*European Water* 13/14: 45-53, 2006.

# Pilot Implementation of EU Policies in Acheloos River Basin and Coastal Zone, Greece

N.P. Nikolaidis[1], N. Skoulikidis[2] and A. Karageorgis[2]
[1] *Technical University of Crete, Department of Environmental Engineering, Crete, GR*
[2] *Hellenic Centre for Marine Research, Institute of Inland Waters, Athens, GR*

**Abstract:** The environmental impact of EU policies aiming at protecting surface and ground waters were assessed in the Acheloos River Basin and coastal zone, Greece. The basin offered the possibility of studying the impact of EU policies on a multitude of aquatic ecosystems: four artificial and four natural lakes and a large estuary with important hydrotops (lagoons, coastal salt lacustrine and freshwater marshes) that belong to the NATURA 2000 or are protected by the RAMSAR Convention. A GIS-database was developed and was used to identify the environmental pressures and develop nutrient budgets for each sub-basin of the watershed to assess the relative contributions of nutrients from various land uses. The emissions based, mathematical model MONERIS was used to model the fate of nitrogen and phosphorous and their inputs to the coastal zone. The model CABARRET was used to assess the eutrophication impacts of these emissions to the coastal zone. Management scenarios were developed and modelling exercises were carried out to assess the impacts of management practices. Phosphorous loads were targeted for management since it was the limiting factor of phytoplankton growth controlling lake and coastal eutrophication.

**Key words:** Modelling, watershed, coastal zone, management, Water Framework Directive.

## 1. INTRODUCTION

An integrated global approach to managing surface, ground waters and coastal zone in Europe was long due. On 23-10-2000 the European Parliament and the Council adopted the Water Framework Directive 2000/60/EC. This Directive created a coherent water policy framework and rationalised the Community's water legislation, as it absorbed and replaced some older Directives, allowing them to retain their obligations, and expand the scope of water protection in order to include all waters. One innovation of the Water Framework Directive was the establishment of river basin management approaches, based on an assessment of the characteristics of the river basin and the introduction of monitoring systems on the status of inland and coastal waters; another was the definition of quality objectives and the establishment of new quality standards.

The environmental objective of the Directive is to ensure that "good" status will be achieved in all waters by the end of 2015. Focusing on this aim, the Directive sets out obligations on Member States to meet environmental objectives and establishes step deadlines for the achievement of this objective. For groundwater, good status refers to both quantity and chemical purity. For inland and coastal waters, an additional criterion of ecological quality is set, using macroinvertebrates, macrophytes, phytoplankton and fish as parts of the assessment procedure. The determination of good status requires definition of the reference conditions and of the boundaries between high-good-moderate quality classes, based on a number of criteria, which are specified in the Directive. The key stages for the general approach for analysing pressures and impacts, as laid out in the WFD, are: identifying driving forces and pressures, identifying the significant pressures, assessing the impacts, and evaluating the likelihood of failing meeting the objectives.

The objective of this research was to evaluate the environmental impact of the implementation of the Water Framework Directive in the Acheloos River Basin and coastal zone, Greece. The work was part of a Joint Research Centre / EU funded project aiming at conducting three pilot studies in three different catchments located in Greece, U.K. and Poland. Here we will present the modelling of the watershed and coastal zone and the development of management scenarios for the improvement of the water quality of surface and ground waters.

## 2. METHODOLOGY

### *2.1 Site Description*

Acheloos river basin offers the possibility of studying the impact of EU policies on a multitude of aquatic ecosystems: nearly pristine upland streams, artificial lakes, which, according to the WFD, are heavily modified water bodies, natural, partly eutrophic, lakes and a large estuary with important hydrotops that belong to the NATURA 2000 sites or are protected by the RAMSAR Convention, as well an intensively cultivated downstream area, with groundwater aquifers that are impaired by agricultural activities. The Acheloos basin has the following water quality and quantity management issues: intensive irrigation due to agriculture, intensive fertilization and pesticide application; altered hydrological regime at the lower part of the basin, due to an extensive irrigation and drainage system; salinization; erosion; habitat and biodiversity disturbance, due to the operation of hydropower plants.

