salinity reflect the influence of the Black Sea;
• the spring flood riverine wetland: as long as the water level in the Danube exceeds
the water level in Stentsovsko-Zebrijeanske Plavny, the inlet sluices are open,
otherwise they are closed; outlet sluices are always closed. Thus the water
dynamics in Stentsovsko-Zebrijeanske Plavny reflect the dynamics of a more or less
isolated riverine wetland that is connected with the Danube only during high
discharges; and
• the spring flood estuarine wetland: as long as the water level in the Danube exceeds
the water level in Stentsovsko-Zebrijeanske Plavny, the inlet sluices are open,
otherwise they are closed; the outlet sluices are open when the water level in
Stentsovsko-Zebrijeanske Plavny is below the waterlevel in the Black Sea, otherwise
they are closed. Thus the water dynamics in Stentsovsko-Zebrijeanske Plavny are the
same as in the riverine wetland except that Black Sea water can enter the Plavny.

An additional option could be to create a spring flood estuarine wetland with the outlet
sluices always open, thereby stimulating the flow of water through the system.

Below the opinions of different experts about a future management strategy are described.

Mrs. Galina Garkavaya, Chief of Hydrochemistry Group at OB-IBSS, proposed the
following measures:

• Increase the flow through the wetland by controlled intake of water, increased
exchange of water between Stentsovsko and Zebrijeanske by additional structures
and the digging of shallow channels;
• Yearly seasonal lowering of the water level to degrade the accumulated organic
matter and hamper the growth of reed; and
• Removal of vegetation, especially reed.

Titar (1997) further elaborates the proposed strategy by Zhmud (1996). Titar proposes to
treat the area with respect to water management as two distinct systems, because it is
foreseen that the Sasik channel will be preserved for a long time. For Stentsovsko Plavny he
proposes the following measures:
• Restoration of the through-flow regime via the Laptysh branch (a former branch of the Danube located in the western part of Stentsovsko Plavny) into a network of shallow waterways and through shallow lakes, based on the flow network existing before canalisation and diking-in took place. This would result in the reappearance of periods during which 50 - 70% of the area is laid dry, hampering the reed growth;
• Reduction of reed growth and already accumulated *Phragmites* detritus and peat, in the first place along the margins of former waterways and open, shallow lakes by mechanical measures, such as cutting the shoots, rotoverting the root felt and collecting the resulting material (immediate measure); and
• Reduction of pollution from point and non-point sources (long-term measure).

For Zebrijanske Plavny Titar proposes to start with a demonstration project for restoration and later extending the measures to the whole area. The proposed demonstration project contains the following measures:

• Winter harvest of reed for commercial purposes;
• Restoration of open clear water habitats by treatment of the bottom for removal of the reed root felt (where the minerogenic bottom topography allows); and
• Restoration of open, periodically flooded littorals by mowing, rotoverting and/or grazing regimes.

For the general management of the reserve Titar proposes the following actions to be taken:

• DPA takes over the ownership and management of the hydraulics structures;
• Organising the protection by extending the warden staff and building at least two new warden stations;
• Implement zonation of the area under protection, distinguishing zones used for reed harvesting and hunting, a buffer zone and a core protection zone of about 2200 ha. including the main nesting sites of colonial birds with least human intervention;
• Regulation of hunting;
• Regulation of grazing of cattle; and
• Environmental education aimed at the local inhabitants to raise public awareness for the natural values of their native area.

Representatives of WWF involved in a project to support the establishment of an extended Danube Plavny Reserve support the opinion of Titar to restore the natural water regime and thereby introducing a major period of low water each year. The DPA staff, however, has the opinion that this management will lead to both economic (fishing and hunting) and ecological (waterfowl) losses because of the lower water levels and the intrusion of salt water. Furthermore they argue, that if no human interference had taken place, the wetland would have evolved into a freshwater wetland as well, as is shown by examples in the actual reserve area. Restoration of the natural water regime is in their view impossible, because of the construction of dikes along the Danube which have changed the water exchange between the Danube and Stentsovsko Zebrijanske Plavny. The proposition of DPA is therefore to maintain the actual water level, but to introduce a dry year with lower water table once every few years, i.e. once every five years.

The measures as proposed by Titar, WWF, and to a lesser extent by Garkavaya can be classified as aiming at establishing a *marginal wetland*, while the ideas of DPA tend towards a *spring flood riverine wetland*. All opinions agree on the necessity to increase the water exchange in the area by construction of shallow channels. The layout of these
channels remains to be determined. The major remaining questions seem to be what water level should be maintained, whether salt water should be allowed to intrude, whether periods with a lower water table should be included and if so, with which duration and frequency.

Iedema suggests to judge the effect of the different options on the long term to incorporate the effect of dry and wet years on the development of the area. He proposes to analyse the impacts of all options for different capacities of the inlet and outlet structures and the siphon (e.g. present capacity and double capacity). Other variables could be the amount of drainage water pumped to the area and the water quality of the Danube and the drainage water. The analysis of the different options can be assisted by modelling of the hydrology and water quality (Chapter 3).
3 Modelling of hydrology and water quality

A methodology is required for the analysis of the effect of different (water) management options. This framework for analysis relates measures to effects on the functions of the system. These relations can be described by a variety of ways ranging from qualitative rules of thumb to complex mathematical models. The selection of an optimum description of the relations depends on the management objectives (see Chapter 2.6 and 2.7) and the available budget and time.

