Available online at www.sciencedirect.com
SCIENCE DIRECT®

Environmental Modelling & Software 20 (2005) 177–185

Environmental Modelling & Software

www.elsevier.com/locate/envsoft

Integrated water management scenarios for wetland protection: application in Trichonis Lake

I. Zacharias*, E. Dimitriou, Th. Koussouris

National Centre for Marine Research, Institute of Inland Waters, Mavro Lithari, Anavissos Attiki 19013, Greece

Received 6 January 2003; received in revised form 31 May 2003; accepted 8 September 2003

Abstract

Sustainable water resources management is a priority issue today, since it can contribute to achieving both environmental preservation and economic prosperity. Wetlands constitute a significant environmental system, since they incorporate unique habitats with endemic and migrant species and therefore contribute to the conservation of high global biodiversity. However, they suffer from degradation because of the intensification of agriculture, the increase in pollution rates and poor water management practices. This study attempts to develop a methodology by combining GIS applications, remote-sensing techniques and physically based hydrologic modelling for the formation of water management plans in lake catchments. This methodology has been tested in Trichonis Lake catchment, in Western Greece, where the endangered calcareous fens habitat undergoes great ecological stresses due to the irrational use of local water resources. The first results indicated that the particular methodology operated efficiently. The suggested scenario has been adopted by the local water authorities and the significant water level fluctuations observed in the past have been eliminated to approximately 25% in the initial implementation period.

Keywords: Water resources management; Wetlands; Hydrologic modelling; Lake catchment

1. Introduction

Developing sustainable water management plans that incorporate both environmental and socio-economic perspectives is a difficult but essential task in order to prevent potential environmental deterioration and enhance economic growth. Human-induced activities and land use alterations often comprise significant disturbances for water resources and aquatic ecosystems. These disturbances may reach intensities that rival the most severe natural disturbances (Turner et al., 1993). Non-rational management of water resources causes lowering of ground water levels in wetland areas, resulting in unseasonably dry conditions that may lead to environmental degradation (Mitsch and Gosselink, 1993). Wetlands are multifunctional and dynamic systems that incorporate very specific hydrologic and ecological conditions. They provide important services, such as purification and regulation of water flows, numerous resources for human uses, habitats for plants, animals and micro-organisms and recreational opportunities. However, during the last century, intensification of agriculture, unsustainable water uses, an increase in pollution rates and climatic changes have put significant stresses on wetlands and have caused their progressive degradation. An increasing need for implementing sustainable water management plans has emerged. Such an effort may result in covering both human-induced and ecological-related water needs, as well as in preserving high quality and quantity storages. Several scientific efforts in developing decision support systems to facilitate wetlands management have been observed during the last decade with special focus on assessing impacts from human interventions on the hydrologic regime of wetland areas (Quinn and Hanna, 2003; Kuper et al., 2003). This study attempts to depict the hydrologic modelling contribution in developing an

* Corresponding author. National Centre for Marine Research, Institute of Inland Waters, Mavro Lithari, P.O. Box 712, Anavissos Attiki 19013, Greece. Tel.: +30-22910-76389; fax: +30-22910-76323.
E-mail address: thakis@ncmr.gr (I. Zacharias).

1364-8152/$ - see front matter
doi:10.1016/j.envsoft.2003.09.003

adaptive water management plan, which takes into consideration both economic development and environmental health. In the basin of Trichonis Lake (Western Greece) the ecologically significant and priority habitat of calcareous fens (Natura 2000 network) has been degraded during the last 40 years due to the high water level fluctuations, caused mainly by unsustainable use of water resources. The implementation of the management plan developed here will offer favourable and stable hydrologic conditions for the area's wetlands, facilitate environmental restoration and achieve long-term water sufficiency for anthropogenic activities. For this purpose GIS technologies, hydrologic models and remote sensing techniques have been combined to enhance the water management scenario formation process and a relevant methodology has been illustrated that can be widely applicable to similar catchments.

1.1. Study area

The study area is Trichonis Lake catchment, a 399 km^2 semi-mountainous area in Western Greece (Fig. 1). This region incorporates significant water resources, since it includes a large and deep freshwater body, Trichonis Lake, which has a surface area of 97 km^2, a maximum depth of 58 m and a potential water volume of approximately 2.8×10^9 m^3 (Dimitriou et al., 2001). The regional climate is characterized as semi-arid to arid Mediterranean with an average annual rainfall of 936 mm and an average annual temperature of 17 °C which fluctuates by 19 °C annually.

The high availability of water contributes to the formation of extended wetlands around the lake. A variety of ecologically significant habitats such as calcareous fens with *Cladium mariscus* and *Carex* sp. are present. Under EU legislation (Habitats Directive, Annex I), calcareous fens are a priority, protected habitat. This habitat type is usually encountered in lowlands close to water bodies and in areas where the water table is very close to the ground surface, since its growth requires high soil moisture conditions (Georgiadis et al., 2000).

