"ASSIMILATIVE CAPACITY OF THE KALAMAS RIVER AND THE LAKE PAMVOTIS"

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1. INTRODUCTION

The city on Ioannina, an old and historical city of Greece, is the cultural, commercial and industrial center of Epirus the northwestern part of Greece. The current population of Ioannina is 65,000 people with some additional 40,000 leaving in the surrounding villages and small-towns.

In the process of decentralization, the Greek Government has given incentives for the development of the greater Ioannina area and therefore more intensive activities both civic and industrial are anticipaled for the near future. Potential sectors of development exist in agriculture, animal raising, fisheries, hand-crafts and tourism. As a basic infra-structure works, the sewarage of the city of Ioannina is almost completed.

The area includes two important and scenic surface water bodies the lake Pamvotis and the river Kalamas which support a wide variety of plant and animal life and whose conservation is of parament important. It is well recognized that very often unprogrammed and quick development can cause serious and sometimes irreversible damage to the quality of the environment. The quality of the surface waters becomes therefore a critical parameter in the process of development of the area and which will enable the decision maker to establish priorities and fields of action.

This paper which is intended to be of informative rather than of a highly technical nature identifies the problems and outlines the methodology of establishing water quality criteria and controlling wastewater effluent in an integrated matter.

It presents the preliminary results of a research programme currently carried out by the Department of Water Resources of the National Technical University of Athens on behalf of the Ministry of the Environment.