The framework for analysis for water management of Stentsovko Zebrijanske Plavny should describe the following system components:

- hydrology;
- water quality (hydrochemistry);
- primary pelagic and benthic production; and
- development of habitats for key-species and communities of both flora and fauna.

Figure 9 presents the interactions between the different system components.

![Diagram showing interactions between hydrology, water quality, primary production, and habitat evaluation for key-species and communities.]

Figure 9: The interactions between the different system components, with:
- h: water level as a function of time;
- v: flow velocity as a function of time;
- Q: discharges of water at in- and outflow;
- N: nitrogen concentration;
- P: phosphorus concentration;
- O₂: dissolved oxygen concentration; and
- OM: production of organic matter.

The framework for analysis should yield results which can be compared with pre-defined criteria for the evaluation of the management strategies. These criteria have not yet been established, but will most likely include the following:

- suitability of the Plavny as a habitat for waterfowl, especially for endangered species and migrating birds, through the conservation and restoration of open water and the mosaic of open water and reed stands;
- conservation and restoration of a mesotrophic and oligotrophic water quality, among others as a habitat for the macrophyte Chara, an important part of the diet of certain species of waterfowl;
• limited pollution of the coastal zone by outflowing water from the Plavny; and
• combination of the nature preservation with socio-economic functions, such as fishing, hunting, reed harvesting and cattle grazing.

As mentioned in the introduction, this study focuses on the development of models for the description of the hydrology (Chapter 3.1) and the water quality (Chapter 3.2), possibly including the pelagic and benthic primary production (Chapter 3.3). Different possibilities will be described below. A possible methodology for the evaluation of habitats for key-species and communities will be described briefly in Chapter 3.4. In Chapter 3.5 necessary steps for the development of the proposed a framework for analysis are suggested.

3.1 Hydrology

Figure 9 clearly demonstrates the basic role of the hydrology in the analysis. The parameters to be determined are the discharges of water at in- and outflows, the water level and the flow velocity. All parameters vary with time and for the level and velocity the spatial distribution within the Plavny is an important aspect as well.

3.1.1 Water balance

The most simple approach to the hydrology of a wetland is the use of a water balance, describing the amount of water flowing through the system over the boundaries (in- and outflow) and the storage of water within the system. Temporal variation can be described by water balances for different months, decades, weeks or days. Description of the spatial variation is limited to the distinction between Stentovsko and Zebrijanske Plavny.

A rough estimation of the mean water level is possible from the water balances. Mean velocities can be estimated from the residence time, however disregarding internal, wind induced circulation. Both level and velocity can be determined for Stentovsko and Zebrijanske Plavny separately, but the variation within the Plavnys remains unknown.

OB-IBSS is preparing water balances with a time step of one month for the Stentovsko Zebrijanske Plavny. More detail might be preserved by the preparation of daily balances. To this purpose water levels up- and downstream of the structures should be measured daily and the flow characteristics of the structures should be determined under different conditions during special expeditions. This will also improve the reliability and accuracy of the resulting balances. Another advantage would be that results could be obtained within a shorter period of time, e.g. some months.

In Chapter 2.1.1 a number of possibly important pathways, especially infiltration, are mentioned, which are not accounted for in the present monitoring campaign. Investigation of the magnitude of these pathways is necessary to construct reliable water balances. A geohydrologic survey of the Plavny and its surroundings including measurements of the piezometric surface is necessary to estimate the flow of underground water from the Kyulia branch of the Danube to the Zebrijanske Plavny. Infiltration of the dams can be estimated from water level measurements on both sides of the dams and survey of the dams' hydraulic conductivity, with special emphasis on preferential flow pathways. It should be taken into account that pathways which are not significant in the current situation might increase after alteration of the water management, i.e. lowering of the water table within the Plavny. These pathways should be included in the water balances in order to use them for the evaluation of future water management strategies.
OB-IBSS plans to determine the relation between the water level, volume and surface area of Stentsovsko and Zebrianske Plavny from the geodetic map of 1984. It is recommended to prepare an update of these data based on recent aerial photographs and additional measurements of the bottom topography, because the topography is expected to have changed significantly by accumulation of organic matter. This also means that these relations should be adapted for the different management strategies to account for their influence on the accumulation of organic matter. The relation might have a complex character in the current situation because of the practical isolation of some parts of the Plavnys by the dense reed root felts.

For the waterlevel and the flow velocity a distinction between different parts within the Plavnys is desirable. To determine the waterlevel a detailed map of the bottom topography including presently submerged topography is required. An approach to quantification of the flow velocity might be to classify the area into hydrological units (deep channels, shallow channels, mosaic and lakes) based on aerial photographs or satellite images. The distribution of the velocity can then be approximated by using empirical relations between the water balance and velocity for the different classes. The addition of parameters describing the distance from the major inlet of water and the actual wind velocity might improve the results.