The geology of the catchment is complex as it is intensely tectonized and comprises many different rock formations with a variety of hydrogeologic properties. In particular, medium weathered, fissured limestone, which has relatively high infiltration rates, covers a great proportion of the catchment (31% of the total area). Flysch formations also have a significant surficial extent in the basin (30% of the catchment) and contain sandstones and clayey schists, which can be characterized as low permeability formations (Fig. 1). Quaternary and pleistocenic sediments greatly affect the local hydrologic regime, since they cover 31% of the catchment extent and facilitate the occurrence of local

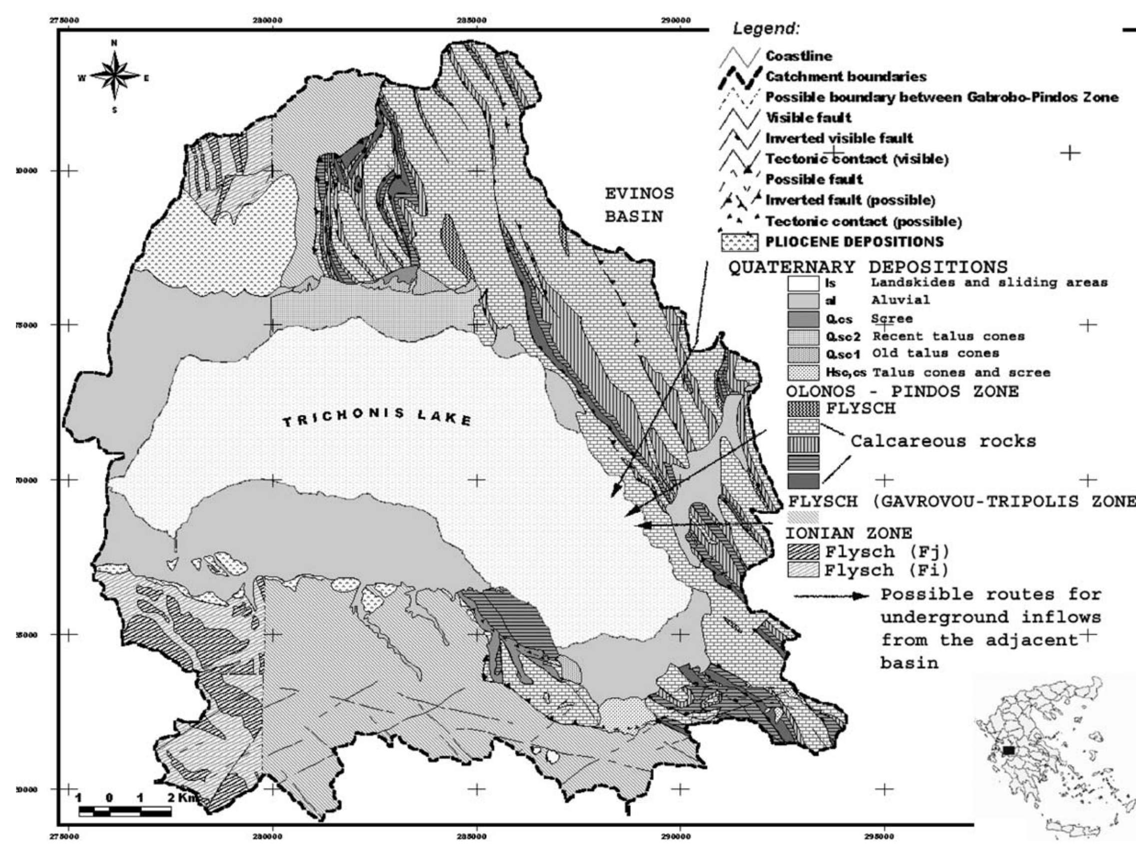

Fig. 1. Trichonis Lake catchment geologic map.

underground water storages due to their low to medium permeability (Fig. 1).

2. Materials and methods

The formulation of a sustainable water management plan involves a multidisciplinary scientific approach and profound study of the area's characteristics (hydrologic, geologic, socio-economic, etc.).

Estimating specific catchment hydrologic properties is a difficult scientific task, requiring good comprehension of the particular water system, profound knowledge of the geologic and geomorphologic conditions and full series of relevant data. Sophisticated physically based hydrologic modelling was used in the present study together with GIS technologies and remotely sensed data to quantify the necessary parameters for the development of the alternative management scenarios.

2.1. Data processing and hydrologic modelling

MIKE SHE modelling software (Refsgaard and Storm, 1995) is a deterministic, distributed hydrologic model that can simulate the water cycle in a catchment scale (Vazquez, 2003). It also provides significant opportunities for developing water management schemes (Christiaens and Feyen, 2001) and works with a variety of input data according to their availability. This modelling software consists of various modules (Water Movement, Water Balance, Water Quality, etc.) that are integrated under a user-friendly graphical interface.

