# MINE DEWATERING DESIGN IN SURFACE MINING TO IMPROVE THE QUALITY OF GROUND WATER

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## ABSTRACT

The paper describes the studies carried out in order to make compatible the under mine water drainage of an artesian aquifer, with the ground water pumpings for township supply and irrigations, specially taking into account the neccesity to reduce the advance of the chemical contamination plume provoked by the evaporite sediments solution.

## INTRODUCTION

The extraction of ground water and the mining of mineral deposits, may both: a) disturb the hydraulic balance of the existing aquifers and b) cause deep changes in its hydraulic conditions. Furthermore, where the inter-bedded sediments contain high soluble evaporit rocks, the induced leakage, due to water extraction, may provoke large changes in the quality of ground water.

This paper describes the studies and planning of an open-pit mine de-watering operation, which design was aimed to minimize the effect of the leakage between an unconfined heterogenous aquitard-aquifer system and a semi-confined unconsolidated sands aquifer, in order to reduce the contamination of the ground water, employed for the town water supply and for the irrigation.

## SITE LOCATION

This palygorskyte clay mine, which activity started in 1980, is situated in the vicinity of Los Tollos lagoon, about two kilometers East of the township of El Cuervo (figure 1), in the South-West of Spain.

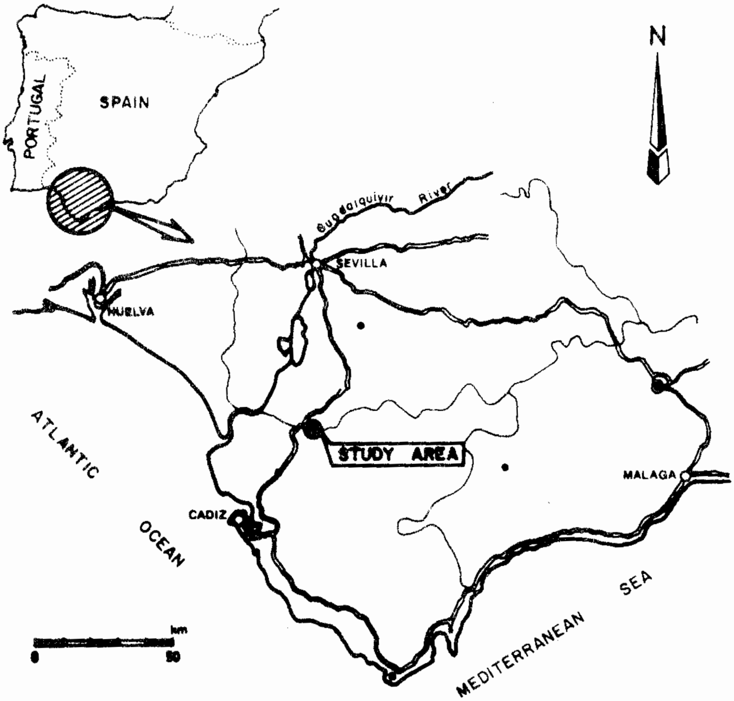



*Figure 1. Location map.*

## GEOLOGICAL ENVIRONMENT

### 1. STRATIGRAPHY

The area, located on the Western part of the Betic range, comprises two major structural units: a pre-orogenic sediments and another post-orogenic deposits of detritic origin, corresponding to the Guadalquivir Basin (figure 2).