The Acheloos River catchment (Fig. 1), one of the largest in Greece (6,329 km$^2$, including sub-catchments), is located in the southwestern part of the country (Fig. 1). The river originates in the Pindos Mountains, one of the less populated areas in Greece, and outflows, after 235 km, in the Ionian Sea. Three climatic zones affect the catchment area: a maritime Mediterranean climate near the coast, a Mid-European climate and a continental climate at the upper part of the basin. The average precipitation in the basin is approximately 1,380 mm/a and the average flow to the sea is estimated to be 4,383 million m$^3$ (Ministry of Development, 1996). The main part of the basin includes a mountainous terrain (mean catchment altitude 840 m) that consists of carbonate rocks (32%), flysch deposits (48%) and Triassic evaporites (3%), while the lowlands consist of Neogene and Quaternary sediments (17%). In the mid catchment four large hydroelectric dams (Tavropos, Kremasta, Kastraki and Stratos) impound river water. Leaving the mountainous terrain, the river crosses the Agrinio Plain, where four natural lakes (Trichonida, Lysimachia, Amvrakia and Ozeros) are located. In the lower part of the basin, which includes a large delta area with important coastal hydrotops, the river is fully meandering. The four natural lakes, the delta plain and the coastal lagoons belong to NATURA 2000 sites. These coastal environments have been altered by anthropogenic activities of the period 1960-1995, while the lagoons are extensively used for aquaculture.

The region has approximately 200,000 inhabitants. 45% of the population is located in urban areas, 11% in suburban/residential areas and 44% in agricultural areas. The watershed is not industrialised and most of the people work in the service sector or agriculture. Most of the agricultural land exists in the middle and lower sector of the watershed. Especially in the lower part of the catchment, which consists of a dense irrigation and drainage network, agricultural land covers 41% of the area. Municipal waste water discharges are the main point source pollution to the river. The municipal wastes of Agrinio, the main city of the area, were up to recently, discharged untreated in the lake Lysimachia, which outflows in Acheloos. In addition, a major diversion project is under development, aiming to transfer water from Acheloos to Pinios basin, in Central Greece.

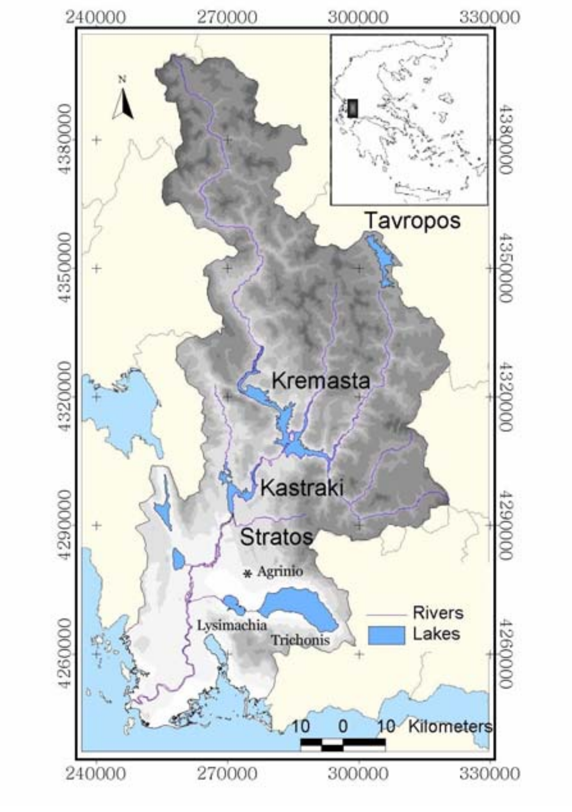

*Figure 1. Digital elevation model of the Acheloos River Basin and coastal zone.*

