Environmental Impacts in Relation to the Ground Water in Open Lignite Mines of P.P.C., Greece

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ABSTRACT

The large open pit lignite exploitations of P.P.C. in the lignite basins of Greece and the dewatering measures for the protection of the mines result in an impact on the aquatic environment. This impact causes changes in the state of ground and surface water conditions around the mine.

This paper deals with these impacts in the lignite basins of Ptolemais, Megalopolis and, Drama where P.P.C. has already or plans to develop mining activity.

SOUTH LIGNITE FIELD OF PTOLEMAIS

Hydrogeological conditions

The lignite open pits of Amyndeon, Sector 6 and South Field are located in the great tectonic trench of Monastirion - Florina Ptolemais.

The Southern part of Ptolemais lignite basin is surrounded by the mountains Version, Askion and Skopos, North is limited by the Komanos horst.

The waterbearing horizons are developed into the loose, unconsolidated Tertiary and Quaternary formations lying above the lignite stratification. The aquifer consists of superposed hydraulically connected horizons and appears unique in its whole extend, despite of the intercalations and transitions of the fluvial and limnofluvial deposits.

The piezometrical observations and the hydrogeochemical investigation as well, have proved that there is no connection between the karst water of the mountainous surroundings of the basin and the water of the unconsolidated sediments.

The renewable resources of groundwater into the basin of the unconsolidated sediments are formed by the percolation of the rainfall through the surface Quaternary deposits into the aquifers. The mean annual rainfall is 629 mm. The real evapotranspiration computed by the water balance in the unsaturated zone is 434 mm.

The percolation estimated by the same water balance is 93 mm and as consequence the mean annual renewable resources of the underground water are approximately 20,2 x 10^6 m^3. The mean annual fluctuation of groundwater potential is 1,5 m.

Transmissivity ranges from 10^{-3} to 10^{-2} m^2/sec. The permeability coefficient of the sand and sandy gravel layers ranges from 10^{-6} to 10^{-4} m/sec. The storage coefficient ranges from 10^{-5} to 10^{-2}. The speCific yield of the mainly waterbearing sand - sandy gravel formations rises to 25% according to Lahmayer - Altigos - Schlegel Study (1968). The whole system of the waterbearing sand, clayey sand, and sandy gravel formation in the area of Ptolemais has a mean specific yield 15%.

Environmental impacts

Because of the already existed excavation an underground water inflow occurs into it. The water entering the excavation is contaminated by grease, oils and not dissolved solids coming from mining activities and becomes undrinkable. In contrary, the groundwater of the area nearby the excavation is suitable for drinking. The city of Kozani is supplied with water pumped out from the dewatering wells around the mine.

In the area of the ex Sarigiol swamp, south of the mine, are existing 220 water wells of more than 50 m depth and more than 50 m^3/h discharge. From these wells approximately 3.8x10^6 m^3 per year of drinking water and 7,5x10^6 m^3 of water per year for irrigation are pumped out. There are also 320 shallow wells of 15 - 20 m^3/h discharge rate. In addition to this abstraction 5x10^6 m^3/year must be taken into account, which represents the groundwater drainage of the aquifers into the open pit and the pumped out water for the protection of the mine. As we can see the hydroeconomy of the basin is in the limit of the renewable resources.

For the next decade (1990-2000) is predicted by groundwater modelling[(16)] a worsening of hydroeconomy because the extension of the excavation will cause a need of 3.000 m_3/h dewatering rate. As consequence of this dewatering procedure, extended drawdown in the area of the irrigation wells will appear. That means a decrease of the efficiency of wells. Sometimes even drying of shallow wells will be observed (Figure 3).

The equipotential lines in the Soulou stream region show an underground drainage of the aquifer into it. 82% of the Soulou outflow comes from this underground recharge. The general lowering of the groundwater table will cause an inverse of flow. So the Soulou stream, as it is already polluted, will be source of contamination for the underground water.

In Soulou there is a low concentration of dissolved oxygen, high concentration of sulphate (SO^4) and very high concentrations of ammonia (NH_4) and Mn. So it is not suitable for drinking but it can be used for irrigation. The mean annual run-off of the stream rises up to 12,64x10^6 m^3.

