

DEVELOPMENT OF A GROUNDWATER MANAGEMENT SYSTEM AND METHODS OF ARTIFICIAL RECHARGE, IN AREAS WITH OPEN PIT EXPLOITATIONS

DEVELOPMENT OF A GROUNDWATER MANAGEMENT SYSTEM AND METHODS OF ARTIFICIAL RECHARGE, IN AREAS WITH OPEN PIT EXPLOITATIONS

CASE OF THE SOUTH FIELD OPEN PIT, WEST MACEDONIA, GREECE.

By D. DIMITRAKOPOULOS, J. KOUMANTAKIS, Z. HELIADIS, G. POUTIOS

SUMMARY

This article describes the edit and the first conclusions, coming from the research project "Elimia", which aims at the development of an automatised groundwater management system and the corresponding software, concerning the area of the South Field open pit, in Ptolemais, West Macedonia, Greece.

In this area there is the largest open lignite pit in Greece, with total reserves up to 1×10^9 tn of lignite. In order to make safe the exploitation of lignite, it is necessary to maintain perimeter and in pit wells, to lower the water table of the overburden. The establishment of a monitoring and water management system is suggested.

This system has to take into consideration the area 's specific features, that is intense mining activity the need for dewatering of the mine, covering of the water supplying demands of the city of Kozani and the irrigation demands of the area, the possibility to irrigate new lands, the negative water balance etc.

A parallel goal of this project is the search for solutions, for minimizing of the non reversable influences on the aquatic environment of the area, beyond the limits of the lignite exploitation, which can be achieved introducing a water management system and using the water coming from the dewatering process for the artificial recharge of the aquifers..

INTRODUCTION

As it is known, during the excavation of mineral ores, in open cast mining exploitations, many problems due to groundwater are often confronted, besides the problems caused by the inflow of precipitation and possibly part of the surface outflow of the surrounding areas. These technical and economical problems can even prohibit the exploitation of the ores.

On the other side, mining activities alter the existing environmental features and the hydrological net, as well as the groundwater supplying systems. Lowering of the water level, around open pits, is one of the most important environmental problems, because of the impacts on the aquatic balance of vast areas. The long term expansion of the cone of depression, affects the existing water wells and conclusively, the water supplying systems, the irrigation of cultivated lands and the

forestry. In some cases, a significant decrease of the arable lands or even a drainage of adjoining lakes and small rivers or land subsidence can be caused.

It is obvious that all this complex aquatic system requires a proper management. The control of human impacts on groundwater resources demands complex technical and economical solutions, taking into consideration the contradictory interests of the various consumers, as well as the protection of the environment.

HYDROGEOLOGY

The South Lignite Field basin, in Ptolemais, is part of the great structural graben element, which extends in a north-south direction between the town of Monastirion (Bitola) in F.Y.R.O.M. via Florina and Kozani town, both in Greece. It occupies the southern part of it. It is surrounded by the mountains Vermio, Askio and Skopos. It is limited by the Klidion Horst in the north.

It has an enormous economical interest, because it includes one of the bigger lignite fields in Greece, with reserves up to 1.10^9 tn of lignite. The same basin also includes well developed groundwater bodies. Therefore, lignite, as well as water, is directly and indirectly connected with the economical development of the area.

PAPAKONSTANTINO (1979) was the first to describe the hydrological and hydrogeological conditions of the Ptolemais basin and the adjacent mountains. Since then, several papers have been published, which have added many details to the understanding of the complex hydrogeological situation of the basin and its mountainous frame (DIMITRAKOPOULOS 1996, DIMITRAKOPOULOS, LOULOUDIS & KOUMANTAKIS 1991, DIMITRAKOPOULOS, LOULOUDIS & KOUMANTAKIS 1994, LOULOUDIS 1991, PAVLAKIS 1990, RE 1988).