MIKE SHE modelling software has been used to estimate the catchment water balance, which is an essential element for the water management plan formation. In the specific project a distributed model has been selected instead of a conceptual one, due to the great complexity of the regional geologic structure and the mountainous geomorphology that lead to significant spatial and temporal variations in the meteorological and hydrogeologic conditions. In particular, rainfall presents noticeable alterations between the low and high zones of the catchment, while the northern section of the basin consists of permeable calcareous formations and the southern part comprises impermeable flysch formations, which have very different hydrologic properties.

Meteorological data for the Trichonis catchment, such as rainfall, air temperature, relative humidity, evaporation, solar radiation, wind velocity/direction, and barometric pressure, were acquired from a network of five stations located within the catchment. The regional Digital Terrain and Bathymetry Model (DTM) was developed to provide the basin slope gradient and the relationship between the lake extent and the volume in different water level elevations.

Infiltration rates for each geological formation were estimated from geological maps, scientific literature and recent regional hydrogeologic surveys (Dimitriou et al., 2001).

Aerial photos of the catchment (Military Geographical Service, 2002) were imported to Image Analysis software to provide the area's land use map, which has been used in combination with irrigation rates to quantify the water demand for irrigation.

Future water demands were calculated by elaborating statistical data concerning annual increase rates for the main water consumptive economic activities (agriculture, tourism, industry) and for the area's population. These rates were used for the projection of the respective present values into the forthcoming two decades. The environmental water needs were quantified by analyzing the dominant biotic characteristics of the area based on recent ecological studies (Georgiadis et al., 2000). Soil moisture and the lake's water level were identified as the most important factors in determining conditions for protecting the regional wetlands. In particular, the low slope gradient of the wetland area and the necessary high soil moisture conditions indicated an optimum lake's water level fluctuation of approximately 60 cm annually. Additionally, the monthly water level fluctuations, which should be less than 10 cm/month, were set as an environmental goal and subsequently were incorporated in the water management formulation process.

The necessary data for the model have been collected including the area's grid codes, meteorological data, topography and land use map (Fig. 2) and were preprocessed with GIS tools (ArcView 3.2, Image Analysis, 3D Analyst and MIKE SHE GIS Interface), in order to become importable to the MIKE SHE modelling package. The selected grid geometry for the particular catchment's model comprises 13,310 computational points in the Saturated Zone module and 6292 computational columns in the Unsaturated Zone module while the grid size is 253 m.

Development of the regional hydrogeologic model was made difficult by the complex dominant geologic structure and the highly tectonized rock formations. In particular, a two-layer model structure has been selected after simulation tests, accompanied by two extensive geologic lenses, which provided the best modelling results and approached the physical geologic structure. The first layer comprises a 3 m deep soil profile (Unsaturated Zone), followed by the second layer consisting of flysch formations (Saturated Zone, average depth: approximately 500 m), which is the basis formation for the entire geologic structure of the area. The geologic lenses extend over this basis formation in specific areas and have depths up to 200 m. The hydrogeologic parameters of these layers have been estimated by in situ measurements and by recent studies conducted in the area (Psilovikos et al., 1995; Kallergis

