

VULNARABILITY STUDY OF AN OVEREXPLOITED AQUIFER TO THE SALINE CONTAMINATION FROM A SEBKAT BY MATHEMATICAL MODEL : SEDJOURI'S AQUIFER'S CASE IN TUNISIA.

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The Sedjouri basin is an internal drainage aquifer system multilayered and spreading over 200 km² in the close neighbourhoods of Tunis - Fig.1.

The major outlet of the groundwater flow is a sebkhat from where the water vaporizes and where the salt content reaches more than 100 g/l (1).

Fig. 2 shows the general functioning of this system.

A 3 layers mathematical model⁺ allows us to calibrate the system functioning on the 1971 water surface piezometry. Fig. 3 (2).

This model shows that in a steady state, the aquifer system, at present, manages an outflow of 250 l/s. Fig. 4.

Inflow		Outflow	
Infiltration	209 l/s	by pumping	113,5 l/s
Inflow from		by "Valley of Tunis"	26,5 l/s
recharge boundaries	42 l/s	by sebkhat	111 l/s
	251 l/s		251 l/s

The Sedjouri basin eliminates by vaporization a flow of the same rate as the exploitation of the aquifer system by pumping.

The vertical exchanges between the phreatic aquifer and the 2 deep aquiferes appear however slightly developed in that foregoing state of the system.

Yet we can notice that in unsteady state, in the case of overexploitation of the system in the first deep aquifer an increase of vertical exchanges occurs by leakage. This is how by 20 years and for the 2 extreme vertical transmissivity values : 0,5 and 2,5. 10⁻⁴ m²/s by km² of exchange surface, the obtained results appear respectively as follow. Fig. 5 and 6.

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At the scale of the whole aquifer system and in relation to the steady state studied before-hand, the supplementary pumping of 76,5 l/s upon the first deep aquifer is only partially compensated (63 to 58 %) by :

- the increase of the recharge boundary inflow
- the outflow decrease by the "valley of Tunis"
- the evaporation loss decrease in the sebkhat.

The rest (37 to 42 %) is in fact taken off the storage.

It unbalances the system balance and provokes a piezometric effect, increasing the leakage between the 3 system layers.

The importance of downward or upward flow depends on the vertical transmissivity of the semipervious layers : The benefit for the first deep overexploited aquifer increases from 37 to 58 l/s in our case.

Due to these exchanges and to the possible inversion of the groundwater flow in case of over exploitation, contamination of fresh groundwater could be feared. A large amount of salt could in fact come from the sebkhat. A less important danger also exists on the side of the second deep aquifere. The overexploited aquifer vulnerability to a saline contamination has been studied by an unsteady state simulation over 20 years of a pollution front evolution in terms of salt content.

The simulation problem of propagation of a solute body in an aquifer is seen from the simplification of the dispersion theory thanks to a mathematical model of an approximate resolution of the transport equations in multilayered aquifers⁺. This model allows us to figure the total water and solute matters transport in the scale of a whole hydrogeological basin (3).

In the Sedjoui aquifer system, the distribution of the salt content can be roughly represented as follows :

In the phreatic aquifer salinity increases from the plain upstream where the content is about 1,5 g/l to down stream where it can reach 5 g/l near the sebkhat.

In the sebkhat it self, the contents can reach more than 100 g/l.

In the first deep aquifer the increase is faster downstream. The salt contents quickly pass from 1 g/l to 10 g/l then to 100 g/l on a short distance.

In the middle of the sebkhat it reaches 150 g/l.

In the second deep aquifer the waters seem moderately salty at first sight (3 to 4 g/l) even downstream.

Starting from the steady results, a first simulation aimed at the approximate estimation of the vulnerability of the aquifer, which is supposed to be homogeneous and without salt content, to a saline pollution coming from the sebkhat supposed to have a content of 100 g/l. The 100 g/l front roughly represents the salty zone limit of the Sedjoui basin. Fig. 7.

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In these conditions and for vertical transmissivities minimum value of $0,5 \cdot 10^{-4}$ m²/s/km² of exchange surface, the exploitation of the first deep aquifer at the rate of 100 l/s, simulated into 10 periods of 2 years, will provoke, by 20 years, the appearing of a polluted intermediate zone which develops mostly in the plain axis, and spreads over about 8 km². Fig. 8.