The previously described increase of flow, will cause reduction of the irrigation potential and extreme pollution of Soulou (that probably becomes unsuitable for irrigation too).

SECTOR 6 OF PTOLEMAIS

Hydrogeological conditions

The geology in the area of Sector 6 Field is the same with the previously described for South Field. The aquifer in Sector 6 consists of medium to fine sandy deposits containing a low percentage of clay and overlying the lignite stratification. Overlying this aquifer is a reddish sandy clay with loose conglomerates. The values of hydraulic parameters deduced from the pumping tests are $T=1{,}1x10_{4}$ - $2{,}8x10^{-3}$ m^2/sec and $S=1{,}5x10^{-4}$.

In order to protect the mining activities by enforcing the stability mainly in the west slope 15 dewatering wells have been drilled. From these wells 2700 m^3/day are abstracted additional to 4200 m^3/day abstracted in the west side of South Field, south of Sector 6. The total amount of 6900 m^3/day are rejected to Soulou stream.

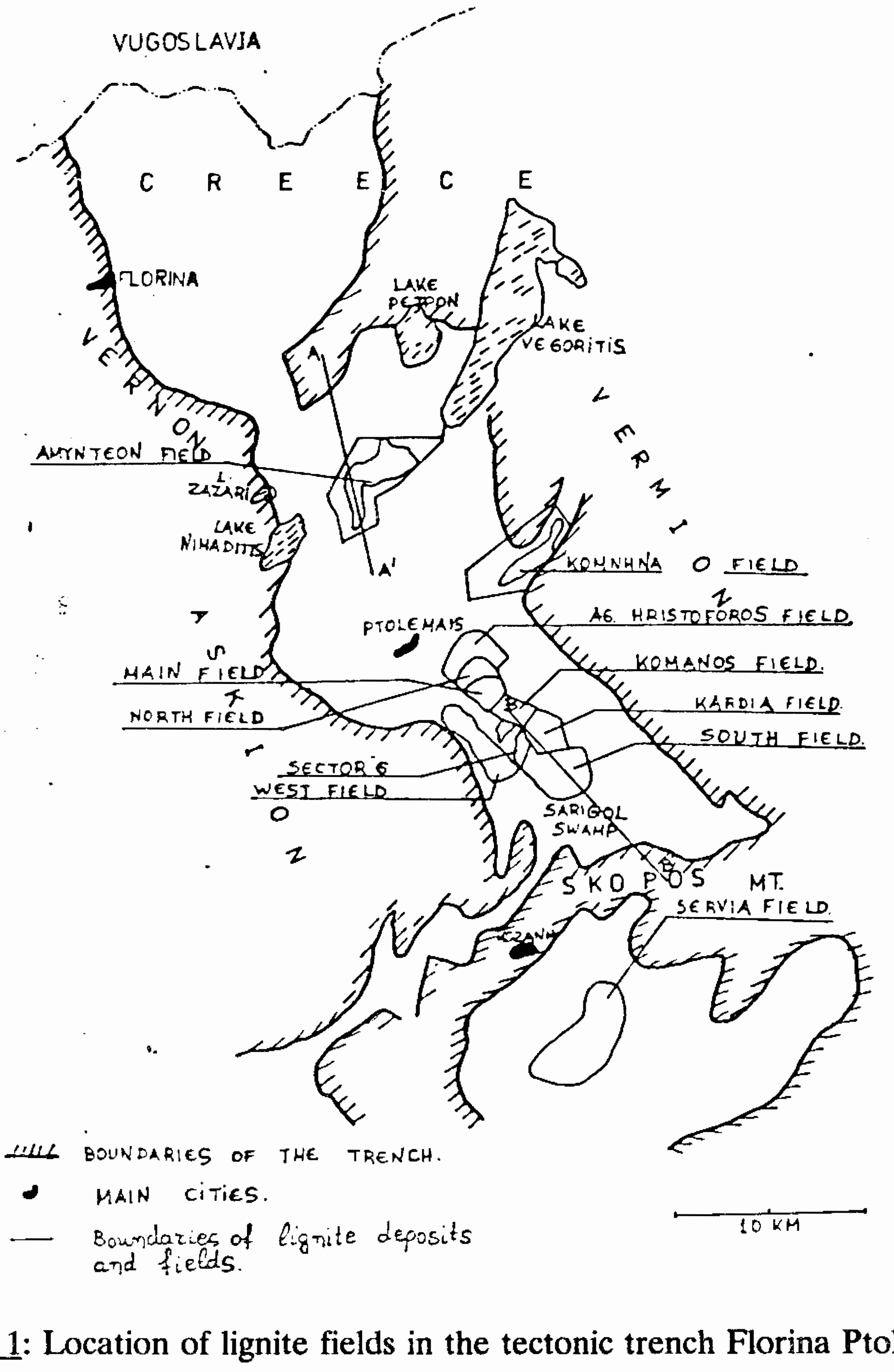

Figure 1: Location of lignite fields in the tectonic trench Florina Ptolemais.

Environmental impacts

The main environmental impacts on the aquatic environment caused by the mining activities in Sector 6 are:

a) Lowering of groundwater head for up to 7 m for the first year.

b) The water pumped out from the sump of the excavation contain fine solids, oils and grease coming from mining activity and washing of trucks, heavy duty machinery, repair houses e.t.c. The rejection of the polluted water to Soulou stream without any chemical or physical processing, cause the further degradation of Vegoritis lake, where Soulou stream runs off.

c) The phenomenon of subsidence in the loose unconsolidated sediments is well known in case that a great reduction of hydrostatic pressure will be caused by the big drawdown of the dewatering process. The phenomenon of subsidence in the rural areas is not of great importance, but its appearance in the traffic net will cause problems. It is referred that the magnitude of subsidence of ground surface may reach 1-8% of the drawdown of the piezometric surface[14]. The whole problem is under investigation.

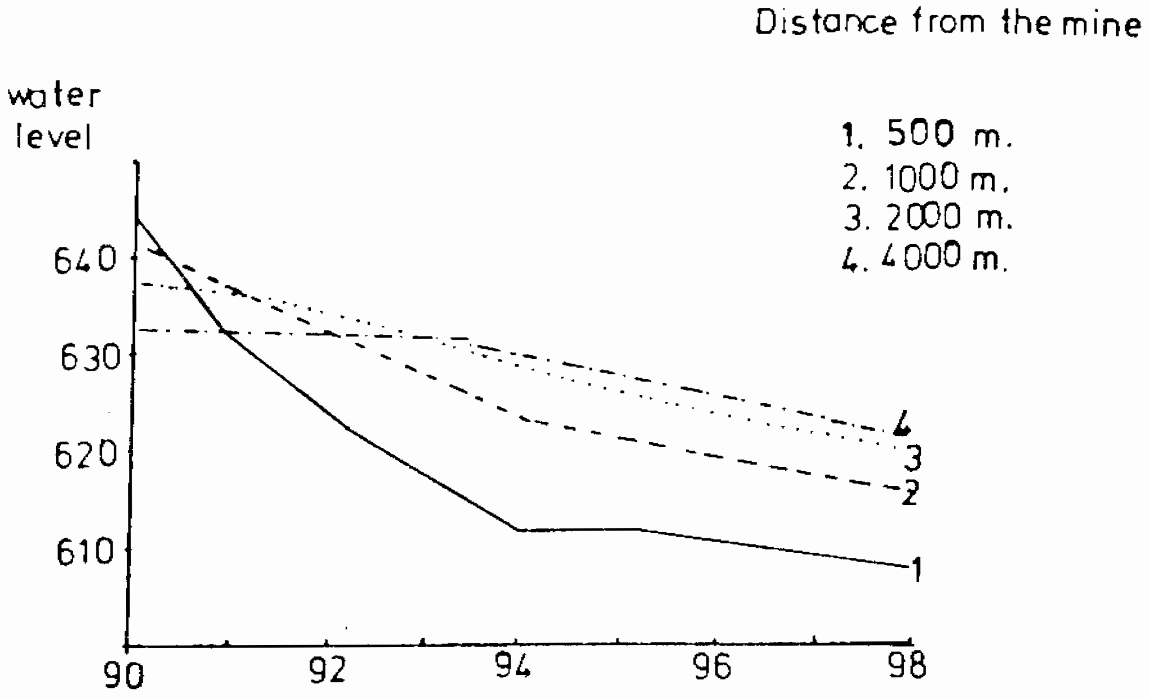

Figure 2: Drawdown south of the mine

AMYNDEON FIELD

Hydrogeological conditions

In Amyndeon lignite field there are many superposed aquifers, separated with marls, clays and lignite. They are in contact sideways, consisting one hydrogeological system.