The water bearing formations are the upper, Neogene and Quaternary, unconsolidated sediments of the basin fill. The clay-marl lignite bearing system is the impermeable footwall of the sandy overburden. This aquifer consists of successive, hydraulically connected, smaller aquifers and appears to be homogeneous in a large scale. They are recharged by infiltrating rainfall. The annual recharge has been estimated to 20.10^6 m³. Heads of the undisturbed aquifers had been near ground surface, i.e. following the surface gradient, between 700 m just near Vermion Mt to the north-east and 640 m a.s.l. to the south-west.

The small Soulou stream had been the receiving surface water body of the basin, finally ending in lake Vegoritis. Locally, where recharge by rainfall was rejected, swamps had been existing. In the mines, excavation and dumping processes have destroyed these aquifers. Beyond the mine rims, the aquifers have been partially depleted. Nowadays the flow of the Soulou stream is composed of water discharged by the mines and untreated waste water of settlements and industrial plants.

DEVELOPMENT OF A GROUNDWATER MANAGEMENT SYSTEM AND METHODS OF ARTIFICIAL RECHARGE, IN AREAS WITH OPEN PIT EXPLOITATIONS

This system of aquifers in the unconsolidated basin fill, exists independently of two major aquifer systems in the hardrock formations, in the deep underground of the basin and the surrounding mountain ranges.

The Askion mountains, which limit the basin to the west, consists of a southern block with highly karstified limestones and marbles of Triassic-Jurassic age and a northern block, which is made up of Paleozoic crystalline schists. In the southern karstic area, a regional karst water table has been found to occur at an average table level of 340 m a m.l., that is well below the heads of the unconsolidated sediments of the basin fill. Limestones, belonging to this Mesozoic sequence of strata and showing the same position of the karst water table, are known to occur beneath the basin fill in the southern part of the Ptolemais basin. The general direction of the karst water flow is towards south.

No aquifers are known to exist within the crystalline schists of the northern Askion Mountains and the Vernon Mountains further north.

The Vermion mountains which form the eastern frame of the Ptolemais basin consists of two major hydrogeological complexes, that in turn are made up of several lithologic-hydrogeological subcomplexes, the hydraulic details of which are not yet known. A geological map, given by PAPAKONSTANTINOU (1979), shows flysch of upper Cretaceous age, limestones and limestones conglomerates of the upper Cretaceous, serpentinites of the Jurassic, and dolomitic limestones belonging into Triassic-Jurassic systems. All carbonate rocks display major karstic features.

FIRST CONCLUSIONS OF 'ELIMIA' PROJECT

Elimia project started in 1996. Up to now there are two groups of conclusions. In the first one they are given the conclusions that stem from the studying and evaluation of former projects. According to those:

1. The basin is under a regime of negative aquatic balance, due to overpumping of groundwater.
2. The water balance has worsened from the impacts of the long term drought and the drilling of many new waterwells, made mostly to cover irrigation needs.
3. The deficiency in the groundwater balance has caused a drawdown on the hydrostatic level, but there is no satisfactory knowledge of the territorial evolution of this drawdown.
4. The municipality of Kozani uses water coming from the South Field basin, to cover the demands for domestic use. The pumped quantities overcome the actual needs, because of the great leaks of the distribution net, but sometimes are not enough.
5. There have been made suggestions, based on the above mentioned aspect, for the drilling of a new set of waterwells, in the rich karstic aquifers, to get over this lack of water, that the town

of Kozani suffers from. The proposed areas are the karstic aquifer of the North-West Vermion and the South Vermio-Skopos aquifer.

6. It has been suggested that is necessary to prohibite the drilling of new waterwells in the karstic aquifer of North-West Vermio, given that it is ascertained a negative equilibrium and a drawdown of the hydrostatic level of 15 m, during the last 15 years. From the evaluation of the hydrologic balance of the Vegoritis lake, it is concluded that in the last 5 years, the leaks from the shallow sinkholes of the lake, rise up to 60 million m³ annually.
7. The groundwater quality is very good, while the surface waters of the Vegoritis lake and the streams are polluted, sometimes, at a high degree.
8. An important part of the needs for irrigation purposes is covered with the water of the Soulou stream and the lakes (Vegoritis, Himaditis, Petra, Zazari).
9. Since the period 1984-85, PPC has been conveying water from the artificial lake of Polifitos and covers the needs of AS Ag. Dimitrios and Kardia. After its use, the water is rejected to the Soulou stream.
10. There has been made a simulation of South Field basin and a mathematical model, by Dr G. Louloudis. The water quantities that need to be pumped by the dewatering waterwells, for the protection of the mine are estimated.