To establish these empirical relations extensive measurements of flow velocities under different hydrological regimes and wind conditions are required for the different hydrological units. Furthermore, recent aerial photographs are required to prepare a map of hydrological units.

3.1.2 Hydrodynamic modelling

A detailed description of the temporal and spatial distribution of water level and flow velocity can be obtained by applying a mathematical hydrodynamic model, like SOBEK (DELFt HYDRAULICS and RIZA, 1996). The variable input consists of the discharges appearing in the water balance and the wind velocity. Detailed input data on the pathways of the water flow and their geometry are however necessary. This implies detailed measurement of topography, geometry of open water, profiles of channels and approximation of flow coefficients for structures, mosaic and reed stands. Because of the amount of input data required, the application of a hydrodynamic model does not seem to be a realistic option in the near future.

3.2 Water quality

Description of the water quality should yield estimates of the concentrations of the available nutrients, the mineralization of organic matter and the oxygen concentrations (Figure 9). The temporal and spatial variability should be based on the results of the simulation of the hydrology. The results for future strategies are especially important because of their relation with the occurrence of Chara, which is limited to meso- and oligotrophic water systems.

3.2.1 Nutrient balances

The most straightforward approach to water quality is the construction of nutrient balances by multiplying the discharges of the water balance with the corresponding concentrations
for the nutrients nitrogen and phosphorus. To simulate future management scenarios the retention of nutrients might be assessed by applying the same retention rate as in the current situation. The retention rate can be expressed as a percentage of the received load of nutrients or as the mass retained per time unit.

This approach yields estimates of the concentrations of total nitrogen and phosphorus under the assumption that the retention of nutrients remains the same under future management scenarios, because the underlying water quality processes are not taken into account. This assumption will only apply if the future management causes no major alteration of the system in terms of water level, residence time and loads of nutrients. Because the process of mineralization of organic matter is not considered, oxygen concentrations cannot be calculated.

The actual frequency of water quality monitoring (three times per year, see Chapter 2.2.1) is too limited for the construction of accurate and reliable nutrient balances. Combination of expeditions for hydrology and water quality is recommended, because this will provide consistent results for discharges and concentrations. A monthly frequency would be ideal, but six water quality expeditions a year could be sufficient, if they are distributed efficiently over the different seasons for the hydrobiology. The parameters to be measured include all forms of nitrogen and phosphorus as well as the amount of organic matter, dissolved oxygen, chloride and the electrical conductivity. When simultaneous data of discharges and concentrations become available an analysis of their correlation might be useful to improve the estimation of the concentrations for days when no measurements are available, but the discharge is known. This might especially apply to the drainage water, which could have e.g. lower concentrations of nutrients during high discharges after precipitation.

### 3.2.2 Water quality modelling

A mathematical description of the water quality incorporates a variety of nutrient compartments and their interacting transformation processes, depending on the required amount of detail. The most important process is the primary pelagic and benthic production, which will be dealt with separately in the next section. A basic approach for modelling of wetland water quality will at least incorporate the following state variables:

- chloride concentration;
- ammonium concentration;
- combined nitrate and nitrite concentration;
- phosphate concentration;
- carbon concentration in pelagic organisms;
- organic matter concentration;
- dissolved oxygen concentration;
- carbon concentration in benthic organisms;
- amount of organic matter in the sediment;
- amount of carbon in living reed; and
- amount of carbon in dead standing reed.

The influence of reed on the water quality can be incorporated by describing the biomass and the amount of dead standing reed as forcing functions. If diatoms form a significant part of the pelagic community, dissolved silicium concentration should also be taken into account.
The following transformation processes should at least be described:

1. primary pelagic production and related nutrient uptake and oxygen production (see Chapter 3.3);
2. primary benthic production and related nutrient uptake and oxygen production (see Chapter 3.3);
3. mortality of pelagic organisms;
4. mortality of benthic organisms;
5. mineralization of organic matter in the water column and related release of nutrients and oxygen consumption;
6. mineralization of organic matter in the sediment and related release of nutrients and oxygen consumption;
7. sedimentation of organic matter;
8. production of reed and related nutrient uptake;
9. mortality of reed;
10. litterfall of reed;
11. reaeration of oxygen;
12. nitrification; and
13. denitrification.

Figure 10: presents the main different compartments and interacting transformation processes. The numbers in the figure correspond with the numbers mentioned above.

A similar basic water quality model for wetlands has previously been implemented in DELFT HYDRAULICS' general purpose water quality model DELWAQ (DELFT HYDRAULICS, 1996 and 1997) and has been applied to a wetland in Slovenia (Van der Vat, 1997). The increase of the mineralization rate of organic matter when it is exposed to air should be added to the existing descriptions of water quality processes. Mathematical descriptions of water quality processes have been applied successfully to wetlands, as summarised by Mitsch et al. (1988) and Costanza and Sklar (1985). Applications to nutrient cycling and nutrient removal in reed swamps are described by Brown (1988), Dørø (1994), Kadlec and Hammer (1988), Jørgensen (1994), Jørgensen et al. (1988) and Mitsch and Reeder (1994).
The water quality model described above yields the temporal and spatial distribution patterns of the concentration of the state variables, thereby providing all necessary input for further analysis. With such a model it is possible to analyse a wide range of management strategies, because the underlying processes are incorporated into the model. A requirement is calibration of the model for the actual situation. This requires data on the actual distribution pattern of the state variables. Besides the results of the water and nutrient balances, additional required input data include wind velocity and water temperature.