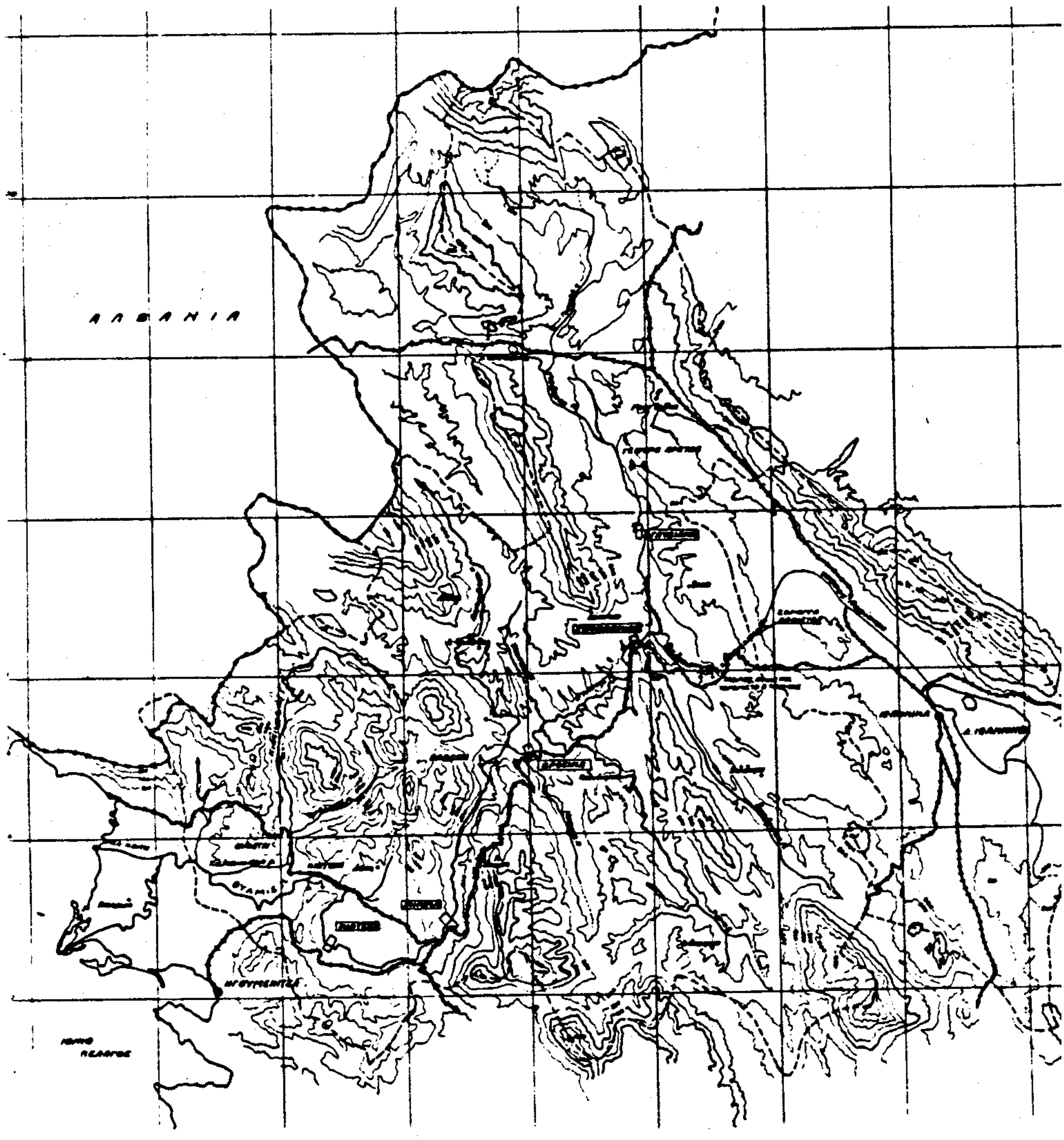

Fig. 1 The study area.

2. PHYSICAL AND TECHNICAL BACKGROUND

The study area comprises two major catchments-the cathment of the Lake "Pamvotis" and the catchment of the Kalamas river (Figure 1).

The lake Pamvotis or lake Ioannina is the largest lake of the Epirus area having a surface area of 22 km^2 and a maximum length and width of 8.5 and 3.5 km respectively. The total capacity of the lake is estimated around $95X10^6 m^3$. The lake lies at the lowest point of a closed drainage basin of 475 km^2 in a region of predominantly limestone geology with strong carstic character. Thus a big amount of the water falling in this area is lost to neighbor basins i.e. to the Kalamas and Arachthos basins.

The lake originally extended mostly to the northwest and also to the south-east forming shallow marshy areas of some 45 km^2. In the 1950's a series of major works were built in order to drain the area and reclaim it for agriculture. These works comprised the Lapsista canal which extends 42 km to the north-east of the lake and drains the Lapsista area to the Kalamas river. The canal is connected by a gravity flow tunnel to the "Veltistikos" a tributary that joins the Kalamas near the village "Soulopoulo". The outflow from the lake to the canal is controlled by headworks. Water is drawn directly from the lake for irrigation of the south-east area, appr. 1000 ha in 1983 and also to supplement. Water needed for the irrigation of Lapsista area and which is taken mainly by springs.(2.100 ha).

The Kalamas river is classified among the most important rivers of Greece with an average flow of 57 m^3/sec near its mouth to the sea. The river flows through a natural cathment area of 1722 km^2, which lies almost entively within the Greek territory. The annual precipitation of the basin is 1360 mm and the surface run-off coefficient was estimated at 0.76. The total length of the river is 120 km, with 80 km downstream the Soulopoulo confluence. It is a swift flowing river with velocities ranging from 2.0m/sec near its spring to 0.5 m/sec. The time of flow below Soulopoulo is estimated at 1 day.

Water is drawn from the Kalamas river to irrigate an area of 2,000 ha at the Kioteki plain . Small amounts of water are also drawn for water supply and fisheries.

3. HYDROLOGICAL BALANCE OF THE LAKE PAMVOTIS-TIME OF RESIDENCE

Very little is known about the flow into and out of the lake due to the large amount of subterranean flows.

However in the basis of available flow records, irrigation practices etc. an attemp was made to estimate the average time of residence in the lake.

The equation for the water balance sheet for the lake can be written in the following way.

$$\underbrace{P + Q + G_I}_{\text{inlet}} = \underbrace{E + Y + A + G_O}_{\text{Outlet}} \quad \text{where}$$

P = annual precipitation on the lake surface
Q = surface runoff
G_I = ground-water inflows
E = evaporation
Y = overflow to the Lapsista canal
A = irrigation
G_O = sub-terranean losses

Each one of these terms was assessed separately based on long rainfall records and evapotranspiration analysis. Thus the average annual inflow to the lake was estimated around 140×10^6 m^3. The average renewal time for the lake is therefore 0.79 years or 1.27 times/year. For dry and wet conditions respectively with a return period of 5 years the residence time is estimated as 1.14 and 0.60 years.