The sandy-clayey sand waterbearing formations have the following parameters: $T=1.5x10^{-5}$ m^2/sec, $S=10^{-4}$-10^{-2}

The second hydrogeological system is the karstic aquifer which is developing in carstified marbles and limestones of the basement and at the north east boundaries. It has been proved from previous and recent works that this aquifer is connected with lake Vegoritis.

The boundaries of the basin at the west are consisted of impermeable crystalline rocks (gneiss). At the north the mountainous area above the line Xino Nero - Petres is a recharge boundary and consists of marbles and limestones. At the east a main fault running N-S isolates Amyndeon basin from Ptolemais basin.

Amyndeon basin is characterized from the existence of four lakes: Zazari (area 2 km^2, depth 15 m, water level +602 m). Himaditis (area 10 Km^2, depth 5 m, water level +573), lake Petron (area 12,5 km^2, depth 5 m, water level +573) and Vegoritis (area 58 km^2, depth 50 m, water level +513 m abe.).

The piezometric surface shows the existence of an outflow direction along the channel connecting lake Himaditis with lake Petron.

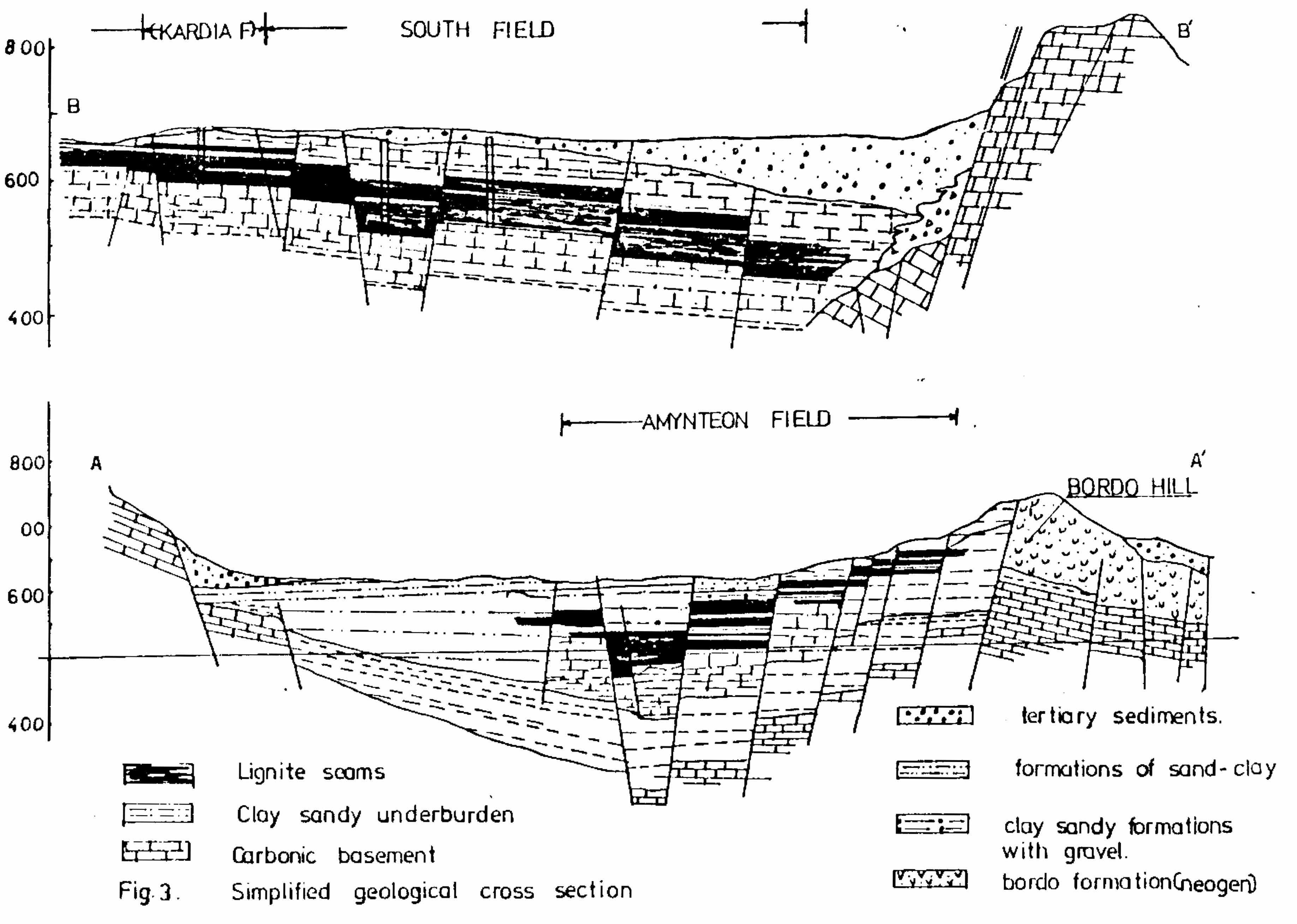

Figure 3: Simplified cross-sections over Amyndeon and Kardia field.

Environmental impacts

According to prefeseability study of R.C.[18] it will be necessary to pump out 4500 m^3/h in order to protect the mine. According to some recent evaluations[5] this amount is decreased to 3000 m^3/h.

As a consequence, the piezometric surface around the mine will be lowered. During the first 4-5 years of the mine life the influence of the pumping will not be extended as the mine floor is at 30-50 m and the piezometric surface is already at 30 m. Later on, the exploitation will be extended reaching the areas of the lower altitude where the groundwater level is near the surface while the mine will reach its maximum extend.