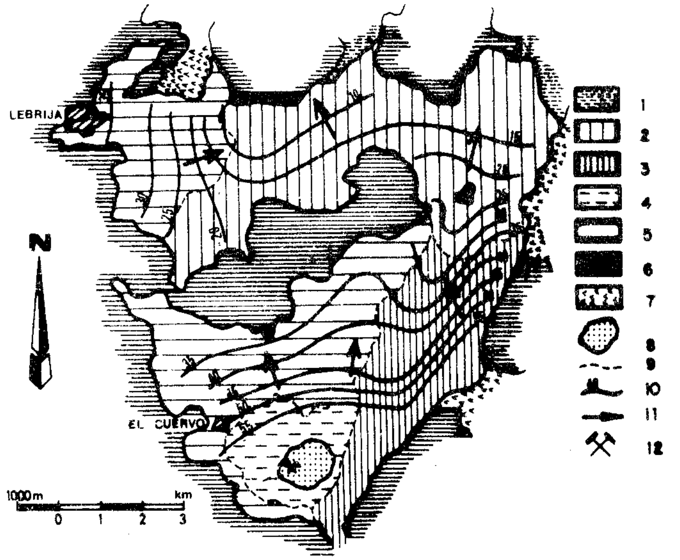
a) Pre-orogenic deposits include the following formations:

Triassic: clay, marl and gypsum beds with the inclusion of some lenses of limestone and sandstone.

Jurassic: limestone formation, with very poor representation in the mining area.

Cretaceous: predominantely inter-bedded marl together with limestone, with over 300 m of total thickness.

Paleocene: detritic sediments together with some calcareous beds.




1. Recent Quaternary
2. Middle Quaternary
3. Old Quaternary
4. Lacustrine Pliocene
5. Marine Pliocene
6. Miocene
7. Triassic
8. Los Tollos Lagoon
9. Geological contact
10. Piezometric isoline
11. Flow direction
12. Los Tollos Mine

*Figure 2. Geological map with natural water table (1965).*

b) Post-orogenic deposits included the following formations:

Upper Miocene to Pliocene: clay or marl.

Pliocene: fosilliferous sand with more than 20 m in thickness forming a semi-confined aquifer, below the mine, and a free aquifer surrounding the area of lagoon sediments.

Partialy overlying these sands, there are lagoon deposits, consisting of limestone, marly clay and clay with frequent changes in vertical and horizontal directions. The mineral deposit (palygorskyte clay) is included in this lagoon formation and change laterally to sand lenses, in the East direction (these sands constitute a part of the upper aquitard-aquifer). The total thickness of this lagoon sediments is approximately 50 m.

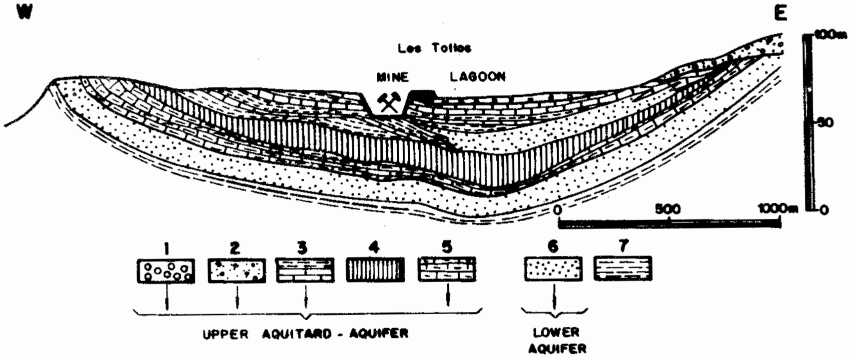
Quaternary: consists of a variety of sediments which include conglomerates, gravels, slimy muds and clays.

2. TECTONIC

The pre-orogenic deposits were affected by gravitational landslide upto middle Miocene. The face of this landslide is consists of marls and clays of Triassic age. The oldest post-orogenic sediments were deposited on a shallow marine basin. After the sea recession, a shallow lagoon was formed, which sediments appears more or less sub-horizontal. Finally, during the Pliocene and Quaternary periods, new sediments, mainly consisting in erosion products, were deposited as alluvial fanglomerates.

## HYDROGEOLOGICAL REGIME

In this area there are two hydrogeological units: the lowest is located in the sands of the base of the Pliocene, and the upper relates to the inter-bedded Pliocene sands and with the Quaternary fanglomerates (figure 3).