### 2.2 Watershed Modelling

Both a watershed model and a coastal model were used to conduct an integrated assessment of the hydrologic and geochemical environment of the Acheloos River Basin. Currently, there are many water quality models available to simulate the fate and transport of N and P in fields and watersheds. For example, CREAMS (Knisel, 1980), ANSWERS (Beasley and Huggins, 1981), HSPF (Johanson et al., 1984), BASIN (Heatwole et al., 1986), LEACHM (Wagenet and Hutson, 1989), AGNPS (Young et al., 1989), CREAMS-NT (Deizman and Mostaghimi, 1991), EPIC-WT (Sabbagh et al., 1991), ANN-AGNPS (Needham and Young, 1993), MONERIS (Behrendt et al., 1999), SPARROW (SPAtially, References Regressions On Watershed; Smith et al., 1997) and NTT (Heng and Nikolaidis, 1998) have been used to evaluate agricultural and urban NPS pollution as well as the effectiveness of best management practices.

The hydrogeochemical environment in Greece presents special problems that are not found in other places in Europe regarding the simulation of the fate and transport of nutrients in large watersheds. The majority of large Greek catchments such as Acheloos River Basin are heavily modified. In addition, many large watershed tributaries dry-out during the summer months. Such conditions create instability in the numerical solution of the watershed models. Watershed models require spatially distributed hydrogeochemical time series. Such data are rarely available in Greece at the spatial scale required. To overcome these problems, we selected the MONERIS (Behrendt et al., 1999) watershed model to simulate in a distributed fashion the watershed. The model, Modeling Nutrient Emissions in River Systems, MONERIS, (Behrendt et al., 1999) was developed to simulate nutrient inputs into river basins of Germany by various point and diffuse sources. The model uses river flow and water quality data in a GIS framework to develop the equations that estimate nutrient emissions in the river.

Six diffuse pathways and two emission point sources are modelled. The diffuse pathways modelled were: atmospheric deposition, erosion, surface runoff, groundwater, tile drainage and paved urban areas. Point source emissions are from wastewater treatment plants and direct industrial wastes that are directly discharged into the rivers. Diffuse emissions into surface waters are the sum of different pathways. Transformation and retention processes necessary to quantify and predict nutrient emissions were included in the model in relation to their sources.

MONERIS equations of the various pathways are developed especially for the modeling of medium to large-scale watersheds. The model incorporates the following seven subroutines.

- A GIS framework for regional estimation of diffuse and point emissions for large river basins (larger than 500 km2).
- A submodel for regionally differentiated estimation of nutrient discharges from wastewater treatment plants.
- A submodel that calculates inputs of nutrients and suspended solids by erosion (it is based on the modified uniform soil loss equation).
- A submodel for estimating groundwater nitrogen concentrations in agricultural areas. The model has a retention function that depends on hydrogeological conditions, the rate of groundwater recharge and nitrogen surplus.
- A GIS-supported submodel for nutrient emissions from agricultural areas modified by tile drainage.
- A submodel for nutrient emissions from urban areas. The model considers regional differences in sewer systems and development of storage volume for combined sewer systems.
- There is a submodel for nutrient retention and losses in surface waters. It is based on hydraulic load or the specific runoff nutrient retention.