In this stage the dewatering operations will have the following results:

1. The groundwater level will be lowered several meters in a continuously extending area causing the decrease of the capacity or even drying of shallow water wells.

2. The possible drying of Lake Himaditis, for its greater part has a depth of only 1-1,5 m and its bottom is not absolutely impermeable.

Some major impact are expected in Lake Vegoritis. According to a study of P.P.C.[3] there is a deficit $28x10^6$ m^3 annually in the water balance of Vegoritis, which results in a 0,6 m drawdown. If the pumped out water for the mine protection will cover the needs of the Amyndeon power station in the already disturbed water balance will cause a greater deficit.

MEGALOPOLIS

Hydrogeological conditions

There are 4 lignite fields in Megalopolis basin. The more significant impacts are expected from the dewatering measures for the protection of Kyparissia field.

The underburden and the lignite seams are considered impervious or semipervious. The overburden consist of some gravel and sandy clays and the underburden of grey to green plastic clays of Miocene.

The most significant aquifer is developing in the carstified limestones which form the basement in the mine area. Its piezometric surface reaches the surface of the ground as it is pressurized in this area under the Miocene sediments. The area of the karstic aquifer is $170km^2$ and 100 Km^2 of them are covered by recent sediments. The coefficient of permeability of the karstic aquifer is $1x10^{-4}$ m/sec. The limestone appears on the surface in Alfios bed in three places near the mine, while the NW, N, and E part of the pit is covered only by up to 15 m of sediments (Figure 4). At the southern part of the pit there are 70 m of sediments between the karstic aquifer and the bottom of the mine.

There is also a Tertiary gravely sand aquifer along Alfios river, of thickness up to 6 m.