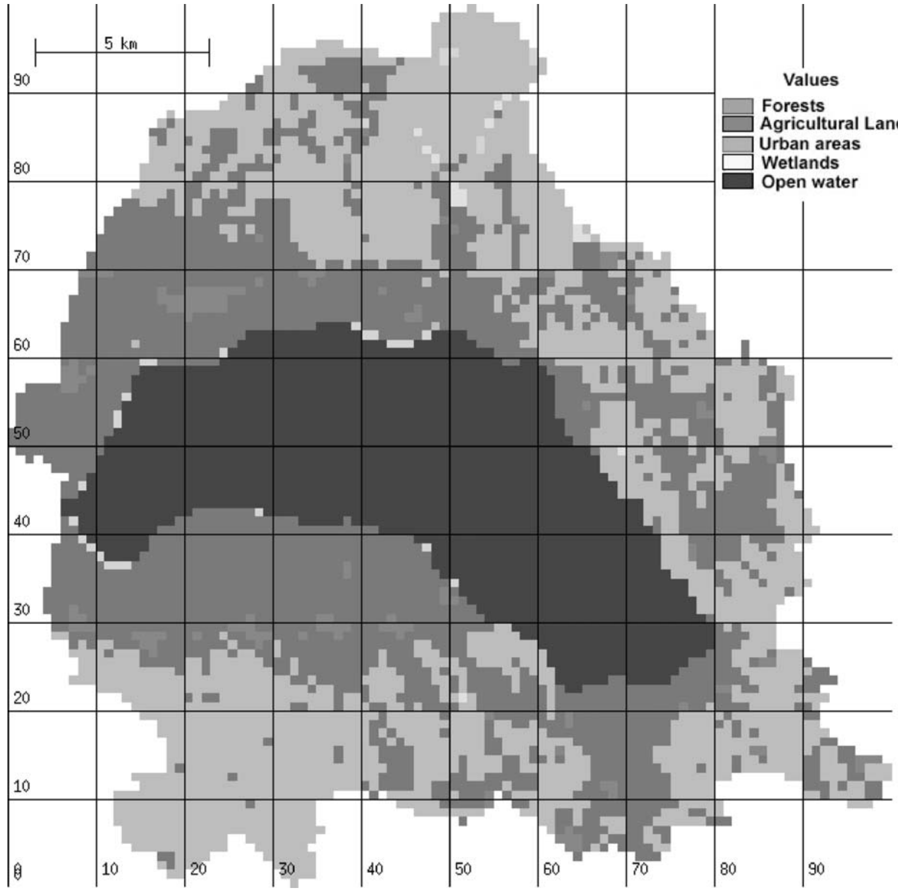

Fig. 2. Land use map of Trichonis Lake catchment.

et al., 1993). The model uses the Kristensen and Jensen method (Kristensen and Jensen, 1975) to estimate actual evapotranspiration by potential evapotranspiration rates that have to be provided as input to MIKE SHE. In addition, a land use map of the area and a vegetation/crop database that describes the hydrologic characteristics of each land use/crop type are also necessary inputs to the model. The potential evapotranspiration rates have been calculated by using the Penman method and daily meteorological data, such as air temperature, solar radiation, relative humidity and wind speed (Hess, 1996).

Calibration of the hydrologic model occurred during the last stage of the modelling process by comparing the estimated water level values to the measured ones. This allowed further amendments to be applied to the models' parameters in order to achieve results with the highest possible accuracy and reliability.

2.2. Water management plan formulation

After studying and analyzing the hydrologic and environmental regime of the Trichonis catchment, all the necessary components for the formation of a sustainable water management scheme were quantified (Fig. 3). The results of the hydrologic model, as well as the respective mathematical relationships of the various water balance components, have been imported to a programmable spreadsheet/database. This software provided the ability to modify various water balance components, such as water abstractions and agricultural water drainage, and to observe the respective changes in the water level conditions. Thus, the estimated hydrologic parameters (monthly and annual water level fluctuations) were compared to the set environmental goals, which facilitated the development of management alternatives and provided significant assistance in quantifying the impacts from each proposed alternative. This comprehensive and easy to use software comprises a preliminary decision support tool that will significantly assist the local water authority to apply sustainable water management to the study area.

The design process for management alternatives has been based on the following principles:

- covering present and future water demands;
- maintaining a slightly positive annual water balance;
- eliminating the danger of flooding and drought;