The Acheloos River Basin database (Skoulikidis et al., 2001a; Skoulikidis et al., 2001b) was used to create the input data for MONERIS at the subbasin level. The model is a steady state emissions model and requires data that are five-year averages. Data for the period 1995-2001 were used in this simulation. Regarding flows, data from Kremasta, Kastraki and Stratos reservoirs and estimates of annual flows for each subcatchment were used. Nutrient loads for each subbasin were calculated from monthly quality time series measurements. The remaining dataset was estimated from measurements made in 2001 that were adjusted to reflect annual average values. The population distribution was obtained from the GIS database. The total population of the basin was 201,300. The CORINE land cover database was used. The model requires estimates of the soil loss, the proportion of the area that is dominated by sandy, clayey, loamy and silty soils and the nitrogen content of topsoil. The soil loss was estimated using the Universal Soil Loss Equation (USLE). The equation requires information on the mean slope of the subbasin and the annual precipitation. The model requires the apportioning of the area into shallow versus deep unconsolidated and consolidated groundwater. The basin was assigned a shallow groundwater, consolidated soil characterisation for upper Acheloos, and deep groundwater, consolidated soil for the lower basin. The nitrogen surplus values were estimated using the OECD methodology. The phosphorous surplus values were estimated at 18 kg/ha-yr and the total P accumulation at 650 kg/ha.

### *2.3 Modelling of the Coastal Area*

CABARET (Gordon et al., 1996) is a mass balance model that estimates the productivity of the coastal zone based on stoichiometric calculations. The coastal area modelled was located between the effluent region of the river, Oxeia Island and Makri Island. It has an area of 27.4 km$^2$ and a mean depth of 33 m. The total volume modelled was 0.904 km$^3$. Precipitation data from Lesini station were used as input to the model. The 1991-1996 average annual precipitation was 1,066 mm. Evaporation was calculated using the Thornwaite equation and monthly average temperatures from Lesini and Neochori stations. The annual potential evaporation for Lesini station was calculated to be 944 mm and for Neochori 868 mm. In the model the average potential evaporation of the two stations was used (906 mm). The annual Acheloos river discharge was estimated to be 3,052 km$^3$/yr. It was assumed that groundwater does not discharge into the coastal zone. This assumption is probably correct since most of the delta area suffers from seawater intrusion. The average salinity for the system box was 38.2 ppt. The outer box salinity was 3.6. Data for atmospheric and river dissolved inorganic (DIN) and organic (DON) nitrogen and dissolved inorganic (DIP) and organic (DOP) phosphorous were obtained from Skoulikidis et al., 2001. The atmospheric inorganic nitrogen load was 0,59 g/m$^2$-yr and the inorganic phosphorous load was 0,034 g/m$^2$-yr.

## 3. RESULTS AND DISCUSSION

### 3.1 Watershed Modeling Results

A comparison of the simulated, versus the observed nitrogen emissions for the Acheloos River Basin is presented in Figure 2 and for phosphorous emissions in Figure 3. Table 1 presents the distribution of nitrogen and phosphorous emissions to different pathways as calculated by MONERIS. The total nitrogen (TN) load was estimated to be 4,347 tn/yr. Groundwater was the largest DIN contributor with 72% of the TN load followed by overland flow (18%) and atmospheric deposition (5%). Erosion contributed 2%, urban runoff 2% and point sources 1%. The total phosphorous (TP) emission was estimated to be 270 tn/yr. Similarly, groundwater was the largest TP contributor with 47% followed by point sources (20%) and overland flow (17%). Atmospheric deposition contributed 9%, erosion and urban runoff contributed 4% each. Here, it should be mentioned that atmospheric deposition contribution represents only the direct atmospheric deposition to surface waters and not the amount of atmospheric deposition that falls on various land uses and ends up into the surface water systems from other pathways.

Figure 2 presents the TN-calculated emissions versus the TN measured load for the various subbasins. The data are very close to the 1:1 line indicating that the model can estimate with reasonable accuracy the total nitrogen emissions from the basin. The overall emission error was 0.4%. The root mean square error was 345 t/yr. Similar results gave the DIN load estimates using the method of specific runoff. 78% of the subbasins estimates fall within 90% brackets. Figure 3 presents the TP-calculated emissions versus the TP measured load for the various subbasins. The phosphorous results were not as good as the nitrogen ones. The overall emission error was 8%. The root mean square error using all the data was 7 tn/yr. However, the mean square error of 5 out of the 7 subbasins was 5 tn/yr. Similar results gave the TP load estimates using the method of specific runoff. 89% of the subbasins estimates fall within 90% brackets. Overall, it can be said that the MONERIS performance in simulating the nitrogen and phosphorous emissions of Acheloos River Basin was very good.