### 3.3 Primary pelagic and benthic production

It appears that the primary production plays a central role as is illustrated in Figure 9. On the one side it influences the water quality by production of oxygen and organic matter and uptake of nutrients, on the other side it provides the basis of the food chain for other forms of life such as fish and birds.

#### 3.3.1 Approach based on structural-functional parameters

At OB-IBSS a method has been developed for the prediction of the composition of the pelagic and benthic communities and their primary production based on structural-functional parameters of the species (Minicheva, 1996). This paragraph is based on discussions with Dr. Galina Minicheva and on one of her publications (Minicheva, 1996). The approach is based on work relating the production capacity of macroalgae with the surface area of their thalli (Hamisak et al., 1988, Khailov et al., 1978, Khailov and Parchevsky, 1983; Khailov et al., 1992; Littler, 1980, Littler and Littler, 1980; Littler and Arnold, 1982). OB-IBSS has successfully applied this approach to the macrophytobenthos of the north-western shelf of the Black Sea (Minicheva, 1989 and 1993).

The main structural parameter is the specific surface area of the different species through which metabolism takes place: S/W with S active surface area (m²) and W wet weight (kg). Measurement of the specific surface area is described by Minicheva (1987 and 1992). Combination of the specific surface with the biomass of the population yields the index of phytocenose surface (IPS). It characterises the total surface area of the community per square meter of substrate and is a measure for the eutrophication level of the ecosystem.

For all major species occurring in the Stentovsko Zebrijanske Plavny the specific surface area has been determined for different seasons. Furthermore relations have been established between the biomass and primary production of each species and the IPS and between the IPS and the environmental circumstances regarding the flow regime and the concentrations of available nitrogen and phosphorus. The flow regime has for this purpose been characterised by the decrease in mass due to dilution of a gypsum construction submerged during a fixed period of time (Kovardakov et al., 1995). Using these relations the primary production and composition of the pelagic and benthic communities can be determined for different management strategies if the environmental circumstances are known from simulation of the hydrology and water quality (Minicheva, 1997). A computer program has been developed by OB-IBSS for this determination.

A limitation of this methodology is that there is no direct feedback with the water quality processes. Application of this methodology is therefore recommended in combination with a water quality model. Furthermore, the characterisation of the flow regime by dilution of gypsum should be replaced by a parameter resulting from the simulation of the hydrology to analyse the effect of different water management strategies. Other conceptual problems
might arise as well. To the author's knowledge, this approach has never before been applied to pelagic communities in fresh water wetlands.

3.3.2 Classical approach based on evaluation of Monod curves

A more classical approach to the simulation of primary production by algae is based on a rough division of the species into a limited number of classes, such as two pelagic types and one benthic. Each type is characterised by the following parameters:

- potential maximum primary production rate (1/d) and temperature dependency (-);
- maintenance respiration rate (-);
- growth respiration rate (-);
- mortality rate (-) and temperature dependency (-);
- daylength for growth saturation (d);
- radiation for growth saturation (W/m²);
- Monod half-saturation value for the uptake of nitrogen (gN/m³); and
- Monod half-saturation value for the uptake of phosphorus (gP/m³).

The selection of values for these parameters should reflect the species composition of the community and its characteristics to justify the representation of the whole community by a limited number of types.

The gross production is calculated by multiplication of the potential maximum rate corrected for temperature with reduction factors accounting for the effect of the environmental circumstances such as day length, available radiation and available nitrogen and phosphorus. The reduction factors have a value between zero and one. To obtain the net production the respiration is subtracted from the production. Biomass is calculated by accumulation of daily production and mortality rates. For a more complete description of this method reference is made to EPA (1985).

The reduction factor for nutrient limitation is calculated as a Monod term:

$$\text{RedFact} = \frac{\text{AvNut}}{\text{AvNut} + \text{KM}}$$

with:

- $\text{RedFact}$: reduction factor for a specific nutrient (-);
- $\text{AvNut}$: available nutrient concentration (g/m³); and
- $\text{KM}$: Monod half-saturation value for the uptake of the nutrient (g/m³).

The reduction factor for all nutrients together is calculated as the minimum value of the reduction factors for the different nutrients. In addition to dissolved nutrients from the water column benthic algae can also use inorganic nutrients produced by mineralization of organic matter in the sediment.

For the calculation of the reduction factor for availability of radiation the extinction of light in the water column should be known, as well as the amount of incoming radiation. For this purpose extinction can be modelled using the correlation with the concentration of suspended matter and algae in the water column.