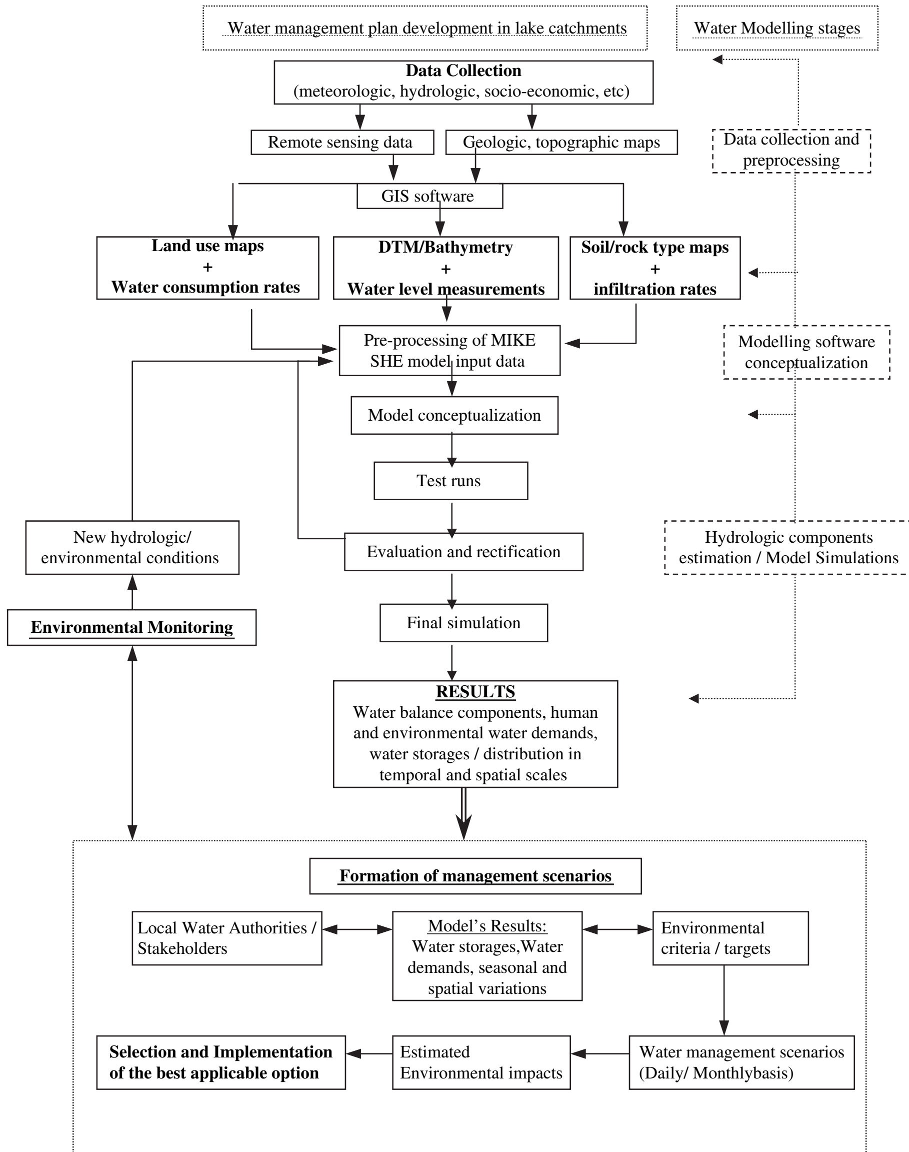

Fig. 3. Water management plan formulation methodology.

- minimizing the lake's monthly and annual water level fluctuation;
- conducting a rational exploitation of the regional water resources;
- establishing environmental protection and preservation;
- allowing an easy implementation process and the potential for future amendments and updates of the management scenarios.

Finally, an evaluation process for the proposed management alternatives followed by the contribution of the project's scientific team, local authorities and stakeholders and the best applicable option, based on the aforementioned criteria and goals, has been illustrated (Fig. 3).

3. Results and discussion

3.1. Application to Trichonis Lake catchment

The MIKE SHE result file after a post-process provided the catchment's water budget components. Thus, rainfall for the simulated period (1998–1999) reached 1337 mm, while actual evapotranspiration was estimated to be 798 mm (approximately 59% of the rainfall, Fig. 4). This increased amount of evapotranspiration is expected since the lake has a large open water surface and temperatures are quite high as well (average annual temperature: 17.25 °C).

The water quantity stored on the ground surface, according to the model, is 416 mm (31% of the rainfall),

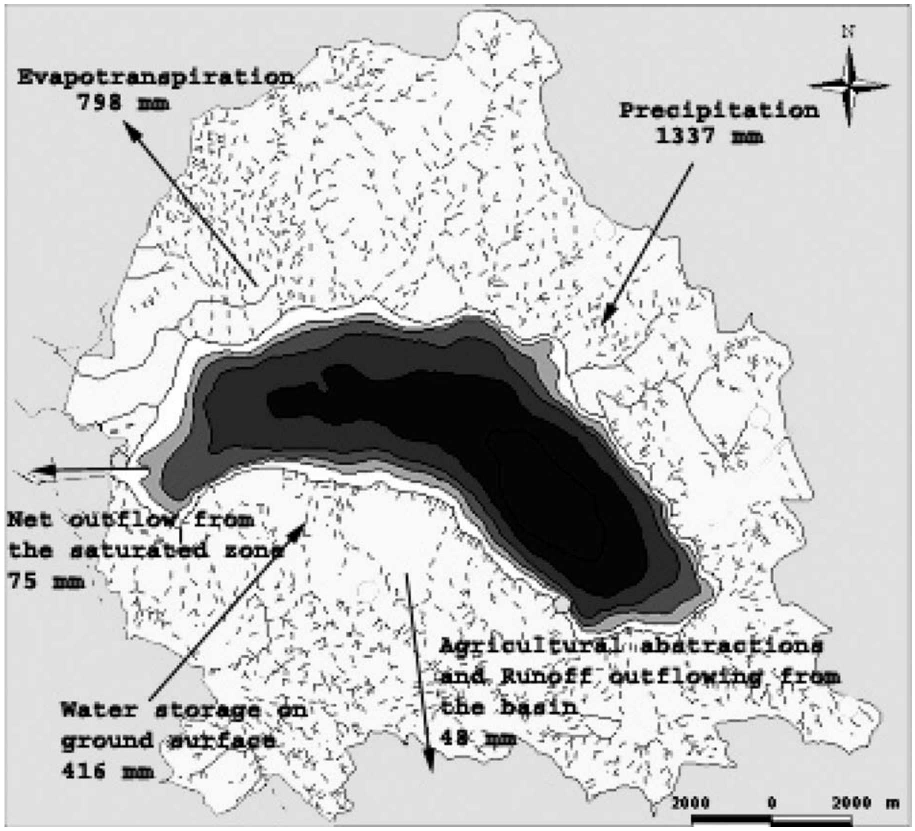

Fig. 4. Hydrologic cycle parameters estimated by MIKE SHE.

while the deficit in the unsaturated zone led to a decrease of more than 185 mm during the modelled period due to infiltration. The net outflow from the top layer of the saturated zone is 75 mm, which represents the groundwater movement towards internal catchment boundaries (depressions, lake, etc.). Furthermore, the runoff water that flows out of the basin reaches 16 mm annually, which is a relatively low quantity due to regional topographic and geologic characteristic that do not allow significant outflows from Trichonis catchment (Fig. 4).