4. MINIMUM FLOWS OF THE KALAMAS RIVER

Data from three flow-gauging stations in the Kalamas river for which records exist for period longer than 10 years were analysed and processed statistically in order to draw the flow-duration curves. Ten-day average values were used in the calculations as these are known to represent pollution transport phenomena better Min values for 6 characteristic sites of the Kalamas (including the exit of Lapsista tunnel) are shown in table 1.

Table 1. Min flows (10-day average)

	Return period-years				
Site	2	5	10	20	50
Lapsista	0.02	0	0	0	0
Soulopoulo	8.22	7.02	6.32	5.72	5.02
Vrossina	11.45	10.16	9.42	8.78	8.03
Minina	14.13	12.78	12.00	11.33	10.53
Irrigation dam	15.29	13.91	13.11	12.42	11.61
Near outfall	17.34	15.94	15.11	14.39	13.55

5. BENEFICIAL USES

The present uses of the lake are fishing for carp and crayfish, eel culture in cages, the supply of irrigation water and recreational boating. Swimming in the lake is also observed occasionaly.

The Lapsista canal serves primarily as a drainage canal for irrigated areas but it also receives the effluent from a number of industries and farms.

Finally the Kalamas river offers to the people of the area a number of beneficial uses which include fisheries of trout and carp, irrigation, water supply and recreational fishing and swiming. It must be noted here that abstraction for water supply is carried out in the summer months, not directly from the river but from wells lying close to the river bed. A total number of 3.000 inhabitants are served in this way. Finally the esthetic and cultural value of the river can not be overemphasized.

6. CURRENT WATER QUALITY ASSESSMENT

Existing data on the quality of the surface waters were scarce and sporadic. For the purposes of this study a systematic sampling program has been organized. The program will be completed at the end of July 1984.

Lake Pamvotis. The sampling program for the lake includes sampling from 7 characteristic points in the lake and 3 points in the Lapsista canal. Parameters measured include BOD, COD, SS, temperature mineral nitrogen, phosphates, dissolved oxygen, transparency and chlorophyl.

Table 2 shows the evolution of some characteristics parameters in the lake from measurements taken in the period 1976-1983 by various organizations.

Table 2. Quality of lake Pamvotis (1)

Parameter				Date - source
D.O	BOD p.p.m	NH_4 p.p.b	PO_4-P p.p.b	
-	5-7.0	-	-	77-79 PERPA
8.4-10.8	-	14-40	16-40	77-79 IOKAE
-	3.05	-	-	June 1981-University of Ioannina
9.0-10.2	3-6	12-56	30-80	Nov. 1982-PERPA (3)
10.2-10.8	0.50	<100	60-150	Nov. 1983-This study

Although some localized pollution occurs seasonally at the lake margin, the lake as a whole is still basically free of pollution. Its water is clear with a greenish tint due to a light plankton growth. The major ecological disturbance which causes considerable concern to the people of Ioannina is a substantial reduction in total fishery catch in the last two decades, a serious reduction in the proportion of carp and a total disappearance of the eels from the lake. It is almost sure however (2) that the reduction in carp production is a result of the physical changes brought about to the lake by the reclamation works which have reduced the shallow margins of the lake (suitable breeding grounds for carp) and have cut off the natural communication between the lake and the river Kalamas.

Kalamas river and Lapsista canal. The river quality monitoring program for the Kalamas river was carried out between July and December 1984. Samples were taken from 4 points in the river and at the outlet of the Lapsista tunnel at 3-hourly intervals. Water quality parameters recorded on 9.8.83 were slightly higher than on other occasion and are shown in table 3.

Four samples taken from the canal in June 1978 by P.E.R.P.A (1) gave BOD values from 5-7 mg/l COD, 15-33 mg/l and E.coli counts from 2400-240000/100 ml. Also two samples from the Kalamas river taken at Soulopoulo and Vrossina gave BOD of 5 mg/l, COD of 17 and 22 mg/l and E.coli counts of 1100 and 2400/100 ml.