1. *Soil (Quaternary)*
2. *Glacis*
3. *Palygorskyte clay and limestone*
4. *Palygorskyte marl*
5. *Marly limestone*
6. *Quarzitic sand (Marine Pliocene)*
7. *Clay and marl (Upper Miocene)*

*Figure 3. Geological cross section.*

1. DESCRIPTION OF THE HYDROGEOLOGICAL UNITS

Lower Aquifer

It is constituted by the lower Pliocene sands, which overlay impervious clay and marl sediments from the Upper Miocene to Pliocene. In the central area, underlaying partially by the lagoon sediments of medium to low permeability (aquitard), its comportment is as semi-confined aquifer, and in the surrounding area as unconfined aquifer. The average permeability is 40 m/d, and the middle transmissivity is 860 $m^2$/d. These sands cover an area of 75 $km^2$. The pumping wells located in this aquifer have yields between 20 to 100 l/sec. The recharge of this aquifer is provided by rain water, infiltrated directly through surface outcrops during the rainy season (November to April), and nowadays also by the leakage of superficial water, accumulated temporarily in the lagoon.

The overlying lagoon sediments have a vertical fissure permeability. When the potentiometric surface of the aquifer is drawdown, a flow through vertical fissure and a leakage through the aquitard is established and a water seepage appears at the top of the Pliocene sands.

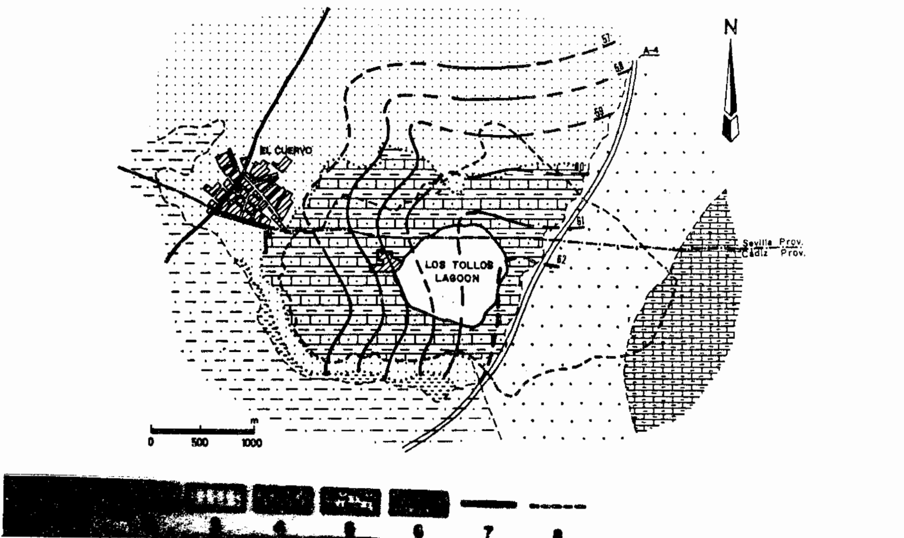
Upper Aquitard-Aquifer

It is developed in the interbedded Pliocene sands, located at the East, and in the Quaternary fanglomerates, which are very irregular in continuity and in permeability.

The lower and upper hydrogeological units merge together in the Eastern part of the area, and it can be considered that they form a single aquifer.

## 2. PIEZOMETRIC SURFACE

The original water table pattern of the lower aquifer was a dip from South to North direction (figure 2). After 1965, as a consequence of some pumpings, in the wells bored at the South-West lagoon area (for the water supply to the township of El Cuervo), was produced the drawdown of the piezometric surface in that area, producing a ground water flow pattern, into the confined aquifer, from East to West (figure 4). The low hydraulic gradient (1 in 400 to 1 in 300) is a consequence of the high permeability of the sand aquifer.




1. Glacis
2. Lacustrine sediments
3. Sand
4. Marly clay
5. Marl
6. Tertiary and Cretaceous sediments
7. Piezometric isoline
8. Limits of Los Tollos hydrographic basin

Figure 4. Piezometric map (February, 1982).