The second group of conclusions, stems from the evaluation of the gathered data and the jobs done within the range of the research project ‘Elimia’.

1. The number of wells and waterwells has been increased dramatically during the last few years. In 1991 there had been registered 220 wells and waterwells. In 1996, in the frame of the research project ‘Elimia’. Among the registered waterwells, there are 26 failed ones, as well as 10 dewatering waterwells which have been destroyed.
2. From the existing 410 operating waterwells, 73% is used for irrigation purposes, 8% for domestic use, 12%(50 waterwells) for dewatering, 3% are used as piezometers and 4% has an unknown use (**fig2**).
3. Within the period 1991-94, the pumped groundwater quantities were doubled. In 1991, these quantities were estimated to be 15,6.10⁶ m³. In 1995, we estimated that, the pumped groundwater quantities reached a total of 29. 10⁶ m³, only by waterwells having pumps operating with electricity. For these estimations, we have taken into consideration the electrical consumption of the pumps. We also have to add quantities, coming from waterwells using petroleum pumps, which consist 10% of the total number of waterwells, as well as 1,5. 10⁶ m³ for the dewatering of the mines of Kardia and Sector 6. Consequently, the total amount of pumped out groundwater is over 33.10⁶ m³. In **figure 4**, it is shown the relation between the drawdown rate and the distance from the mine.

DEVELOPMENT OF A GROUNDWATER MANAGEMENT SYSTEM AND METHODS OF ARTIFICIAL RECHARGE, IN AREAS WITH OPEN PIT EXPLOITATIONS

4. From the 29 million m³ of pumped water from waterwells with electrical pumps, during the year 1995, 14 million covered irrigation needs, that is 48%, 7 million m³ cover the domestic use (24%) and 8 million come from the dewatering of the mine. 4 million of these pumped quantities, come from inside the mine and are, partially, originated from precipitation.
5. Because of the continuous pumping, for domestic use and the mine protection, the corresponding pumped quantities are 24% and 28% of the whole, while from the irrigation waterwells, which represent a 73% of the total number of waterwells, is pumped the rest 28%.
6. About 150-200 private and public waterwells, as well as all the dewatering ones, already or to be made by PPC in the future, are to be destroyed gradually till the end of the mining activities.
7. The water coming from the dewatering of the mine, which is, totally, about 10 million m³ are rejected in the Soulou stream and to the connected drainage ditches. Large quantities of water are pumped from these ditches and are distributed for irrigation purposes.
8. During the period 1983-87, there was a steady state and the groundwater level didn't fluctuate widely. In the following years, because of the increased pumped out quantities and the drought a more or less continuous fall of the groundwater level was observed. The last 15 years, this drawdown varies from 0,5-1 m annually, depending on the area (**fig3**).
9. The piezometric level fluctuates between 20 and 40 m. Deeper levels are observed in the southern zone, where the waterwells of Kozani and of many villages had been made. In this area, at the first water supplying drills of Kozani, made in 1960-62 by the Ministry of Agricultural, the hydrostatic level was at 4-5 m. With a yield of 200-250 m³/hr, the water level fell at about 5-10 m. That means that we are dealing with an area where the water level drawdown exceeds 30 m, from 1960 till today. Deep hydrostatic levels can be notified west from AS Agios Dimitrios, while at the mine area, the level is at 25 m below the surface.
10. In the area, where the waterwells of the municipality of Kozani are made, there is a local lowering zone due to overpumping. In this area has been decided to be applied an artificial recharge project, with injection of water coming from the dewatering drills of the South Field mine. For this purpose, new drills and piezometers will be made. The existing ones will also be used, on an experimental basis.
11. The groundwaters are of good quality and can be used for artificial recharge.
12. In the Northern zone, near Agios Dimitrios the possibility of artificial recharge was examined, with ditches flooded with water coming from the stream flow of Vermion Mt. This project seems to be unrealistic because the percolating water flows to the Triassic-Jurassic limestones underneath.
13. A shallow "poor" unconfined aquifer is developed at areas. The water level depth usually varies from 2-10m.