Compared to the structural-functional approach, this approach yields a much less detailed description of the composition of the pelagic and benthic communities. The advantage of
this approach is, that it is linked with the other water quality processes in the water quality model DELWAQ. For a complete description of this methodology reference is made to the DELWAQ Technical Reference Manual (DELFT HYDRAULICS, 1997). Application by DELFT HYDRAULICS of this methodology to eutrophication of the North Sea is described by Glas and Nauta (1989). Furthermore, it has been applied to a large number of different situations, among others to shallow lakes. The successful application of this approach depends on the ability to describe the population by the characteristics of a limited number of types.

In this approach concentrations of organisms are expressed in carbon and chlorophyll concentrations. If this approach is to be applied, these parameters should be incorporated into the monitoring program. For the estimation of the characteristics, the variation in time of these concentrations must be known with a sufficient amount of detail. Therefore at least monthly measurements should be carried out.

3.4 Habitat evaluation for key-species and communities

If the management objectives for Stentsovsko Zebrijanske Plavny are to be formulated in terms of the occurrence of species and communities, it might be necessary to formulate the results of the analysis in these same terms. This can be done by performing a habitat analysis, such as HEP (developed in the USA) (US Fish and Wildlife Service, 1980).

A habitat analysis consists of a comparison of habitat requirements of species and communities with the habitat factors. Because most species require different circumstances for different functions, such as feeding, breeding and spawning, requirements are formulated for each function separately. A database must be constructed with for all relevant species and communities the functions and their requirements. As a second step the actual distribution of the habitat factors must be mapped. An analysis for the actual situation can now be performed by comparison the factors with the requirements. The data can now be validated by comparing the results of the analysis with the actual distribution of the species and communities. The results of management strategies can be analysed by using not the actual habitat factors, but the ones resulting from the simulation of the hydrology, water quality and primary production. Other variable input might come directly from measures described in the management strategy, such as grazing and burning.

Because of the geographic nature of most of the data a habitat analysis can be performed using a geographical information system (GIS) containing maps of the actual distribution of species and communities (and their functions) and maps of the habitat factors.

A relatively large amount of data should be collected for the successful performance of a habitat evaluation. Maps of the actual distribution of the (functions) of the species and communities must be made based on field surveys and aerial photographs. These maps may be digitised to use them in the GIS. Furthermore the database with habitat requirements should be constructed based on literature and knowledge of the actual situation. As a starting point existing databases for other locations (i.e. wetlands in the Netherlands) may be used, but they should be adapted for application to Stentsovsko Zebrijanske Plavny.

The habitat evaluation methodology can also be applied to assess the effect of different water management strategies and other management practices on the development of the reed vegetation. The surface area of the mosaic of open water and reed can thus be evaluated based on expert judgement relative to factors such as the water level dynamics, salinity and burning of reed or destruction by other methods.
3.5 Development of a framework for analysis

In this paragraph a development path for the framework for analysis is sketched. The data requirements for the application of the framework are described in Chapter 4. Because the management objectives for Stentovsko Zebrijanske Plavny have not yet been established, the following description of the development of the framework for analysis is a preliminary one, which might need to be adopted, if the achievement of the final objectives cannot be determined with this framework. A step-by-step development is proposed. In this way, each step can be reformulated based on the outcome of the previous step. Based on the current understanding of the situation and problem analysis, the following steps are recommended:

- Preparation of daily water balances of the Stentovsko and Zebrijanske Plavnys separately.
- Preparation of monthly nutrient balances by combination of the water balances with data on hydrochemistry.
- Classification of the area into hydrological units, assessment of relations between flow velocity in these units and the water balance. Mapping of the bottom topography to translate data on water level into water depth for all hydrological units.
- Preparation of an evaluation methodology similar to a habitat evaluation procedure for the development of reed under different hydrological and management circumstances, based on a review of existing literature.
- Implementation and calibration of a wetland water quality model.
- Establishing a relationship between the determined flow velocity and the primary production to replace the measurement of dilution of gypsum.
- Incorporation of the structural-functional approach to determine primary production and composition of the pelagic and benthic community into the water quality model.
- Application of the framework as implemented through steps 1 to 7 for the actual situation to calibrate and validate the models. Application for some possible management strategies to evaluate the suitability of the framework. Subsequent prioritising of future developments.
- If the results of the hydrologic simulation are not satisfactory, a hydrodynamic model of the area might be implemented.
- If the results of the water quality model are not satisfactory, it might be extended by implementation of a more complex description including inorganic sediment chemistry.
- If the results of the structural-functional approach are not satisfactory, it might be replaced by the classical approach based on evaluation of Monod curves.
- Implementation of a habitat evaluation procedure for key-species and communities of both flora and fauna.

Appendix B provides an estimate of the required resources for the implementation of this framework for analysis.
4 Advice on monitoring programme and storage

In this chapter recommendations will be formulated for monitoring. The ongoing monitoring has yielded an impressive amount of data and knowledge on the Stentsovsko Zebrijanske Plavny over the last years. In Chapter 2 an attempt has been made to summarise this information. The following recommendations are meant as additions to the current monitoring program in view of the implementation of the framework for analysis for management strategies as described in Chapter 3.5. Table 4 presents an overview of the recommendations. It is recognised that additional resources are required for an extension of the monitoring program. The recommendations are limited to monitoring of hydrology and water quality and only concern the first eight steps for the development of the framework for analysis, excluding the evaluation of the development of the reed vegetation.