## 3. CHEMISTRY OF THE HYDROGEOLOGICAL UNITS

As a part of the investigation, more than 100 samples of ground water, from the wells located in the area, were taken and analysed in three data groups (February and May 1982, and November 1984), in order to obtain information about water quality and aquifer characteristics.

The water in the central part of both hydrogeological systems are predominantly sodium chloride, as consequence of the lixiviation of evaporite sediments from the lagoon (figures 5 and 6) . In the surroundings of the confined area, the water of the lower aquifer is predominantly calcium bicarbonate with low salt contents.

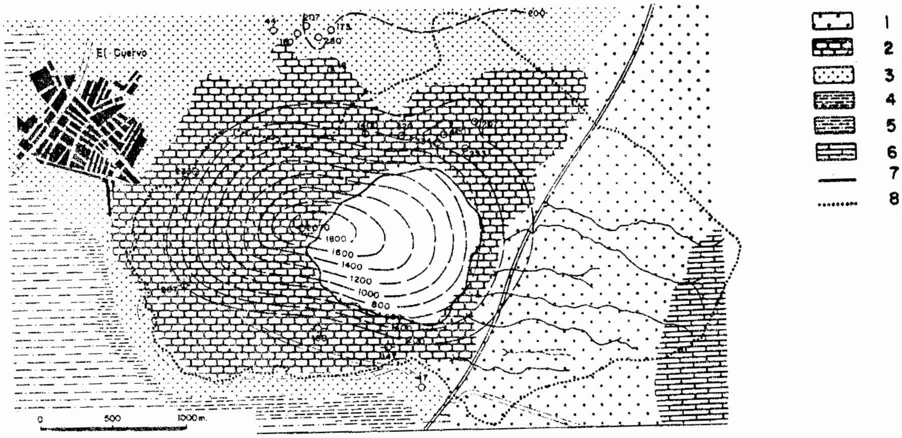



*Figure 5. Sodium distribution in the Lower Aquifer (November, 1984).*

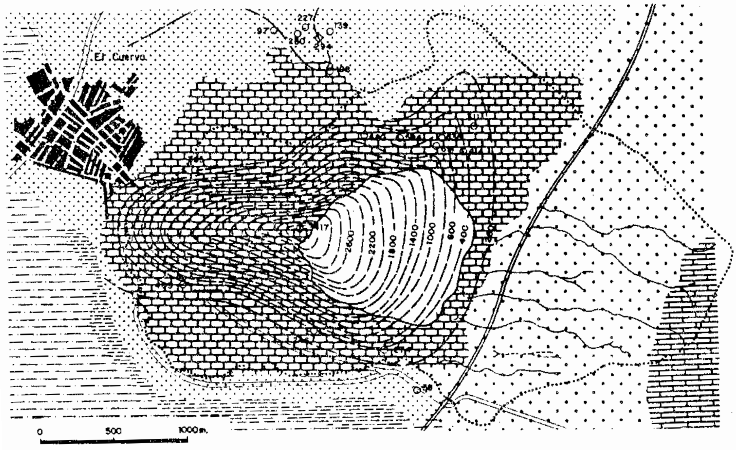



*Figure 6. Chloride distribution in the Lower Aquifer (November, 1984).*

1. Glacis
2. Lacustrine sediments
3. Sand
4. Marly clay
5. Marl
6. Tertiary and Cretaceous sediments
7. Ionic isocontent line
8. Limits of Los Tollos hydrographic basin

Complementary to this spatial sampling, a monthly sampling was taken in three wells, surrounding the mine.

In general, salt content was observed increasing during the dry period, related to percolation through the lagoon sediments, and a decreasing of salt contents during the humid period, due to the rain water recharge.