SYSTEM DESCRIPTION-SUGGESTIONS

It is obvious that the above described hydrological basin of the South Lignite Field, with the complex ground and surface water system, needs an integrated water management system and the establishment of a program for monitoring of the water status. This is going to cover the "Elimia" project. We are now installing, at selected points, of the South Field basin, automatic monitoring devices.

The devices have been installed in:

- dewatering wells, for the protection of the open pit from ground water
- water supplying wells of the municipality of Kozani (domestic use)
- piezometers in front of the exploitation face
- piezometers in the dumping area (later on)
- Soulou river
- outlets of the Power Stations

The aim is to monitor the ecological and chemical status of surface waters and the quantitative and chemical status of the groundwater.

The parameters that will be recorded are:

- water level fluctuation in water wells and piezometers
- abstraction rate, that is pumping rate of dewatering wells, irrigation wells and water supplying wells
- quantity of water that comes into the basin from the Power Stations
- changes of the quality of water

The whole installation is controlled automatically for its good operational status.

The data collected are transmitted directly to a central unit, which undertakes the further analysis and presentation of the results. The Automatic Monitoring System uses sufficiently the capabilities, given by modern technology, for direct data collection, their transmission to a Central Unit at a remote position, where the supervisory and surveillance of multiple points will be done.

The Local Automation Devices are programmable Logical Controllers (P.L.C.), placed locally in each point, while a personal computer will be used as the Central Unit, running the software InTouch of Wonderware, in cooperation with InSupport.

The system of the Planned Logical Controller of each drillhole, consists of the Central Consideration Unit of the SLC-500 series, the essential input and output cards for digital and proportional signals which are put in proper frame, with corresponding Power Supplying System.

DEVELOPMENT OF A GROUNDWATER MANAGEMENT SYSTEM AND METHODS OF ARTIFICIAL RECHARGE, IN AREAS WITH OPEN PIT EXPLOITATIONS

The Central Unit has been established in a PPC building, in South Field. This Station is connected with two other InTouch Stations, which have been placed in the buildings of the other two members of this research project, municipality of Kozani and C.T.A.F.F (Centre of Teechnology and Applications of Fossiles Fuels).

The system will be extended to the whole Ptolemais-Kozani basin, after a period of experimental operation. We must say that this water monitoring and management system covers the proposals of the European Community for the water policy, as they have been expressed in a draft paper (Commission Proposal on Water Policy, draft 14/2/97)

According to the above, the suggestions need to be stated are the following:

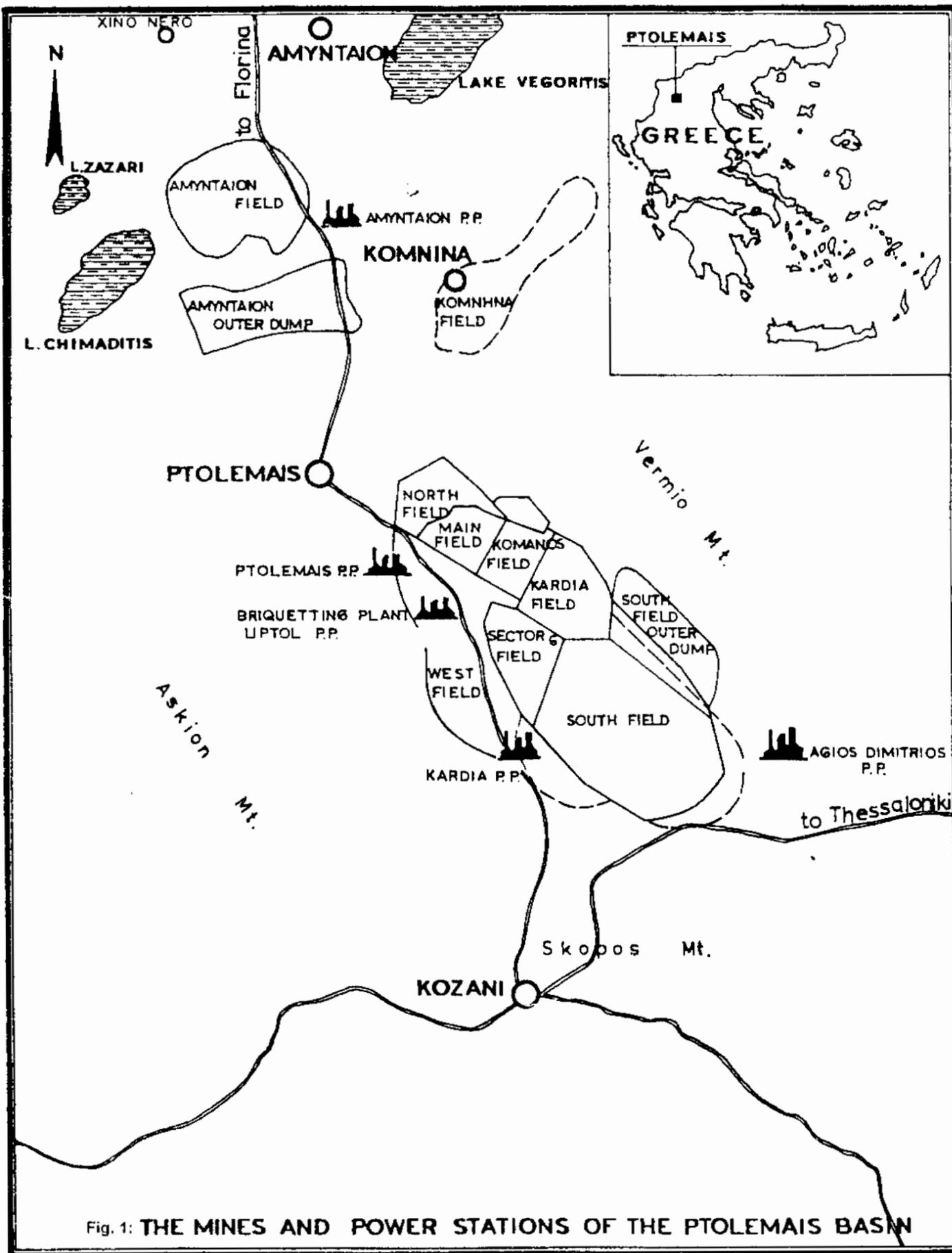
1. aiming at the conservation and protection of the groundwater aquifers of the basin, during the period and after the mining activities, measures need to be taken as soon as possible. These measures will be about:
 - the protection of the zones of natural recharge of the water bearing layers, that is of the area where infiltration and recharge of precipitation to the unsaturated zone and surface outflow takes place.
 - increasing of the groundwater quantities, with artificial recharge
 - the reduction of the consequences to the groundwater flow, because of the interference in the area.
2. the Prefecture of Kozani has to set prohibition measures, concerning the drilling of new irrigation waterwells in South Field basin
3. the permission to drill new waterwells should only be given, for the pumping of the water from the deep karstic water bearing Triassic-Jurassic limestones.
4. proper actions should be taken, to reduce the pumped groundwater for irrigation purposes. In that range, there should be given motives to change the cultivations with others, which acquire less water. The irrigation systems should be improved, to reduce the losses due to evapotranpiration and the water supplying system should be checked, in order to minimize the leaks etc.
5. the water quantities, pumped by the waterwells for the protection of the mine, should be distributed gradually for artificial recharge of the water bearing layers, through existing and especially chosen for this purpose waterwells. The first steps of carrying out such a task, are already in progress. For this purpose, water will be conveyed from chosen drillholes of the PPC, pumped on a constant basis, to the area where the drillholes of the municipality of Kozani have been made. This water will either be used directly for water supplying purposes or will be injected in the ground through drillholes, existing and new, for artificial recharge in an

area with an excessive fall of the hydrostatic level. In the range of the research project ‘‘Elimeia’’, has been programmed the construction of 4-5 new drillholes for artificial recharge.