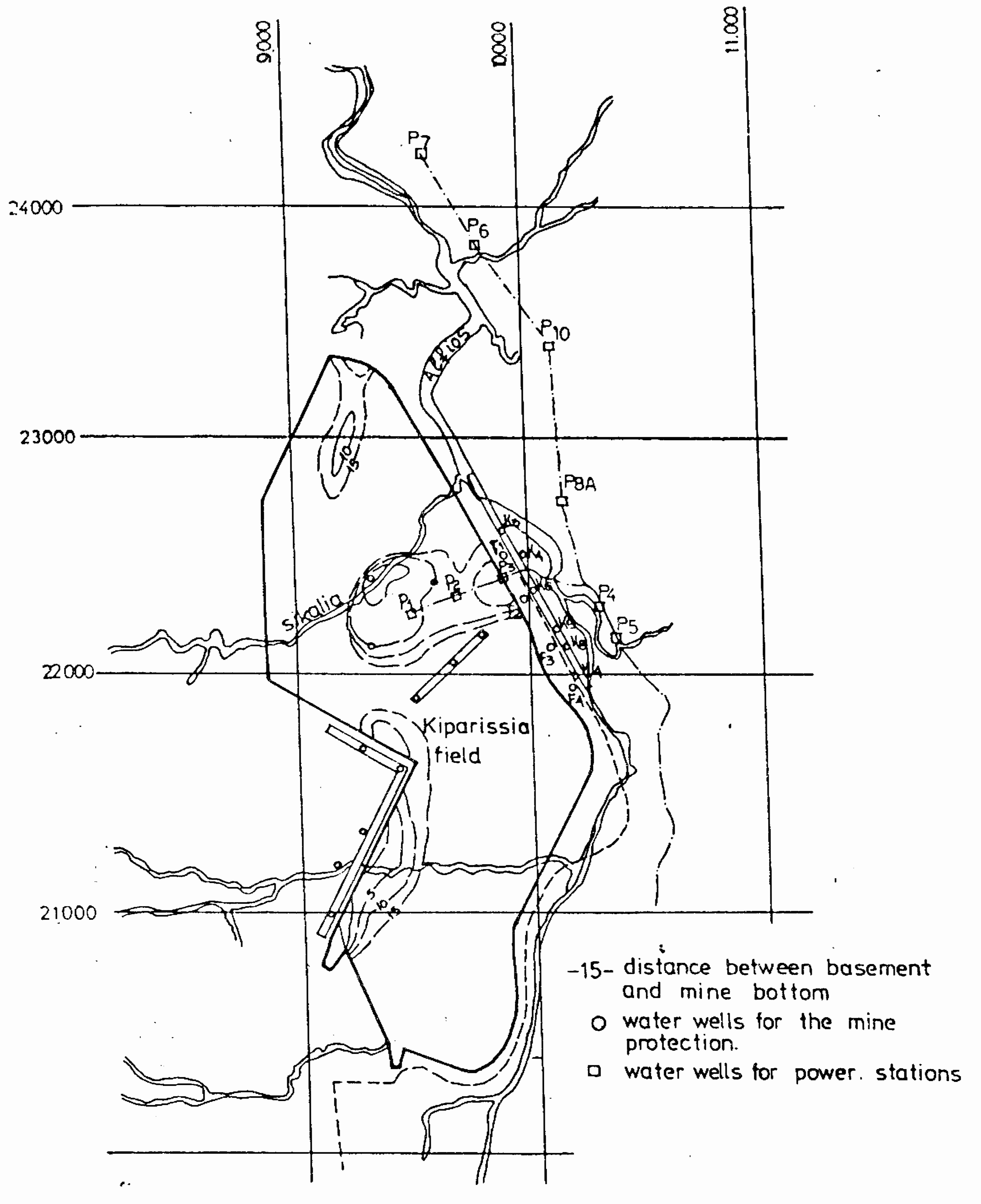

Figure 4: Kiparissia lignite field. Map showing the locations of water wells and isopaches of the sediments between basement and mine bottom.

Environmental impacts

The dewatering of the overburden needs the pumping of only a few m^3/min as it is isolated from Alfios after the construction of a dump for the protection of the mine from the river. On the other hand Alfios has been relocated in a new bed which is planned to be sealed.

According to the mining planning, the mine bottom will reach at +270 m abe. while the piezometric surface of the karstic aquifer is at +330 m a.s.l. Consequently it has to be lowered almost 70 m, 10 m below mine bottom. For this reason it will be necessary to pump out 15x106 m^3 of water from the permanent reserves and 30-35x10^6 m^3 from the renewable reserves annually at maximum.

For the protection of the mine it has been planned the construction of 22 water wells with maximum pumping capacity 9.200 m^3/h. The most significant impacts are expected after 8-15 years of pumping.