6. WASTEWATER LOADS

Waste loads applied to the surface waters originate from two sources: point or discrete sources like sewer outfalls, industrial discharges etc., and non-point or diffuse sources such as urban storm water run-off, precipitation and run-off from agricultural land. Precipitation run-off from undeveloped lands will have certain

Table 3. Average water quality parameters on 9.8.83

Parameter		Sampling location		
		Lapsista	Soulopoulo	Kioteki
pH		7.3	7.3	8.1
temp. 0^{C}		20.0	16.5	19.0
Conductivity		364	703	483
D.O	p.p.m.	85%	100%	112%
BOD	p.p.m.	-	0.50	0.60
COD	p.p.m.	24.0	7.0	14.2
NO_2^{-}-N	p.p.b.	56	2	3.0
NH_4-N	p.p.m.	1.1	0.1	0.5

Table 4. Pollution loads from domestic sources.

Year	Popul. equiv.	Waste flow m^3/d	BOD kg/d	SS kg/d	Total-N kg/d	Total-P kg/d
1985	63,000	13,000	4095	4410	756	190
2011	81,000	20,000	6480	6885	1215	324

physical, chemical and biological characteristics which will affect water quality in the river and lake, yet this natural load cannot considered as a waste.

6.1 Point sources

Domestic wastewaters: Present and future domestic wastewater flows and pollution loads are shown in table 4.

In the calculation of these figures, the past records of increase in water consumption, in the last 20 years were considered. Population projections were made on the basis of the anticipated development of the area.

Industrial effluents. The main industrial effluent point-sources are localed on the north side of the lake and along the Lapsista canal. They represent effluents mainly from food-processing industries and slaughter houses. Effluents from fish farms were also included in the survey as sometimes they can affect the quality of the receiving waters mainly due to unused food, fish wastes and disease infection. There is evidence (4) that effluent quality vary considerably throughout the year depending on the river flow and temperature.

For the assessment of pollution loads from industrial sources, 24-h composite samples were taken and analysed. These results were verified with data taken from the literature.

Table 5 shows the total amount of pollution contributed by industry. Future projection assume a 30% increase in all loads.

Table 5. Pollution loads - Industrial sources

Year	Flow m^3/d	BOD	SS	Total-N kg/nu	Total-P
1985	1440	580	243	470	-
1985 (fish-farms)	110000	77	330	44	4.4

6.2 Non-point sources

Non-point sources of organic pollution and nutrients are a result of agricultural activities (irrigation, animal raising), natural activities (atmospheric precipitation), run-off from paved areas, subsurface disposal of wastewaters etc.

Whereus phosphates are retained to a great extent by adsorption and precipitation in the ground, nitrates are very mobile and can easily be transferred through ground water to the lakes and rivers.

Annual areal contributions of nitrogen and P to the surface waters are shown in table 6.

Table 6. [illegible] loads - Non-point sources

Source	Drainage area km^2	P		N		Water body
		Unit rate $gr/m^2/y$ (6) (7)	tn/year	Unit rate $gr/m^2/y$ (6) (7)	tn/year	
Urban run-off	3.5	0.1	0.35	0.50	1.75	Lake
Irrigation	10,0	0.05	0.50	0.50	5.00	lake
"	21,0	0.05	1.05	0.50	10.50	Laps
"	15,0	0.05	0.75	0.50	7.50	Kalamas
Uncaltivaled	345	0.01	3.50	0.30	103.50	lake
	100	0.01	1.00	0.30	30.00	Laps
	1700	0.01	17.00	0.30	510.00	Kalamas
Precipitation	22	0.025	0.05	2.0	44.0	lake

Run-off from the spreading of piggery-wastes In the study area there exists a great number of pig-farms. For the purposes of this study the most important, from a point of view of size and potential pollution, were singled out and investigated. With the exception of two farms lying near the Lapsista tunnel which treat their effluent in anaerobic laggons prior to land disposal, all other units spread their wastes directly on farm land. Because of this fact the pollution caused by piggery wastes is considered as a diffuse source. In order to be able to estimate the amount of pollutants leached out to the lake the criteria for land disposal of wastewaters and sludges put forward by EPA (9) were used. Data for the amount of wasteflows produced were obtained from the farmers from a national survey carried out by the Ministry of Hygiene and were correlated with published information(10). Pollution loads were estimated using data aquired in our laboratory from analyses of similar wastes as well as literature sources. Two different soil types were recognized: soils with very slow infiltration rates in low areas lying very close to the lake, with max annual application rates of 0.25 m/year and soils which can support application rates of the order of 1.0 m/year.