*Table 1: Nutrient emissions calculated with MONERIS for Acheloos River Basin*

Nutrient emissions calculated with MONERIS for Acheloos River Basin calculated for the period for 1995

Total emissions and proportion of the different pathways

| | N | | P | |
|---|---|---|---|---|
| | [tn/yr] | [%] | [tn/yr] | [%] |
| Atmospheric deposition | 212.6 | 4.9 | 24.0 | 8.9 |
| Tile drainage | 0.0 | 0.0 | 0.0 | 0.0 |
| Groundwater | 3,131.5 | 72.0 | 126.7 | 46.9 |
| Overland flow | 801.9 | 18.4 | 45.3 | 16.8 |
| Erosion | 89.9 | 2.1 | 10.3 | 3.8 |
| WWTP(Point Sources) | 34.2 | 0.8 | 53.5 | 19.8 |
| Urban systems (total) | 77.4 | 1.8 | 10.1 | 3.8 |
| Total emissions | 4,347.4 | 100.0 | 270.0 | 100.0 |

### *3.2 Coastal Zone Modelling Results*

The molar ratio of N/P is a very important factor in the management of eutrophication of surface waters. It is generally accepted that the optimal N/P molar ratio for the growth of algae in marine waters is close to 16/1 (Redfield Ratio). If the ratio is greater than 16/1, then there is excess of N, and P is the limiting factor to algal growth. When the ratio is less than 16/1, then N is the limiting factor. Knowing the limiting factor, we can then manage the appropriate N and P loads in the watershed to control surface water eutrophication. A more detailed classification is that for N/P>30 there is nitrogen surplus, N/P=15-30, the species are in balance, N/P=10-15, there is a moderate nitrogen deficit, N/P<10, there is a large nitrogen deficit. The N/P ratio of Acheloos River discharging in the coastal zone was 42. This indicates that Acheloos River water entering the coastal zone has P as the limiting factor instead of N (which is typical the limiting factor). A possible explanation for the drastic decrease of P is that P is readily adsorbed on the suspended matter of the river which settles before entering the coastal zone. An analysis of the coastal zone water column average N/P molar ratios indicated that the absolute values of nitrogen and phosphorous in the Acheloos coastal zone were relatively low and they were representative of an oligotrophic system. It is interesting to note that there was a concentration gradient from the shore to the open sea with increasing nutrient concentrations in the open sea. The low N/P ratios can be explained by the fact that the degree of eutrophication of the coastal area was controlled by the open sea nutrient levels and not by Acheloos River discharges.

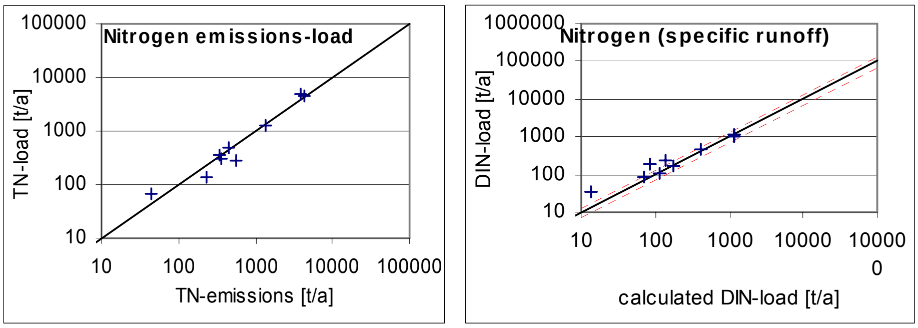

*Figure 2. Comparison of simulated TN-emissions with the TN load and calculated (based on specific runoff) versus measured DIN load.*