North of the mine there are some important karstic springs which yields 2x10^6 m^3. The outflow of the springs will decrease and some of them will become dry. The groundwater flow will be inverted and will be directed towards the area of dewatering works.

A great scale interference on the environment is the relocation and sealing of Alfios river bed.The pollution of Alfios with ash, lignite dust and polluted water from the mines is an already existing problem.

DRAMA LIGNITE FIELD

Hydrogeological conditions

Drama basin is part of a tectonic trench, directed NW-SE. The basin is surrounded by mountains consisting of metamorphic rocks, mainly marbles. These marbles form also the basement of the basin. On the basement are developed sediments consisting of clays, silts sands, sandstones and marls. Above them we observe tertiary sediments (clay, clayey sand, fine sand) and between them the lignite seams and peat.

The most significant aquifer systems are:

1. In the overburden and between the main lignite seams there is one phreatic aquifer and more superposed hydraulically connected horizons under pressure. The values of hydraulic parameters deduced from pumping test in the sediments are:
   $$T=1,4 - 3,3x10^{-3}\ m^2/\ sec$$
   $$S=10^{-2} - 8,5x10^{-4}$$
2. The karstic aquifer which is developed at the surrounding the basin mountainous area and the basement.

Environmental impacts

It has been estimated that for the protection of the mine 3.600 m^3/h have to be pumped out. As the hydrogeologic investigation and the mine planning have not completed yet, it is not possible to determine precisely the environmental impacts.

From the first elements it can be deduced that:

1. The artificial trench of Philippi will not be any more the final receiving body of the shallow groundwater, as an inverse of the flow towards the mine area is predicted.

2. The relocation of Doxato and Philippi trench will be necessary for a length of 5-10 km.

3. The drawdown of the groundwater in the area around the mine will cause the total drying of the numerous shallow (6-10 m) irrigation wells.

4. In Drama basin there are areas that are not irrigated, because the groundwater level reaches at the ground surface and plants can absorb the necessary quantity of water. It is certain that change in the aquatic environment will affect the previously described process and the construction of water wells and irrigation network will be necessary.