## STATEMENT OF THE MINE GROUND WATER PROBLEM

The main problem associated with this open-pit mine, of a clay deposit over an artesian aquifer, is the danger of floor heave at the botton of the mine opening, originated by the hydrostatic pressure of the confined aquifer. Also, in this mine, the water seepage through the marly-clay floor, creates additional problems of loss in traction of heavy vehicles on the slippery floor.

In addition, in this case, one of the main requirements of the design of mine dewatering system was to improve, or at least to maintain the present quality of ground water. As this water is employed for irrigation and town supply it is esential to continue producing enough quantities of water.

In summary, the principal design requirements were: a) to prevent migration of water pollution plume from the central area, below the lagoon sediments, to the water supply and irrigation wells, and b) to lower the piezometric surface below the mine area by placing advance dewatering wells at appropriate positions, with the lowest hydraulic balance.

## RESEARCH APPROACH

The investigation was carried out in different phases as follows.

### 1. INVESTIGATION OF HYDRAULIC PROFILE

The first part of the investigation approach, was to establish an interrelationship and flow profile, between the hydrogeological units within the mine boundary.

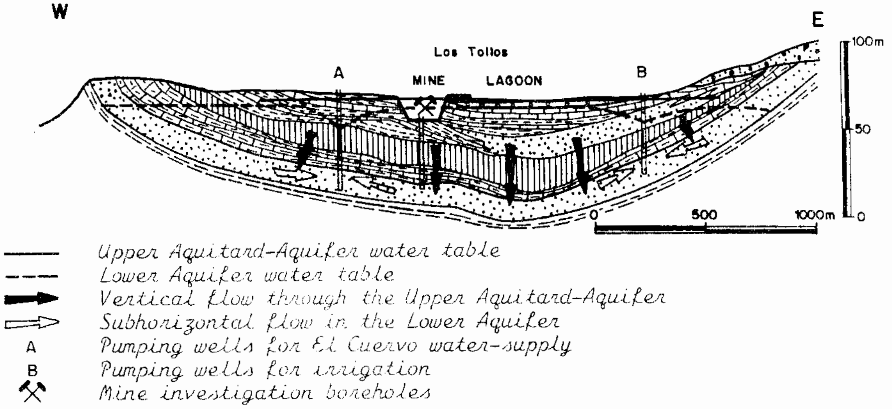



*Figure 7. Summer simplified hydraulic profile.*

The hydraulic profile of the mining area, at the end of the Summer season (dry period), is the result of intensive pumping operations, both for town water supply and for irrigation during Spring and Summer periods (figure 7). At this moment, the main features are related to the piezometric surface slightly above the pit-bottom. The lagoon and the spring are dry, and a leakage effect, from the upper to the lower hydrogeological units, through the lagoon sediments, dissolving the interbedded evaporite sediments, increased the salt concentrations in the lower aquifer.

The hydraulic profile of the mining area during Winter season is characterized by the following main features (figure 8):

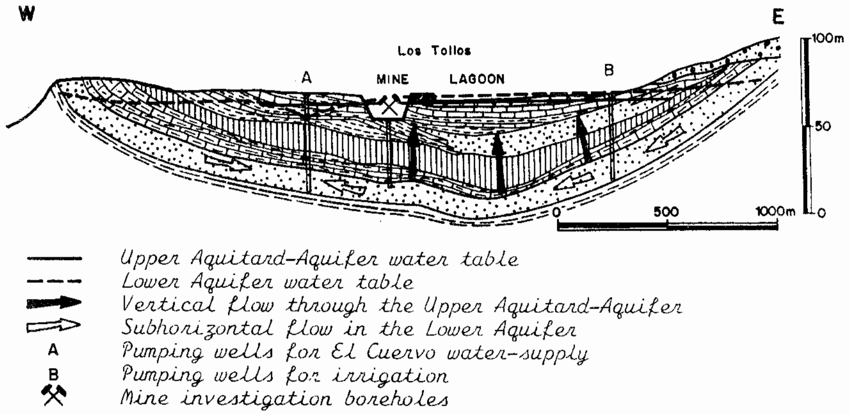



*Figure 8. Winter simplified hydraulic profile.*

The potentiometric surfaces of both hydrogeological units are much higher that during the dry season, and the corresponding ones to the lower aquifer are coincident or slighly higher.