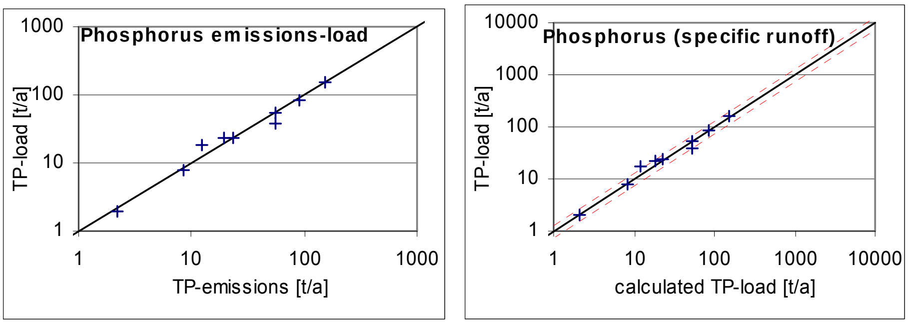

*Figure 3. Comparison of simulated TP-emissions with the TP load and calculated (based on specific runoff) versus measured TP load*

The mass balances for water, salt and nutrients for the coastal zone were calculated. The system was very flashy and its annual average hydrologic retention time was 1.1 days. The mixing flux was 795 million m$^3$/day. The mass balance calculations indicated that the coastal zone was a net sink for both dissolved inorganic nitrogen (ΔDIN= - 302E+3 moles/day) and dissolved inorganic phosphorous (ΔDIP=-5.58 E+3 moles/day). Both DIP and DIN were taken up to produce organic matter in the system. This is consistent with the conclusion that the system is phosphorous limited determined in the eutrophication analysis of the river water. Regarding the metabolism of the system, if we assume that $(N:P)_{part}=16$, the difference between photosynthesis and respiration can be calculated as $(p\text{-}r) = -[\Delta DIP \times (C:P)_{part}] =$ 21.56 mmoles/m$^2$/day. Since the resulting difference is positive, the system was net autotrophic (net organic matter producer). The difference between nitrogen fixation and denitrification can be calculated as $(Nfix\text{-}denit) = \Delta DIN - [\Delta DIP \times (N:P)_{part}] =$ -7.78 mmoles/m$^2$/day. The negative difference in (Nfix-denit) indicated that the system was a net denitrification system.

### *3.3 Management Scenarios*

Three distinct management scenarios for Acheloos River Basin and their impact on water quality were evaluated. Each scenario targeted phosphorous loads since it was the limiting factor of phytoplankton growth controlling eutrophication. All scenarios simulated the water quality for the year 2025. The 3 scenarios were:

1. ***Water Quality Improvement Scenario (WQI):*** Surface water systems (lakes and reservoirs) that were classified as eutrophic were targeted and alternatives to change their trophic status to mesotrophic were simulated.
2. ***Business as Usual Scenario (BAU):*** Certain rates of development for the region were assumed and their impacts on water quality were projected.
3. ***Green Scenario (GS):*** All available technologies and best management practices to improve water quality were applied.

#### *Water Quality Improvement Scenario (WQI)*

This scenario is a direct application of the Water Framework Directive, which indicates that all water bodies should be accessed and then a management plan should be established that aims at the improvement of the ecological quality of each system, to reach a "good" status. In the Pressures and Impact Analysis, three lakes that can be classified as eutrophic are being identified. These are Lakes Amvrakia, Ozeros and Lysimachia. The total phosphorous concentrations of the lakes were 40, 51, and 60 μg/L respectively. The aim of this scenario is to change the trophic status of the lakes to mesotrophic. In a simplified way, this means that their phosphorous concentrations should be between 10-20 μg/L. In other words, their P loads should be reduced by 50-75%, 60-80% and 67-83% respectively to achieve a TP concentration of 10-20 μg/L so the lakes would be considered mesothrophic. At this point, it should be noted that this is a simplified way of classifying a lake status. In order to classify appropriately the trophic status of a lake, one needs to consider also its primary productivity and transparency. The analysis was performed for each lake separately. The following assumptions were made.