The saturated component of the model indicated a water storage of approximately 40×10^6 m^3 in the 1st layer (Unsaturated Zone). This figure is in accordance with respective calculations that have been conducted prior to the simulation and a deficit in the 2nd layer (flysch formations) that reaches 289×10^6 m^3, which is also expected, since this layer supplies both the water abstraction scheme and the lake. Significant subsurface flow in the unsaturated zone has been recorded by the model (171×10^6 m^3 annually). This flow contributes to covering the vegetation water needs, the soil evaporation and the lake's recharge.

The water abstractions for irrigation reach 176×10^6 m^3 annually and most of this water (65%) is flowing outside Trichonis catchment through a controlled-flow canal (with a sluice gate) that connects Trichonis Lake with the adjacent lake of Lysimachia (Dimitriou et al., 2001; Kallergis et al., 1993; Psilovikos et al., 1995). This canal also discharges water excess during wet periods and is therefore a significant managerial tool that makes an important contribution to regulating the water transfer system in a sustainable and environmentally friendly manner.

During the 6 month period from April to September, 40% of the total annual outflows are pumped from the lake for agricultural purposes, while during the same period water inflows to the lake are minimal due to the limited amount of rainfall. Consequently, the lake's water level drops more than 60 cm within a short time period (May–September), causing extended drought in the wetland area (approximately 400,000 m^2) surrounding the lake. Additionally, the abstraction rates illustrate a non-smooth and irrational variation, temporally and spatially, increasing the environmental stresses in the area. In contrast, during the wet period of the year the drainage system is left unmanaged and the excess water cannot flow towards the broader river system. This increases the extent and time period of flooding. This unsustainable management of the area's water resources creates extremely unfavourable conditions for the significant wetland habitats existing in the area.

3.2. Management scenarios

All the formulated alternatives were assessed for their feasibility and for their environmental impacts and finally the best applicable option was chosen.

Moreover, the formulated management alternatives are briefly described as follows:

- The 1st scenario maintains the present hydrological status, which covers all human water needs but incorporates a high annual water level fluctuation of approximately 1 m and a maximum monthly fluctuation of 32 cm (Fig. 5, Table 1). These fluctuations are considered extremely high for the existing wetlands in the area.
- The 2nd alternative concerns the maintenance of the present annual water balance and the coverage of irrigation needs. Monthly outflows are slightly altered, so as to provide a relatively smooth monthly variance. With this plan a reduction of 25% of the annual water level fluctuation (approximately 75 cm, Fig. 5, Table 1) is achieved and the total water demands are still covered by Trichonis Lake. The maximum monthly fluctuation reaches 24 cm, implying fast transitions between wet and dry conditions and therefore unfavourable conditions for the area's significant habitats.
- The 3rd scenario suggests a 15% reduction of the water abstractions for irrigation during the summer period, smoothing of the monthly outflows and a respective increase in the water excess outflows during the winter. The additional amount of water needed for irrigation (approximately 20×10^6 m^3) can be provided by an adjacent reservoir through the existing canal system. The response of the lake to the implementation of this plan would be a reduction of the annual water level fluctuation to approximately 50 cm and a respective decrease of the maximum monthly fluctuation to 20 cm (Fig. 5). This comprises a rational management scheme, since it offers solutions for the great water needs of the local fiscal activities without compromising the area's environmental health.
- The 4th alternative further reduces the water abstractions for irrigation to approximately 75×10^6 m^3 (60% of the present value), resulting in a significant minimization of the annual water level fluctuation (~30 cm annually) but also incorporating certain problems with covering the irrigation needs (Fig. 5, Table 1). The maximum monthly fluctuation is also considerably reduced (~10 cm) but the additional amount of water needed in the agricultural fields within a short time period is very large (~40×10^6 m^3) and cannot be provided by any reservoir or canal system in the area. Additionally, due to the increased outflows from Trichonis Lake towards the adjacent basin in the winter period, a rising possibility for extreme flooding occurrence in this area becomes apparent.