The hydraulic pressure of the confined aquifer is increased due to prolonged recharge by rainfalls and consequently, there is vertical ascensional leakage from the lower aquifer through the lagoon sediments.

During this period, water entry has been produced into the open-pit bottom, because of vertical flow in the pre-existing and induced mining fissures or cracks, and because of the leakage effect.

## 2. ESTABLISHMENT OF WATER FLOW PATTERN

Using Darc'y Law, the estimated flow of water, in the lower aquifer, from South to North, in natural condition (prior to 1965) has been estimated in 7-10 m/day (figure 2). Now, due to water supply pumping, in the South area, the piezometric level has lowered and a hydraulic embalance has been created. Nowadays the flow of water pollution plume from the lagoon to the South wells is estimated as 20-50 m/year (figure 4).

During the period of the investigation, without drainage below the mine area, the drawdown of the piezometric surface was between 0.5 - 1.5 m. This can be attributed to the increasing rate of pumping, especially during the dry season.

Together with this drawdown, an increase in salinity has been observed, especially in the North area, because of pumpings for irrigation, and by the consequent migration of saline infiltrated water below the lagoon sediments.

## DESIGN OF MINE DEWATERING SYSTEM

### 1. DATA ACQUISITION

The design of mine dewatering system, was based on the piezometric and hydrochemical data acquisition, followed by a computer simulation analysis.

#### Piezometric study

The record of the water table, in the lower aquifer, was obtained in seven boreholes in regular intervales of one week (figure 9). With the piezometric studies a record of rainfall was also maintained in order to establish the relationship between rainfall and recharge of the lower aquifer.

This control indicates that there is a progressive drawdown of the water table as a result of water extraction for agriculture and domestic water. The rate of water extraction is higher than the recharge of the aquifer, with a reduction of the water reserves.

#### Hydrochemical monitoring

Water samplings were carried out at three wells in regular monthly intervals in order to establish salt concentrations and flow profiles. This control indicated that there is a migration of saline water from the central part of the lower aquifer to the pumping wells, especially in a North direction.

#### Water conductivity and temperature in monitoring wells

The conductivity and water temperature records were obtained in the three observation wells. The results show that the salinity is the consequence of flow through the lagoon sediments, with a maximum immediately below the lagoon, during the dry period.

### 2 COMPUTER STUDIES AND PROPOSED SOLUTION

On the basis of the above studies, a computer simulation study was carried out, in order to select the best locations for advanced dewatering pumping wells, with the following objectives in mind:

To lower the piezometric surface below the mining area.

To divert the plume of saline water towards the advance mine dewatering wells.