Given that the max. BOD rate which can be supported by a fallow soil rich in organics cannot exceed 30 t/ha (9) it is obvious that leaching of BOD to the drainage water will occur. Assuming an average drainage run-off coefficient over this part of the area of 0.30, the loss of BOD to the surface waters is estimated as 20% of the total. This result is in excellent agreement with work done in Ireland (11). For N and P the recommended values for crop production should not exeed 500 kg N/ha and 26 kg P/ha (11). Based on experiments done in Ireland and an extensive survey of the literature done by Kolenbrander the corresponding losses of N and P to the surface waters is estimated at 40% and 20% respectively. The later will be almost entirely in the mineral from (11). Pollution loads from piggery wastes are shown in table 7.

Table 7. Piggery wastes - Pollution loads to surface water

Sows	Flow m^3/y	BOD t/y	Total-N t/year	Total-P t/year	Water body
1250	33200	130.0	60,0	7.0	lake
475	11170	-	48,0	2.4	Lapsista

7. WATER QUALITY CLASSIFICATION

Whilts rivers and lakes are legitimately used for the disposal of effluents, the control of the quality of such discharges is necessitated by other uses which are made of the waters and the need to protect these uses. It is also important to recognize the dilution and self-purification afforded by the river or lake in order to minimize the treatment required.

In determining the quality requirements for the river it is necessary both to recognize the uses which require to be protected and the quality necessary for their protection. The latter is usually described as "criteria". The concept of water quality criteria is been currently adopted by most European countries the U.S.A. and the U.S.S.R who have published quality criteria and prepared directives prescribing the qualities judged necessary to support various water uses.

In order to put into practice the principles outlined above, the major steps required to derive quality conditions for discharges are:

- indentification of a classification system of water uses
- formulation of water quality criteria in the form of maximum desirable and max. permissible concentrations for these various uses
- selection of flow and quality conditions to be adopted in the design
- calculation of the required effluent qualities by mass balances and mathematical modeling.

The system of classification of uses. The system of classification of water uses proposed for the area is shown in table 8.

Table 8. Classification of surface water uses

Primary use	Uses for which criteria have been described		
I Potable water supplies	1.	Categorie	A1
	2.	"	A2
	3.	"	A3
II Fisheries	1.	Trout	
	2.	Carp	
III Bathing waters	1.	Bathing waters	
IV Irrigation			
V Amenity and conservation			