REFERENCES

1. Commission proposal on water policy, draft 14/2/97.
2. DIMITRAKOPOULOS D: ‘‘ Hydrogeological conditions and groundwater problems of Amynteon lignite mine ‘‘, Doctoral Dissertation, NTUA 1996, 198p
3. DIMITRAKOPOULOS, LOULLOUDIS, KOUMANTAKIS: ‘‘Environmental impacts in relation to groundwater in open pit mines of PPC Greece’’ Proceedings 4th congress Int,mine water Association.
4. DIMITRAKOPOULOS D., LOULLOUDIS G., KOUMANTAKIS J., ‘‘ The impacts of drought on the aquifers of the Plio-Quaternary sediments in Ptolemais basin (North Greece)’’, Proc. 2nd Hydrogeological Congress of the Hellenic Society of Hydrogeology
5. DIMITRAKOPOULOS D., VOIGT R. : ‘‘Postmining water management problems in the Ptolemais-Amyndeon Lignite district, Macedonia, Greece.’’, Geocongress, Grundwasser und Rohstoffgewinnung Freiberg 1996.
6. LOULLOUDIS G. : ‘‘ Hydrogeological Conditions of the South Lignite field, Ptolemais. Confrontation of groundwater problems during exploitation-Doctoral dissertation, Nat. Techn. University of Athens, 1991, pp 1.1-6.45
7. PAPAKONSTANTINOU A.:’’ Die hydrogeologischen Verhältnisse im Raum der Ptolemais-Senke und des westlichen Vermiongerbirges in Griechisch-Mazedonien-Berliner geowss.’’ Abb A13, Berlin 1979, 79 S.
8. PAVLAKIS P.,:’’ Hydrogeologische Untersuchungen im Amyndeon-Braunkohlebecken, N-Griechenland’’, Dissertation, Universität Münster, 1990, 140S
9. POUTIOS G.,:’’ Groundwater management of the larger South Field area. Problems and confrontation.’’, dissertation, Nat.Tech.Univ. of Athens, 1996.
10. RHEINBRAUN ENGINEERING:’’ Dewatering study for the Amyndeon Lignite Opencast Mine, Ptolemais district’’, Cologne, 1988, p.p.1.1-12.2