4.1 Hydrology

The following recommendations are made with respect to the monitoring of the hydrology:

1. Include daily measurements of the waterlevel on both sides of Siphon 1 into the monitoring program, because correlation with measurements further away seems inaccurate. These measurements could also replace the measurements used for the estimates of the waterlevel in the Plavny, because they seem to be more representative;

2. Exclude discharge measurements from the routine monitoring program and prepare a special monitoring program for all structures to establish the relation between upstream water level, downstream water level and position of the shutter (only for the locks). This monitoring program should consists of a number of expeditions during periods with different water levels. Discharge measurements must be obtained for different positions of the shutter to obtain relations for all situations. This would improve the reliability and accuracy of the constructed water balances and it would enable the construction of the first water balances within a shorter period of time.

3. Have a special investigation into water losses at siphon 1 through measurement of the discharge at both sides at the same time in order to determine possible loss of water. For this purpose the inlet structure of the siphon must first be cleared of vegetation.

4. Include daily measurement of the water level near the outflow from Stentsovsko Plavny at Siphon 2 in the routine monitoring program and establish the relation between this waterlevel, the level in Sasik channel and the flow.

5. Construct daily water balances instead of monthly balances in order to avoid loss of accuracy for the construction of nutrient balances.

6. It is recommended to quantify the precipitation and evapotranspiration from the daily meteorological measurements made in Primorske and Vilkove instead of using the monthly measurements made within the Plavny, because these might be biased by anthropogenic influence. Approximation of the total wetland evapotranspiration by calculation of the open water evaporation is considered to be the most accurate possibility.

Table 4: Overview of the recommendations for the regular monitoring program
<table>
<thead>
<tr>
<th>Current</th>
<th>Recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hydrology</strong></td>
<td><strong>Hydrology</strong></td>
</tr>
<tr>
<td><strong>1</strong></td>
<td>Measurements at both sides of Siphon 1 only during monthly expeditions. Daily values from correlation with daily measurements several hundred meters further to the south in both Plavnys.</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>Measurement of discharge during monthly expedition</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>Assumption that there are no water losses from Siphon 1.</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>Assumption that there is no flow from Stentsovsko Plavny to Sasik channel.</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td>Calculation of water balances on a monthly basis.</td>
</tr>
<tr>
<td><strong>6</strong></td>
<td>Calculation of precipitation and evaporation from monthly measurements within Stentsovsko Plavny.</td>
</tr>
<tr>
<td><strong>7</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>8</strong></td>
<td>Assumption that there is no significant infiltration of dams and influence of groundwater.</td>
</tr>
<tr>
<td><strong>Water quality</strong></td>
<td><strong>Water quality</strong></td>
</tr>
<tr>
<td><strong>1</strong></td>
<td>Three monitoring expeditions per year (June, August and October)</td>
</tr>
<tr>
<td><strong>2</strong></td>
<td>Separate expeditions for monitoring of hydrology and water quality</td>
</tr>
<tr>
<td><strong>3</strong></td>
<td>Only irregular monitoring of water quality at the pumping stations</td>
</tr>
<tr>
<td><strong>4</strong></td>
<td>Determination of organic nitrogen and phosphorus by oxidation with persulphate on the filtered samples</td>
</tr>
<tr>
<td><strong>5</strong></td>
<td>Monitoring of all parameters at all locations</td>
</tr>
</tbody>
</table>
7. Include the measurement of electrical conductivity to the hydrological monitoring to be able to determine the origin of water at different locations in the system.
8. Make a geohydrologic survey of the Stentsovsko Zebrijanske Plavny and its surroundings to determine the role of infiltration of dams and flow of groundwater.

Besides regular monitoring, additional one-time monitoring is required for the implementation of the framework for analysis. Aerial photographs have become available recently and should be used in combination with a field survey of the bottom topography to prepare maps of the topography and the hydrological units for the determination of the flow velocity and the relation between water level, volume and surface area. Furthermore the relationship between flow velocity, hydrological units and operation of structures should be established during special surveys to be able to describe the flow velocity within the Plavyns. For this purpose special methods to determine low flow velocities are necessary (see Appendix C). During the field survey the depth of the substrate and the composition of the bottom sediment and substrate can as well be determined.