5. The degradation of ground and surface water quality is one of the expected impacts.

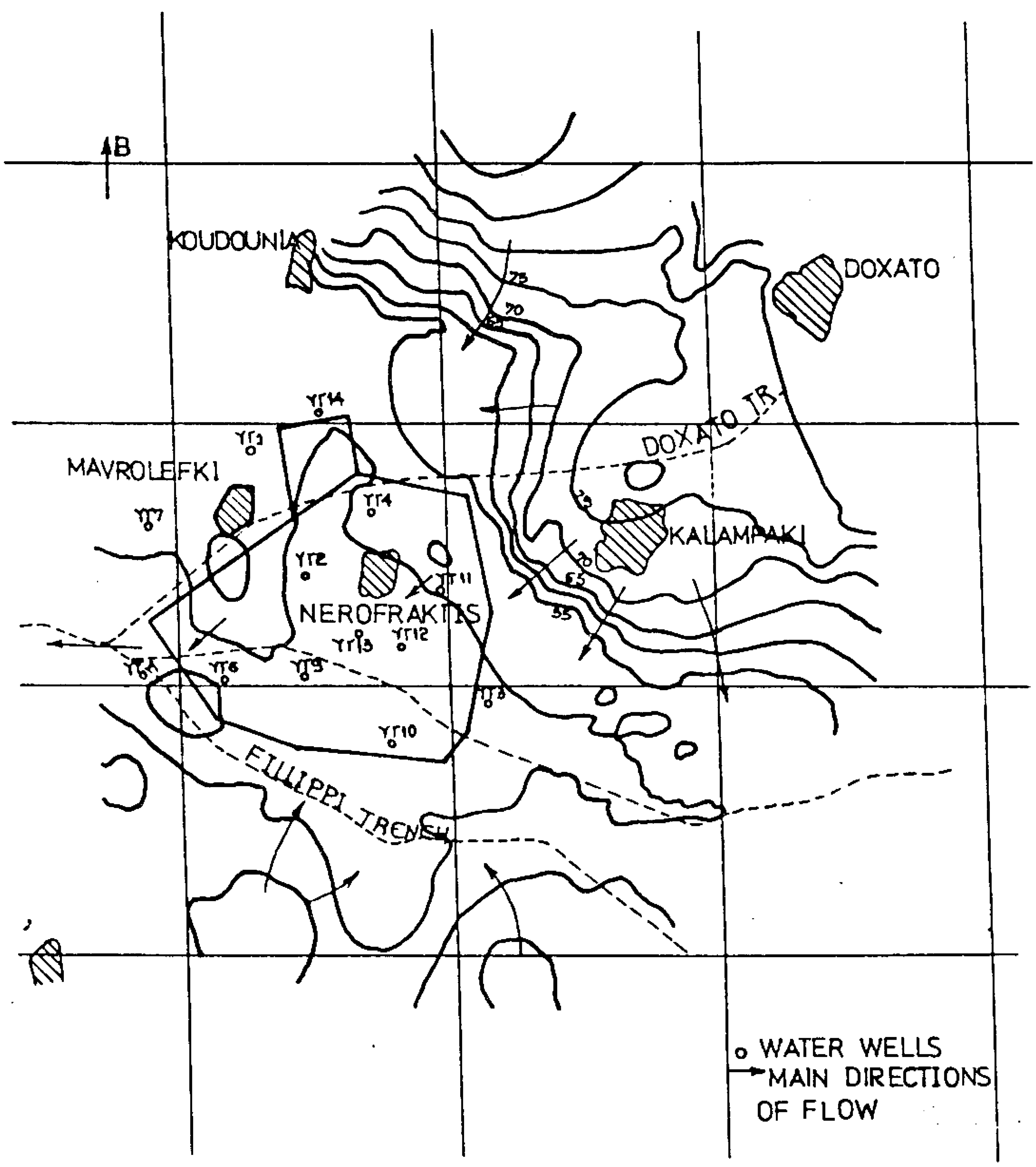

Figure 5: Drama lignite field. Piezometric surface of the upper aquifer.

CONCLUSIONS - PROPOSALS

The mining activities of P.P.C. in the lignite bearing areas in Greece, in combination with the measures taken for the protection of the mines against groundwater, cause major changes in the hydrologic budget and in the hydrogeological conditions in an broader area.

The most important impacts on the aquatic environment are in relation with the big drawdown around the mines caused by the continuous pumping through dewatering wells for the protection of the lignite exploitation.

The main phenomena observed or predicted by groundwater modelling following the evolution of mining are:

a) Decrease of the efficiency of wells. This impact is observed in all lignite mines. The water production from the dewatering measures can cover this need.
The rational management of groundwater resources will play a serious role in confrontation of this problem.

b) More intensive leakage from the rivers, streams and lakes which result, in case of small streams and shallow lakes, in even total drying. This impact is expected in the lakes of Vegoritis and Chimaditis after the completion of dewatering procedure in the mines of Amyndeon and Komnina. A net of automatic recording the fluctuation of the groundwater level is proposed so the phenomenon will be observed in time in order to take the proper measures.
The reverse phenomenon, decrease of aquifers recharge due to the rivers bed sealing, will also take place. E.g. Sealing of Alfios bed for the protection of Kyparissia mine.

c) Subsidence in unconsolidated sediments because of the increased consolidation that follows the extended drawdown combined with the load from the external dumps.
Sector 6 and Amyndeon are two lignite fields in which this phenomenon may be observed even in the main road Kozani - Florina which is not far from the mine. The continuous recording of the process of this phenomena is recommended.

d) Decrease of soil moisture in the area of the cone of depression in the areas where shallow phreatic aquifers are existing. This phenomenon will be observed in Drama and Amyndteon lignite fields.
P.P.C. plans to confront this phenomenon allotting water coming from the water wells for irrigation.

Other problems correlated with the water quality are:

e) Pollution of underground water caused by the infiltration of polluted mine waters. Degradation of the Quality of surface waters due to the rejection of polluted mine waters into them.
The water management policy that P.P.C. has, minimizes this effect. The most of the water is pumped out before entering the excavation and be polluted. This water is distributed in order to cover the needs for drinking water of villages or cities in the mine area, for irrigation or for industrial use.

f) The degradation of the water quality caused by the leaching of chemical elements from the dumps by the rain water. This kind of pollution has not been studied yet.

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