DEVELOPMENT OF A GROUNDWATER MANAGEMENT SYSTEM AND METHODS OF ARTIFICIAL RECHARGE, IN AREAS WITH OPEN PIT EXPLOITATIONS



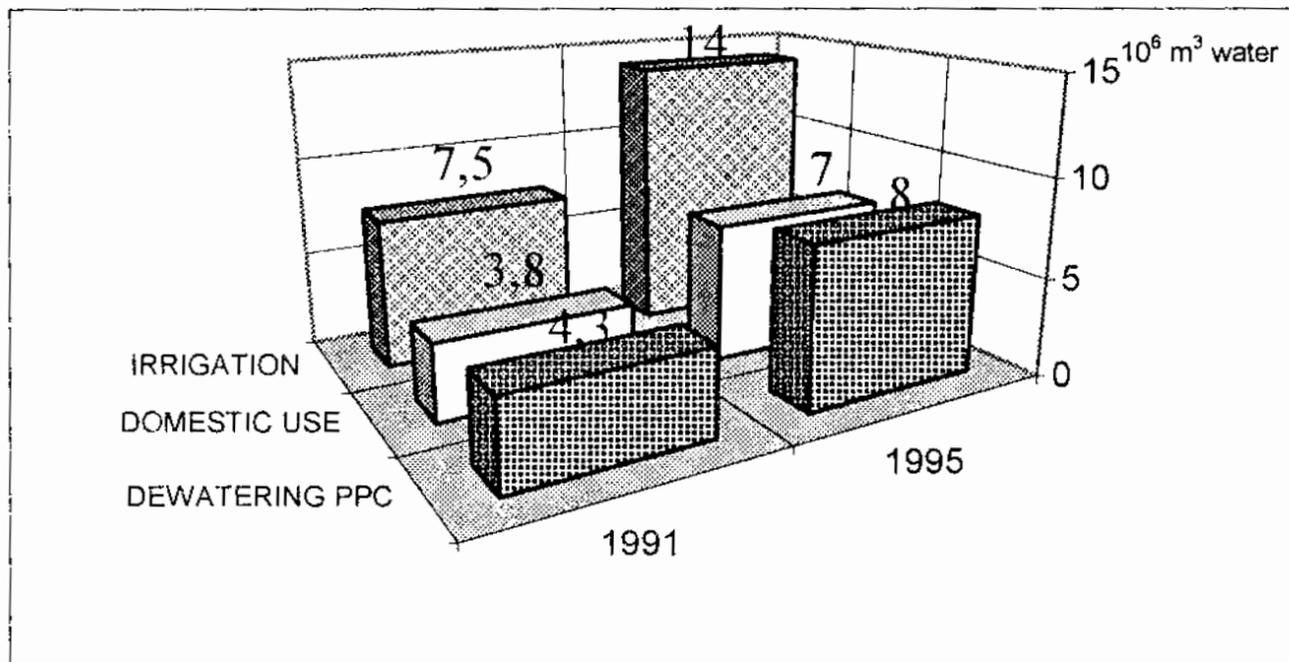


fig2: Comparison of groundwater pumpings, for the years 1991 and 1996

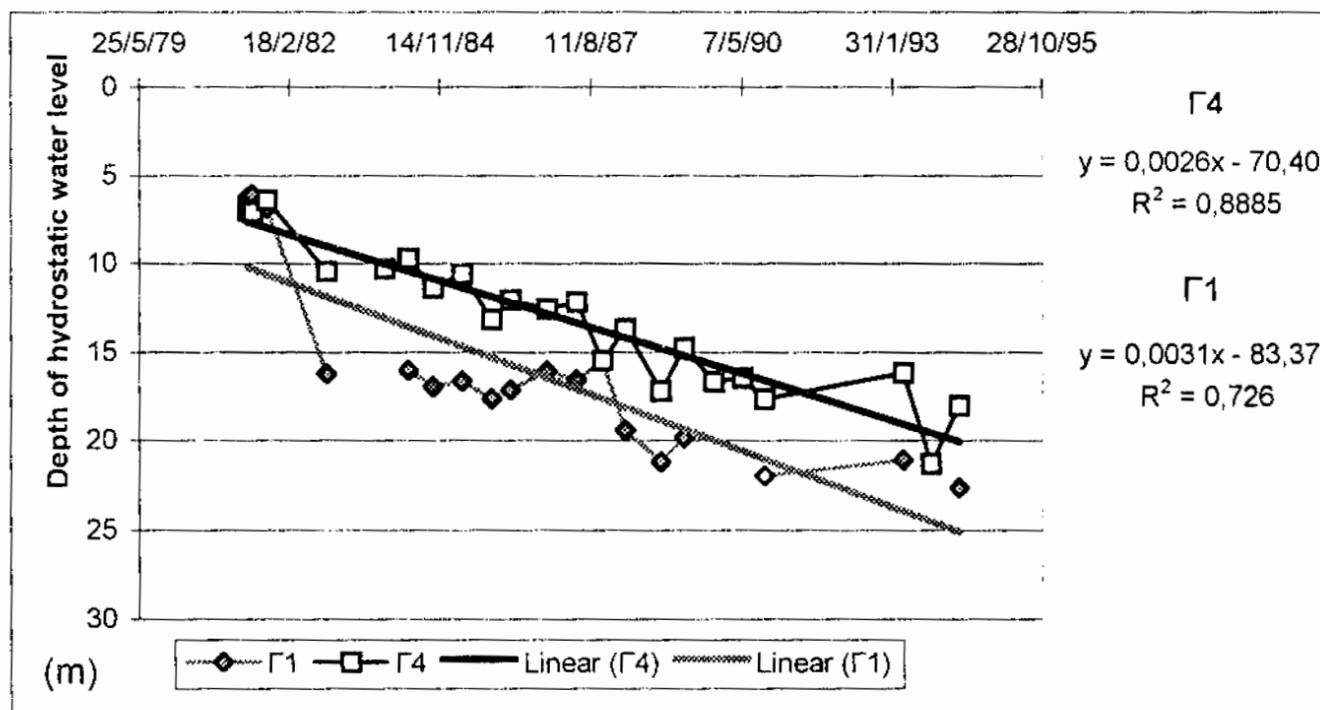


fig3: Hydrographs of waterwells in the South Field Basin and application of linear trend