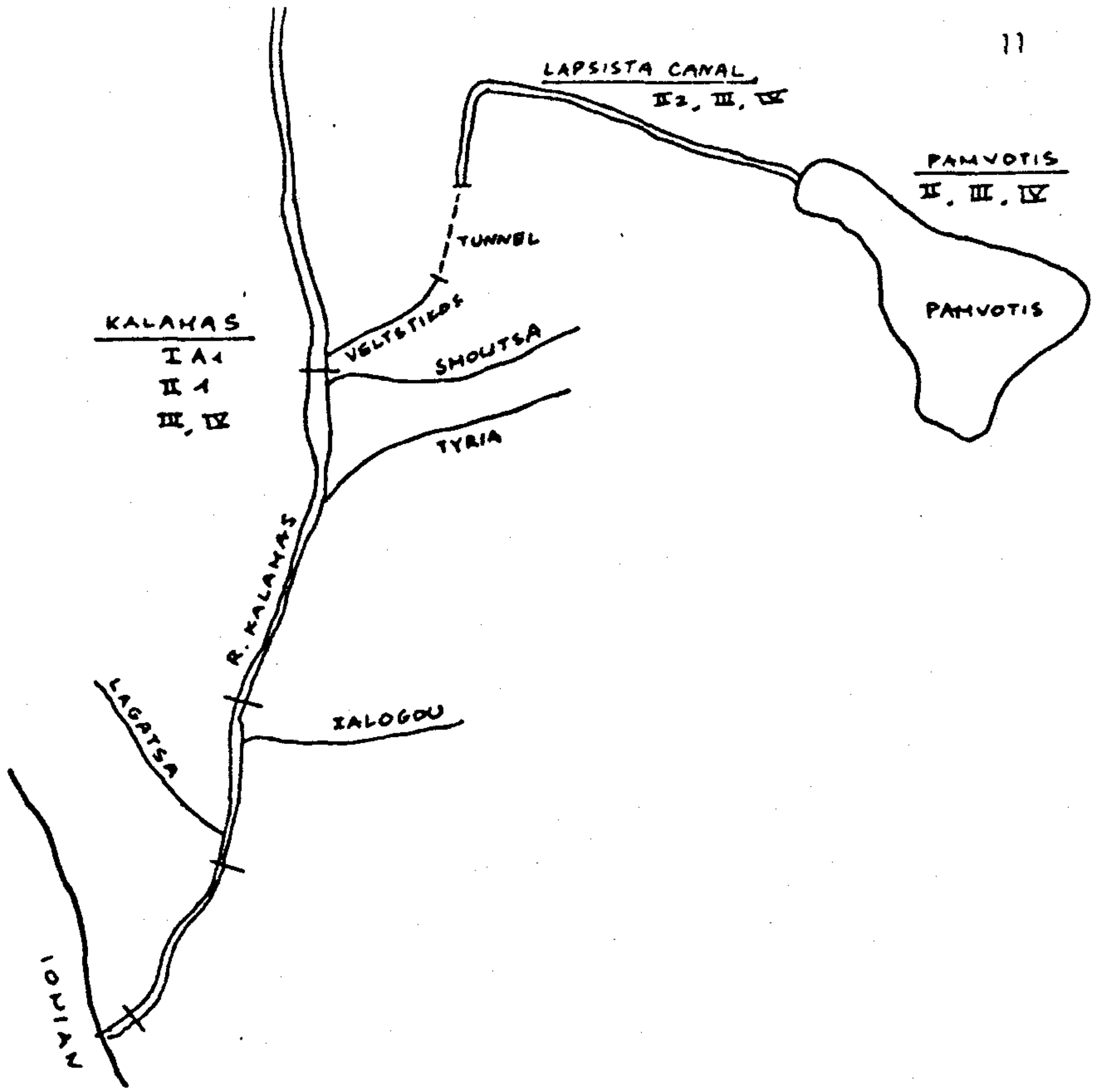

Fig. 2. Allocated water uses for the surface waters

Water quality criteria. Water quality criteria, for uses I,II,III in table 8 have been taken from the respective EEC directives. For irrigation, quality requirements depend upon crop type, soil type and water applied. For the purposes of this study we have adopted the criteria proposed by the Anglian Water Authority (12). Finally amenity is usually not stated as a river use in as much as, rivers and lakes forming a feature of the landscape, contribute to the general amenity of the area. It is desirable that rivers with high amenity value should not have a BOD greater than 5 mg/l.

Based on the above classification system, and taking into consideration the current uses of the surface waters and their present quality, the desired water use allocated to each stetch of river or lake is shown in figure 2. Having defined the desired uses the most stingend value for each determinand is then selected among the various uses and this value constitute a river quality criterion the determinand.

Calculation of effluent standards by mass-balance. Effluent discharge loads can easily be calculated using simple mathematical models. For the Kalamas river a mathematical model based on the Streeter-Phelps equation and prepared by SOGREAH for the Pinios river is being used (Programme CARIMA). In addition the model makes use of the Saint-Venant equations of the unstready flow. The adjustment of the model for the Kalamas river and its solution for a series of typical situations is outside the scope of this paper.

For the lake, a eutrophication model proposed by Jones (8) is being used. To model is used to predict the long-term concentration of phosphates in the lake, since PO_4-P is known to be the limiting factor.

8. CONCLUSIONS

This paper has outlined a comprehensive approach to the problem of controlling water pollution in an important catchment. This method is currently being used by a number of water authorities in Europe and the U.S. Despite the high amount of time and effort required it offers the opportunity to tackle water pollution problems in a rational way and to promote, co-operation within a given catchment especially in cases such as this where administrative jurisdiction over the waters is exercised by different authorities. It also offers a unique way to establish priorities and make cost-benefit assessments.

Finally it is a means for the public to be involved in the problem of preserving the environmental quality.

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