4.2 Water quality

With respect to the monitoring of water quality (hydrochemistry and hydrobiology), the following recommendations can be made:

1. Increase the frequency of water quality monitoring to at least six times a year or, preferably, monthly. A minimum scheme could include measurements in March, May, June, August, October and December to obtain data in different circumstances with respect to important water quality processes such as production and mineralization of organic matter.
2. Combine the water quality monitoring with the hydrological monitoring to obtain consistent data for the same date and time. This would allow for making an analysis of the possible correlation between discharge and concentrations of the nutrients.
3. Include the most important pumping stations of drainage water into the regular monitoring program (if they are in operation). Perform irregular monitoring of the other pumping stations while they are in operation to investigate whether their water quality differs significantly from the stations included into the regular monitoring program.
4. Addition of the determination of Kjeldahl-nitrogen and total-phosphorus on unfiltered samples to the analysis of all samples. In this way the total nutrient concentration can be determined more accurately than by oxidation with persulphate and the results will be comparable with investigations from Western-Europe.
5. When monitoring the water quality of the in- or outcoming water flows, it is not necessary to measure all water quality parameters with the same frequency. The following hydrochemical parameters should be included: ammonium, nitrite, nitrate, Kjeldahl-nitrogen, ortho-phosphate, total-phosphorus, organic carbon, biological oxygen demand in five days (BOD₅), total suspended matter, suspended inorganic matter, chloride and electrical conductivity. If diatoms form a significant part of the pelagic population, dissolved silicum should also measured. Most of these parameters are already included in the water quality monitoring scheme. Determination of hydrobiological parameters is deemed not necessary for the in- and outcoming water. This is, however, very important for the characterisation of the water quality within the Plavynys.
Furthermore the relationship between flow velocity and primary production should be established during special surveys to use the structural-functional approach for the analysis of management strategies.

For monitoring during extreme conditions with respect to the oxygen and hydrogen-sulphide concentration field measurement equipment is required. Based on these observations direct action can be taken to prevent mass mortality of fish.

### 4.3 Data storage

Central storage of data in an unambiguous format is essential in order to make them available to all concerned. Currently OB-IBSS has a geographically oriented data storage, retrieval and presentation system operational for the north-western shelf of the Black Sea. This system was developed by experts of OB-IBSS. It might be worthwhile considering to use this system for the Stentsovsko Zebrijanske Plavny. Another option is the development of such a system in the GIS ARC/INFO as planned by OB-IBSS. This would also enable the storage and presentation of maps, such as the map of hydrological units and bottom topography. The use of a GIS would furthermore be favourable to possible future analyses, such as the evaluation of habitats.
5 Conclusions

Currently an impressive amount of data and knowledge on Stentsovsko Zebrijanske Plavny has been acquired by OB-IBSS and DPA. Major efforts are being made to increase this knowledge such as the ongoing monitoring programs for hydrology, hydrochemistry and hydrobiology. To optimise future efforts it is necessary to base them on explicit objectives of the management of Stentsovsko Zebrijanske Plavny.

In Chapter 3 an outline is presented of a framework for analysis of management strategies. This framework might by used to assess the effects of different strategies for the management of the reserve, especially regarding the water regime. The framework has been drafted under the assumption that the major management objective of the area would be the conservation and restoration of the biodiversity, especially regarding waterfowl. The framework might be modified and made more specific, when more specific management objectives are defined.

In Chapter 4 recommendations have been made for the future monitoring of hydrology, hydrochemistry and hydrobiology. Although these recommendations have been made in connection with the implementation of the framework for analysis, most of them also have a more general character. The main recommendation concerns increase of the frequency of regular monitoring enhancing its accuracy. To allow for effective water management it is recommended to start with regular inspection and maintenance of the hydraulic structures as soon as possible and to secure against their operation by unauthorised personnel.

The implementation of the recommendations on monitoring and of the framework for analysis enable decision making on the management of Stentsovsko Zebrijanske Plavny based on quantitative arguments. The resulting management plan should be translated into unambiguous operation rules for management activities, especially the operation of the structures.
References


Mission report of the visit of Marnix van der Vat to Ukraine from July 15th till July 26th, 1997.

Monday, July 14
6.50   Departure from Amsterdam
13.30  Arrival in Odessa. Welcomed at the airport by Dr. Nikolaj Berlinsky, Scientific Secretary of the Odessa Branch of the Institute of Biology of the Southern Seas (OB-IBSS).
15.00  Visit to OB-IBSS. Discussions on the aim and program of the mission with the director Dr. Boris Alexandrov and Dr. Nikolaj Berlinsky. Introduction to the characteristics of Stentsovsko-Zebrijanske Plavny (SZP).

Tuesday, July 15
10.00  Discussion Mr. Vladimir Egorashchenko, Chief of Hydrology Department, Southern Ukrainian Water Management Institute, on the hydrology of SZP, monitoring and construction of water balances.

Wednesday, July 16
10.00  Discussion with Mrs. Galina Garkavaya, Chief of Hydrochemistry Group at OB-IBSS, and Mrs. Maria Helmboldt, post-graduate student at OB-IBSS, on monitoring of hydrochemistry, construction of nutrient balances and water quality problems in SZP
12.00  Discussion with Dr. Sergey Daytlov, toxicologist at Odessa State University, on monitoring of biotoxicity and the accumulation of toxic substances in SZP.
13.00  Discussion with Dr. Galina Minicheva, Senior Scientist OB-IBSS, on modelling of primary production and species composition of submerged vegetation.
15.00  Discussion with Dr. Nicolaj Berlinsky and Dr. Evgeny Khlebnikov, GIS and Data Base expert at OB-IBSS, on data storage and analysis. Demonstration of the existing system and discussion on the construction of a new system using ARC-INFO.