DEVELOPMENT OF A GROUNDWATER MANAGEMENT SYSTEM AND METHODS OF ARTIFICIAL RECHARGE, IN AREAS WITH OPEN PIT EXPLOITATIONS

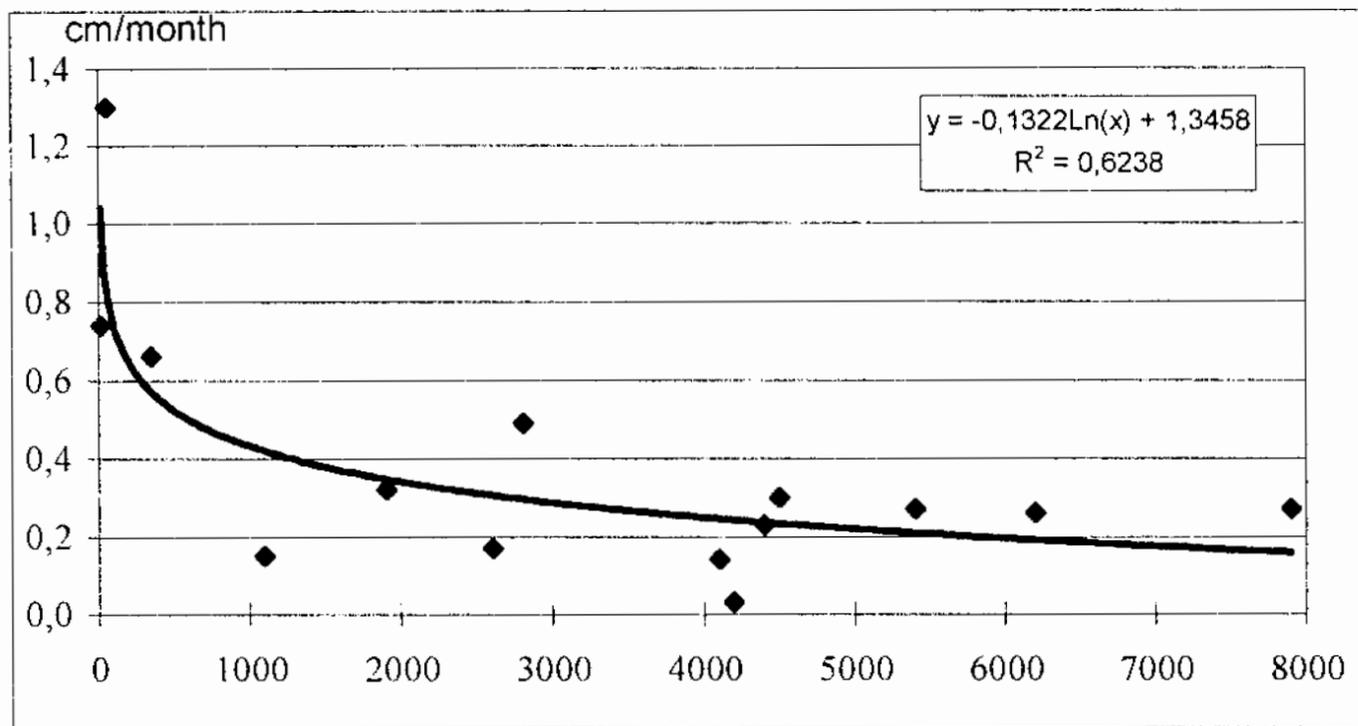


fig4:Relation between drawdown ratio and the mine distance