Among the 20 meshes where pumping occurs, only 5 of them are strongly affected by pollution. For the next simulation we started from real salt contents distribution of the 3 model layers. But for the first deep aquifer we have admitted that in meshes where the initial salt content is equal or superior to 10 g/l the content remained constant with time. This device allows us to prevent any pollution from the sebkhat in the case of flow inversion. Fig. 9.

This case is obviously far better than the preceding one in the point of view of salt content evolution, since by 20 years, the increase, in general moderate, doesn't exceed 5 g/l any where. Certain meshes even show us a decrease in their salinity. Fig. 10.

At the place of the 20 meshes where we pump, only 5 of them will, by 20 years, exceed 1,5 g/l in salt content, and only 2 of them will exceed 2,5 g/l.

A last simulation done in the same conditions as the foregoing one, but with vertical transmissivity value multiplied by 5, presents the good effect of the leakage from the phreatic aquifere on the chemical evolution of the first deep overexploited aquifere.

By 20 years the salt content of this overexploited aquifer is smaller than in the foregoing case. The biggest salt increase doesn't exceed 4,3 g/l. Fig. 11.

At the place of the meshes where we pump we notice by 20 years that only 4 meshes with a content bigger than 1,5 g/l and only one with a content bigger than 2,5 g/l.

As a reference, in that case, by 10 years of pumping, only one mesh would exceed 1,5 g/l in salt content.

IN CONCLUSION :

All these simulations must be considered as exploratory attempts aiming at preventing a potential danger coming from the unbalancing of an aquifere system which is now relatively some what exploited.

More trustworthy conclusions should take into account realistic hypothesis concerning :

- The deep aquifere vertical link with the phreatic aquifer
- replenishment conditions of the deep aquifer from the Sedjoui sebkhat in case of over exploitation.

The mathematical model allows us to simulate the different conditions on which this replenishment depends.

Only field data could however allow to reach acceptable values of the leakage factor between the 2 aquiferes.

Besides we should take into account the fact that all these simulations are pessimistic : The mathematical model suppose that the salt goes through the semi-pervious layer without delay, whereas in reality the salt may take a very long time to go through these semi-pervious layers, or even may be retained.

ACKNOWLEDGEMENTS

I thank G. De Marsily for allowing the use of the C.I.G. programmes as well as M. Besbes for the help he brought me in the carrying out of these programmes.

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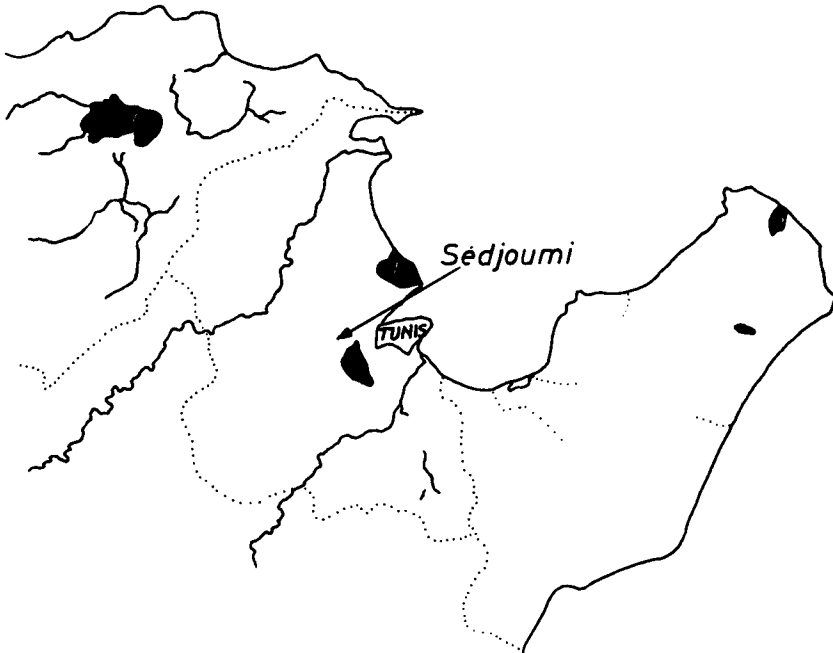