- An annual population growth of 1% was assumed (actual increase by 35%).
- 100% of the population is connected to a wastewater treatment plant.
- 100% reduction of the emission from point sources in the watershed.
- 60% reduction in P surplus in agricultural and livestock activities.

Amvrakia Lake: The base emission load for the lake was 3.1 tn/yr and it should be reduced between 1.6-2.3 tn/yr. Based on the assumed reductions, the resulting emissions to Amvrakia will be 2.3 tn/yr, which will make Amvrakia mesotrophic. The sources of this load were: Atmosphere = 1.3 tn/yr; Erosion = 0.4 tn/yr; Overland Flow = 0.2 tn/yr; Groundwater = 0.3 tn/yr; and Urban = 0.2 tn/yr. Amvrakia is a difficult case for lake management because it does not have any point sources in the watershed and a significant fraction of the load comes from atmosphere (30% at the base case). If the agricultural and livestock activities are not reduced by 60%, the emission load would be 2.6 tn/yr

Ozeros Lake: The base emission load for the lake was 5.1 tn/yr and it should be reduced between 1-2 tn/yr. Based on the assumed reductions, the resulting emissions to Ozeros will be 4 tn/yr, which is double the minimum emissions load that is required for a mesotrophic status. The sources of this load were: Atmosphere = 2.2 tn/yr; Erosion = 0.4 tn/yr; Overland Flow = 0.5 tn/yr; Groundwater = 0.5 tn/yr; and Urban = 0.4 tn/yr. The lake will never achieve a mesotrophic status since the atmospheric emission is higher than the minimum emissions load that is required for a mesotrophic status (43% originates from the atmosphere).

*Lysimachia Lake:* The base emission load was 55.8 tn/yr and it should be reduced between 9-13 tn/yr. Based on the assumed reductions, the resulting emissions to Lysimachia will be 25.7 tn/yr, which is double the minimum emissions load that is required for a mesotrophic status. To achieve further reductions, one needs to look into the various sources in the subcatchment upgradient from Lysimachia. Lake Trichonida has a significant point source load. Assuming 100% reduction in that point source load and that 100% of the people are connected to wastewater treatment plants, the resulting emissions to Lysimachia will be 20.9 tn/yr. The sources of this load were: Atmosphere = 5.0 tn/yr; Erosion = 3.0 tn/yr; Overland Flow = 4.4 tn/yr; Groundwater = 9.7 tn/yr; and Urban = 1.7 tn/yr. It will be very difficult to achieve mesotrophic status even if all agricultural and livestock activities stop in the watershed.

### *Business as Usual Scenario (BAU)*

This scenario constitutes an upper limit to bracket our projections. The following assumptions were made:

- An annual population growth of 1% was assumed (actual increase by 35%).
- An annual development growth rate of 3%, which corresponds to an annual increase in point source emissions of 3% and an annual increase of P surplus of 3%. The annual increase of 3% does not relate to actual increase in landuse change, but rather to intensification of agricultural practices.

The resulting emissions increased the TP load to lakes Amvrakia, Ozeros, Trichonida and Lysimachia by 10%, 10%, 5% and 92% respectively. The overall emission increase from Acheloos to the coastal zone was 25%.

### *Green Scenario (GS)*

This scenario constitutes a lower limit case to bracket our projections. The following assumptions were made:

- An annual population growth of 1% was assumed (actual increase by 35%).
- 100% of the population is connected to a wastewater treatment plant.
- An overall reduction to point source emissions by 80%.
- An overall reduction to agricultural and livestock emissions by 20%.

The resulting emissions decreased the TP load to lakes Amvrakia, Ozeros, Trichonida and Lysimachia by 19%, 16%, 27% and 49% respectively. The overall emission increase from Acheloos to the coastal zone was 14%.