3.3. Modelling environmental/hydrologic conditions

In this study, a comprehensive and physically based methodology was used in combination with a widely approved hydrologic model (MIKE SHE), remote sensing and GIS techniques, water management criteria, an environmental impact assessment process and communication strategies (Fig. 5). The advantages of this approach are the simple and reliable scientific methods that include coupling of hydrologic modelling and site-specific environmental goals to form and test water management scenarios. The suggested process also incorporates local community participation and the estimation of the environmental and economic impacts from the application of each suggested scenario, which is important for the long-term viability of the management plan. This methodology was integrated in a software

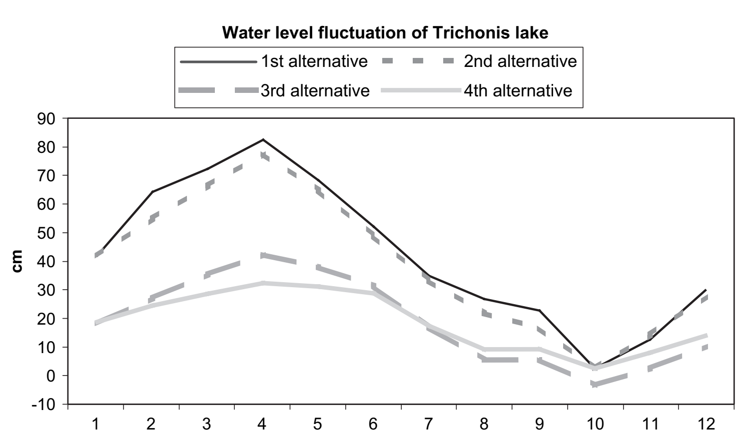

Fig. 5. Estimated water level fluctuation after the implementation of the management scenarios.

Table 1
Water management alternatives in Trichonis catchment and their hydrological characteristics

Water management alternatives for Trichonis catchment water resources	Maximum estimated annual water level fluctuation (m)	Maximum estimated monthly water level fluctuation (m)	Percentage of irrigation water needs covered by the alternative (%)	Water demand from the broader hydrologic system of Acheloos river for the coverage of irrigation needs ($\times 10^6$ m^3)
1st alternative	1	0.30	100	–
2nd alternative	0.74	0.14	100	–
3rd alternative	0.50	0.20	80	30–40
4th alternative	0.30	0.10	60	40–50

tool, which is in a preliminary version and can be used as a decision support system by environmental managers. Therefore, the aforementioned characteristics of the particular methodology make it applicable in other wetland areas by using either the specific software tool or the presented methodological workplan (Fig. 3).

Significant assistance in the particular scientific effort was offered by the hydrologic simulation, which provided important qualitative and quantitative information. The dominant hydrologic conditions have been examined and specific components which are difficult to measure, such as subsurface flow, groundwater flow and overland flow, have been quantified. The physical interpretation of the model offered profound understanding of the regional hydrologic system and valuable information to scientists, environmental managers and water resources authorities. Furthermore, the water management plan selection process has been enhanced by the use of the particular model and therefore maximizing the ecological and economic benefits from the proposed plan's implementation has become feasible.

The basic disadvantage of the modelling approach used in this study is the difficulty to conceptualize the geologically complex Trichonis Lake catchment in the MIKE SHE environment due to the lack of an additional sophisticated coupling option of the unsaturated and saturated zones in the geologic module. However, the user friendly interface of the MIKE SHE program allowed a relatively fast modelling conceptualization, detailed representation of the local environmental conditions on a spatial and temporal basis and graphical manipulation of the input data and results.

The establishment of an environmental monitoring network has been proposed for Trichonis Lake catchment that will provide continuous recordings of hydrologic and ecologic parameters, in order to act as an indicator for future potential amendments and updates of the plan (Fig. 5). The methodology used in this study proved to be effective and the modelling approach contributed significantly in developing the management scenarios, assessing environmental impacts and remediating various management practices.

Apart from the technical-scientific part of the water management plan formulation process there is also an important institutional and legislative section that is necessary for the efficient application of the selected plan. In some areas, the appropriate institutions and legislation to support the implementation of an environmental management scheme are absent. This places great constraints on experts that attempt to provide sustainable planning solutions for the exploitation of water resources and may compromise their effectiveness.

Public acceptance and support is also a prerequisite for the successful implementation of any political measure and thus public participation in the decision making process is necessary if consensus is to be achieved. For this purpose informative campaigns about the significant regional environmental problems and their effects on both humans and the ecosystem should be conducted under the framework of a sustainable water management scheme.

4. Concluding remarks

Designing and implementing sustainable water management plans can provide solutions to water deficiency problems. However, this is not an easy task since it requires a multidisciplinary approach and an effective tackling of numerous problems that may arise. Understanding natural disturbance regimes on the environment and eliminating the new forthcoming nuisances from human interventions are crucial foundations for designing management systems (Nakamura et al., 2000). Further, the use of non-physically based scientific methods and the potential lack of data both on a temporal and spatial basis impose great constraints on the quantification of a particular catchment's hydrologic regime (Beven, 2000). Elimination of these uncertainties requires extensive analysis and study of the basin's characteristics, long and credible time-series data and widely tested adaptive scientific methods that will be carefully validated against in situ measurements. Significant scientific efforts have been made to simulate environmental conditions in wetland areas and suggest management alternatives by combining hydrologic estimations, ecological requirements and impact assessment approaches (Harty and Cheng, 2003; Quinn and Hanna, 2003; Kuper et al., 2003).