Fig : 1 Position map

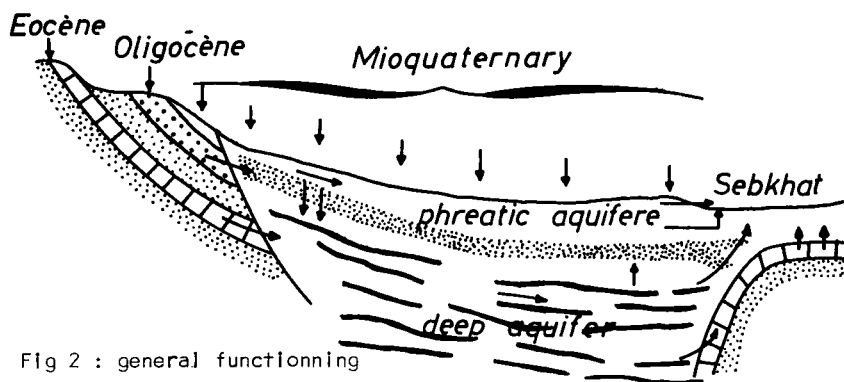


Fig 2 : general functioning of the sedjoui

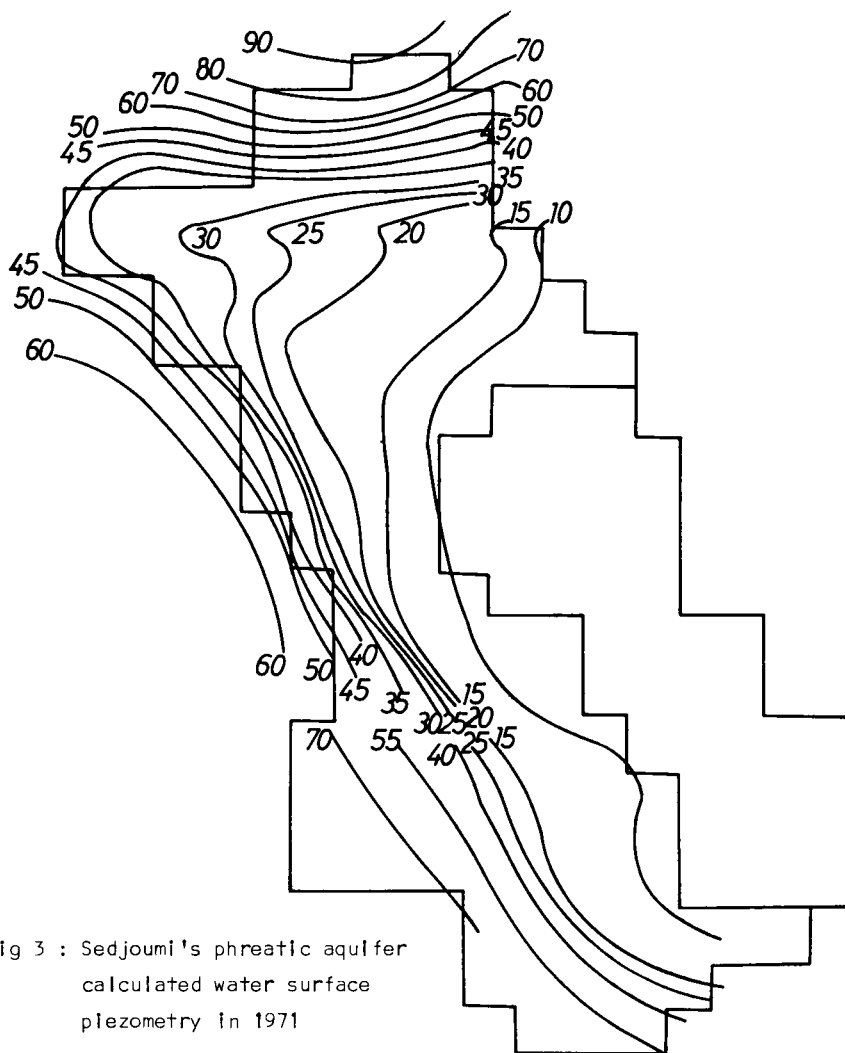


Fig 3 : Sédjoui's phreatic aquifer calculated water surface piezometry in 1971