## REFERENCES

Beasley, DB, and LF Huggins (1981). ANSWERS Users Manual. EPA-905/9-82-001. U.S. Environmental Protection Agency, Region V. Chicago, IL.

Behrendt, H, P Huber, M Kornmilch, M Opitz, O Schmoll, G Scholz, and R Uebe, (1999). Nutrient Emissions into River Basins of Germany, Federal Environmental Agency, UFOPlan-Ref. No. 296 25 515

Deizman, MM and S Mostaghimi, (1991). A model for evaluating the impact of land application of organic waste on runoff water quality. Res. J. Wat. Pollut. Control Fed. 63:17-27.

Gordon J, DC, Boudreau, PR Mann, KH Ong, J-E Silvert, WL Smith, SV, Wattayakorn, G Wulff and T Yanagi, (1996). LOICZ Biogeochemical Modelling Guidelines. LOICZ Report and Studies No 5, 1-96

Heatwole, CD, PL Diebel and JM Halstead (1990). Management and policy effects on potential groundwater contamination from dairy waste. Wat. Resourc. Bull. 26:25-34.

Heng, H and NP Nikolaidis, (1998). Distributed Modeling of Non-point Source Pollution of Nitrogen. Journal of American Water Resources Association, 34 (2) 359-374

Johanson, RC, JC Imhoff, JS Kittle and AS Donigian, (1984). "Hydrological Simulation Program - FORTRAN (HSPF): User's Manual for Release 8.0," EPA-600/3-84-066, NTIS: PB84-224385, Springfield, VA

Knisel, WG ed. (1980). CREAMS: A field scale model for chemicals, runoff, and erosion from agricultural management system. USDA-SEA Cons. Res. Rept. 26, Washington D.C. 643 p.

Needham, SE and RA Young (1993). ANN-AGNPS: A continuous simulation watershed model. p 432-439. In: Proc. of the Federal Interagency Workshop on Hydrologic Modeling Demand for the 90's. U. S. Geol. Survey water resources Investigation Report 93-4018. Reston ,VA

Nikolaidis, NP, H Heng, R Semaginand and JC Clausen (1998). Non-Linear Response of a Mixed Land Use Watershed to Nitrogen Loading. Agriculture, Ecosystems and Environment, 67, 251-265.

Sabbagh, GJ, RL Bengtson and JL Fouss, (1991). Modification of EPIC to incorporate drainage systems. Trans. ASAE. 34:467-476.

Skoulikidis NTh, N Nikolaidis and E Zagana (2001a) Assessment of the contribution of agriculture to the aquatic pollution of Acheloos catchment. Athens, Final Report (in Greek)

Skoulikidis, N, N Nikolaidis, Th. Koussouris, A. Karageorgis, A. Economou, A. Economopoulou and F. Batzias (20021b). Impact of EU environmental policies on Acheloos river basin – Watershed description and data collection. Athens, Interim Report

Skoulikidis NTh (2002). Hydrochemical character and spatiotemporal variations in a heavily modified river of Western Greece. Environmental Geology, Vol. 36, No 1/2, 1-17

Skoulikidis, NTh, KC Gritzalis, T Kouvarda, and A Buffagni, (2002b). The implementation of AQEM procedure in Greece – Development of new pollution and biotic metrics. AQEM meeting, 9-10/12/2002, Ede, The Netherlands

Smith, RA, GE Schwarz and RB Alexander (1997). Regional interpretation of water-quality monitoring data. Wat. Resour. Res., 33, 2781-2798

Young, RA, CA Onstad, D Bosch and WP Anderson (1989). AGNPS: A non-point source pollution model for evaluating agricultural watersheds. J. Soil Wat.Conserv. 44: 168-173

Wagenet, RJ and JL Hutson, (1989). LEACHM: Leaching estimation and chemistry model: A process-based model of water and solute movement transformation, plant uptake and chemical reactions in the unsaturated zone continuum. Volume 2, Version 2, Water Resources Institute, Cornell University, Ithaca, NY