Thursday, July 17
10.00  Discussion with Prof. dr. Yuvenanal Zaitsev, Chief Scientist OB-IBSS, on the environmental development of the Black Sea and its catchment area.
15.00  Visit to the zoo of Odessa with the aim to see a video presentation on the ecology of SZP. This was unfortunately not possible at that moment.

Friday, July 18
10.00  Discussion with Dr. Boris Alexandrov on the framework for analysis for management strategies

Saturday, July 19
Preparation of draft report

Sunday, July 20
Preparation of draft report

Monday, July 21
10.00  Discussion with Dr. Boris Alexandrov on the draft report

Tuesday, July 22
10.00  Departure from Odessa together with Mr. Vladimir Egorashchenko
16.00  Arrival in Vilkove, discussion with Dr. Alexander Voloshkevich, Director of DPA, Dr. Michael Zhmud, ornithologist at DPA, and Mr. Vladimir Egorashchenko on
<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Activity and Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wednesday, July 23</td>
<td>10.00</td>
<td>Excursion through and around the Stentsovsko Zebrijanske Plavny together with Dr. Michael Zhmud and Mr. Vladimir Egorashchenko. Visit to all major hydraulic structures, except for the Tupikovy lock, which could not be reached due to the heavy rainfall.</td>
</tr>
<tr>
<td>Thursday, July 24</td>
<td>11.00</td>
<td>Discussion with Dr. Alexander Voloshkevich, Dr. Michail Zhmud, Dr. Anata Zhmud and Mr. Vladimir Egorashchenko on the framework for analysis and the draft report</td>
</tr>
<tr>
<td>Friday, July 25</td>
<td>10.00</td>
<td>Excursion through the Danube Plavny Reserve together with Dr. Michail Zhmud and Mr. Vladimir Egorashchenko.</td>
</tr>
<tr>
<td></td>
<td>16.00</td>
<td>Discussion with Dr. Alexander Voloshkevich, Dr. Michail Zhmud and Mr. Vladimir Egorashchenko on the framework for analysis and the draft report</td>
</tr>
<tr>
<td>Saturday, July 26</td>
<td>10.00</td>
<td>Departure for Izmail</td>
</tr>
</tbody>
</table>
B  Required resources for the framework for analysis

The required activities for implementation of the framework for analysis include the development and application of methodology. The following table presents an overview of estimates of the required resources for the different activities. The activities are limited to modelling of hydrology, water quality, primary production and evaluation of the development of reed and concern only the first eight steps for the development of the framework for analysis. It is assumed that all necessary data and maps are available in the required form.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Budget estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction of a proper schematization for modelling of the area</td>
<td>kr 20,000,-</td>
</tr>
<tr>
<td>Incorporation of the structural-functional approach into the water</td>
<td>kr 10,000,-</td>
</tr>
<tr>
<td>quality model</td>
<td></td>
</tr>
<tr>
<td>Preparation of an evaluation methodology for the development of reed</td>
<td>kr 40,000,-</td>
</tr>
<tr>
<td>Calibration of the hydrological model</td>
<td>kr 20,000,-</td>
</tr>
<tr>
<td>Calibration of the water quality model</td>
<td>kr 20,000,-</td>
</tr>
<tr>
<td>Interpretation of results</td>
<td>kr 20,000,-</td>
</tr>
<tr>
<td>Reporting</td>
<td>kr 20,000,-</td>
</tr>
</tbody>
</table>
C  Equipment

For the measurement of flow velocities three different types of instruments can be distinguished:

1. Mechanical devices, where the water flow drives the rotation. The minimum flow velocity for accurate operation is approximately 10 cm/s, with an accuracy of approximately 3 cm/s. The price for these advanced mechanical devices is in the order of $4500.
2. Acoustic devices, with a minimum flow velocity for accurate operation of approximately 3 cm/s and an accuracy of approximately 1 cm/s. The price for this type of devices is in the order of $8000.
3. Electromagnetic devices, with a minimum flow velocity for accurate operation of approximately 3 cm/s and an accuracy of approximately 1 cm/s. The price for this type of devices is in the order of $10000.

Manufacturers include:

1. DELFT HYDRAULICS, electromagnetic devices. Address: p.o.box 177, 2600 MH Delft, The Netherlands. Telephone +31 15 2858585, telefax +31 15 2858582, e-mail info@wldelft.nl. Contact person ir. J.D. van den Bunt, telephone +31 15 2858449, e-mail Jan.vdBunt@wldelft.nl;
2. Nortek AS, acoustic devices. Address: Bruksveien 17, N-1390 Vollen, Norway. Telephone +47 66 790190, telefax +47 66 790420, e-mail inquiry@nortek.no; and
3. Valeport Ltd., mechanical and electromagnetic devices. Address: Unit 7, Townhall Ind. Est. Dartmouth Devon TQ6 9LX United Kingdom. Telephone +44 1803 834031, telefax +44 1803 834320, e-mail sales@valeport.co.uk.

Information on field units for the measurement of dissolved oxygen has been send separately by RWS-RIZA to DPA.