The suggested management plan in Trichonis Lake catchment has been determined after analyzing the environmental impacts that will result from the implementation of the plan and by taking into consideration the conducted feasibility study. Initially, a transitional stage has been proposed so that the forecasted changes of the hydrologic properties arise progressively and smoothly. Consequently, for the first year of the plan's application, the 2nd management scenario is suggested as it slightly alters the hydrologic parameters and smoothes the monthly outflows (Fig. 5, Table 1) without establishing, however, the most favourable conditions for the area's wetlands. This problem will be tackled with the application of the 3rd aforementioned scenario (final plan) in the second year after the management scheme's initiation. The adoption of this particular plan will result in eliminating the extended water level fluctuations observed today (50% reduction from the present condition) and also provide slight seasonal alterations in the area's soil moisture. Furthermore, the agricultural water uses will undergo only a 15% reduction that can be met by external sources (existing, out-of-the-basin reservoir). Consequently, it should be stated that the suggested alterations will not influence the agricultural economic activities in the area and will satisfy the present and future needs. The local water authorities have accepted the proposed management scenarios and the first stage of the application has already been initiated, while the water level measurements have depicted the positive effects from this initial implementation process (approximately 25% decrease in the warm period's water level fluctuation). Furthermore, improving the regional environment will provide the opportunity for ecotourism development and therefore potentially increase economic growth in the region.

References

Beven, K., 2000. On the future of distributed modelling in hydrology. Hydrological Processes 14, 3183–3184.

Christiaens, K., Feyen, J., 2001. Analysis of uncertainties associated with different methods to determine soil hydraulic properties and their propagation in the distributed hydrological MIKE SHE model. Journal of Hydrology 246, 63–81.

Dimitriou, E., Zacharias, I., Koussouris, Th., 2001. Water resources management plan for Trichonis Lake catchment, final report. In: Zacharias, I., Koussouris, Th. (Eds.), Actions for the Protection of Calcareous Bogs/Fens in Trichonis Lake. Technical Report, NCMR/IIW, 70 pp.

Georgiadis, Th., Dimitrelos, G., Theocharopoulos, M., Chochliouros, S., Verios, G., Lambada, S., Ceramonte, M., 2000. Study for the calcareous bogs/fens present state in Trichonis Lake, final report. In: Zacharias, I., Koussouris, Th. (Eds.), Actions for the Protection of Calcareous Bogs/Fens in Trichonis Lake. Technical Report, NCMR/IIW, 24 pp.

Harty, C., Cheng, D., 2003. Ecological assessment and strategies for the management of mangroves in Brisbane Water—Gosford, New South Wales, Australia. Landscape and Urban Planning 62 (4), 219–240.

Hess, T., 1996. Evapotranspiration estimates for water balance scheduling in the UK Cranfield University.

Kallergis, G., University of Athens—Department of Ecology and Taxonomy, Sigma Ltd., Euroeco Ltd., 1993. Ecological, Land Planning Study of the Characteristic Ecosystems of Aitoloakarnania Lakes, Ministry of Environment, Town Planning and Public Works.

Kristensen, K.J., Jensen, S.E., 1975. A model to estimate actual evapotranspiration from potential evapotranspiration. Nordic Hydrology 6, 70–88.

Kuper, M., Mullon, C., Poncet, Y., Benga, E., 2003. Integrated modelling of the ecosystem of the Niger river inland delta in Mali. Ecological Modelling 164 (1), 83–102.

Military Geographical Service, 2002. Aerial Photos of Trichonis Area, Scale 1:15,000, Athens, Greece.

Mitsch, W., Gosselink, J., 1993. Wetlands, second ed. John Wiley & Sons, New York.

Nakamura, F., Swanson, F.J., Wondzell, M., 2000. Disturbance regimes of stream and riparian systems—a disturbance-cascade perspective. Hydrological Processes 14, 2849–2860.

Psilovikos, A., Tzimopoulos, Ch., Spiridis, A., Papadopoulou, E., Tsitsopoulos, I., 1995. Appraisal and management study of water resources in Acheloos downstream basin for the development and environmental reclamation of the area's estuary. Ministry of Environment, Town Planning and Public Works, Technical Report, University of Thessaloniki, Department of Geology and Physical Geography.

Quinn, N.W.T., Hanna, W.M., 2003. A decision support system for adaptive real-time management of seasonal wetlands in California. Environmental Modelling and Software 18 (6), 503–511.

Refsgaard, J., Storm, B., 1995. MIKE SHE. In: Singh, V. (Ed.), Computer Models of Watershed Hydrology. Water Resources Publications, pp. 809–846.

Turner, B.L., Moss, R.H., Skole, I.L., 1993. Relating land use and global land-cover changes: a proposal for an IGBP-HDP core project. Global Change Report, IGBP Report No. 24, HDP Report No. 25, Stockholm, Sweden.

Vazquez, R.F., 2003. Effect of potential evapotranspiration estimates on effective parameters and performance of the MIKE SHE-code applied to a medium-size catchment. Journal of Hydrology 270, 309–327.