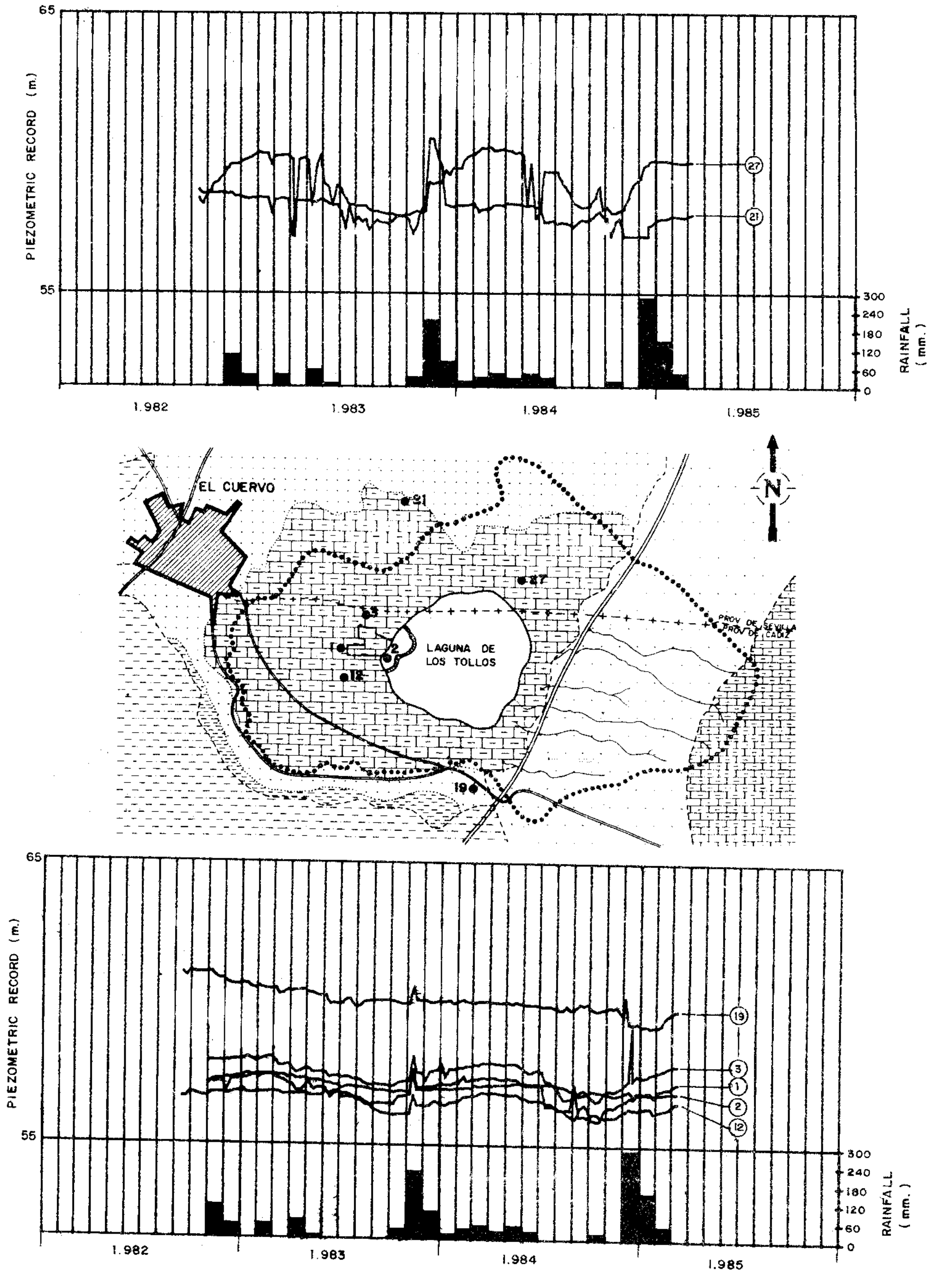



*Figure 9. Piezometric level evolutions corresponding to the Lower Aquifer.*

To minimise the lowering of the piezometric surface near the water supply wells.

The simulation studies were carried out on a desk top Apple IIe microcomputer. This was in order to analyse the drawndown effects of pumpings, in the advanced mine dewatering wells in several profiles and, consequently, to estimate the directional variation of the salinity. Several trial runs on the computer programms were carried out in order to calibrate the model. This simulation enabled the authors to establish that the best location of the advanced dewatering wells is Nort-Eastern part of the lagoon. It was also recommended a detailed monitoring programm to follow the performance of advance dewatering wells. This will allow observation of changes in water table and in salinity.

## CONCLUSION

The mine dewatering problems is often related with a multi-disciplinary scope, and the interests of various concerned parties are always diverse. For example, in our case, the interest of the mine operators is to reduce the hydrostatic pressure in the floor of the mine, at a minimum cost, while local inhabitants look to obtain enough water for urban consumption and irrigation, and to minimize water quality degradation. However, if a multi-disciplinary approach is adopted, a satisfactory solution can be found to the benefit of all the parties.

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