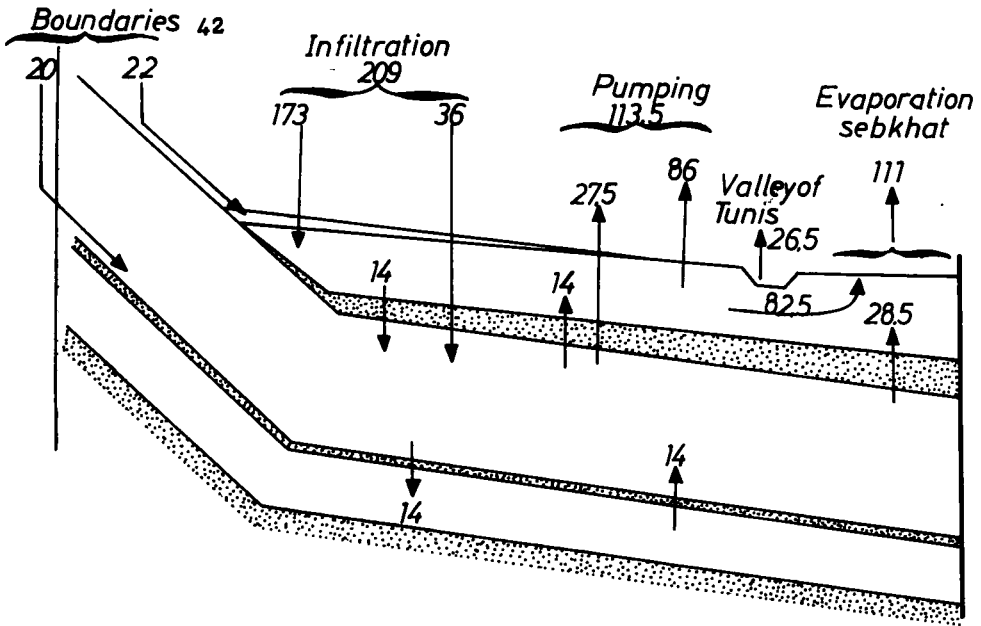


Fig 4 : Sedjourni's aquifer system : steady state balance

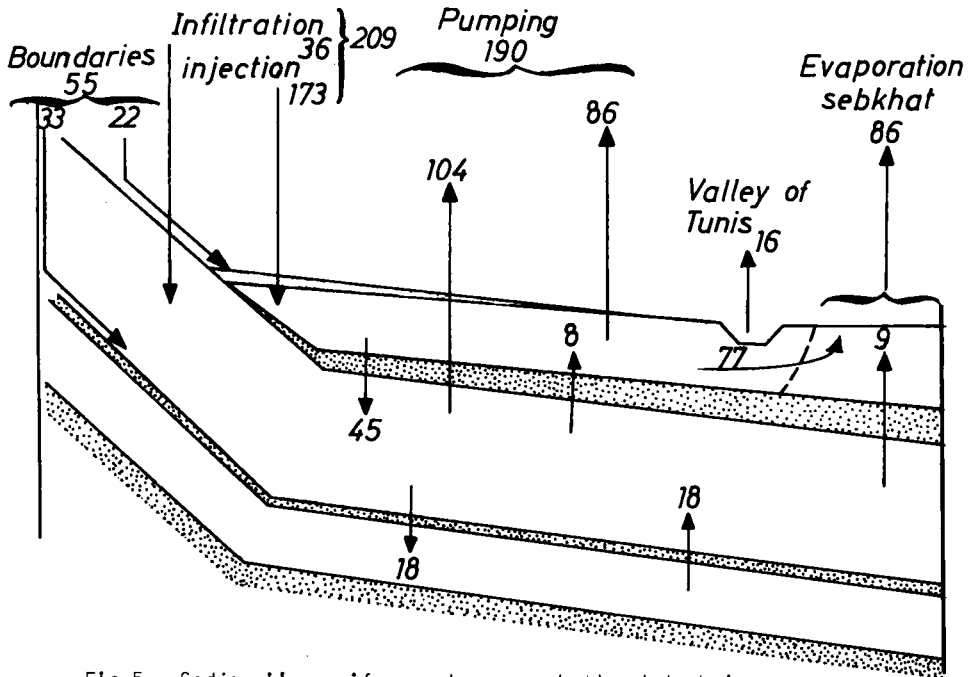


Fig 5 : Sedjourni's aquifer system : unsteady state balance

with $t_v = 0,5 \cdot 10^{-4} \text{ m}^2/\text{s}/\text{Km}^2$

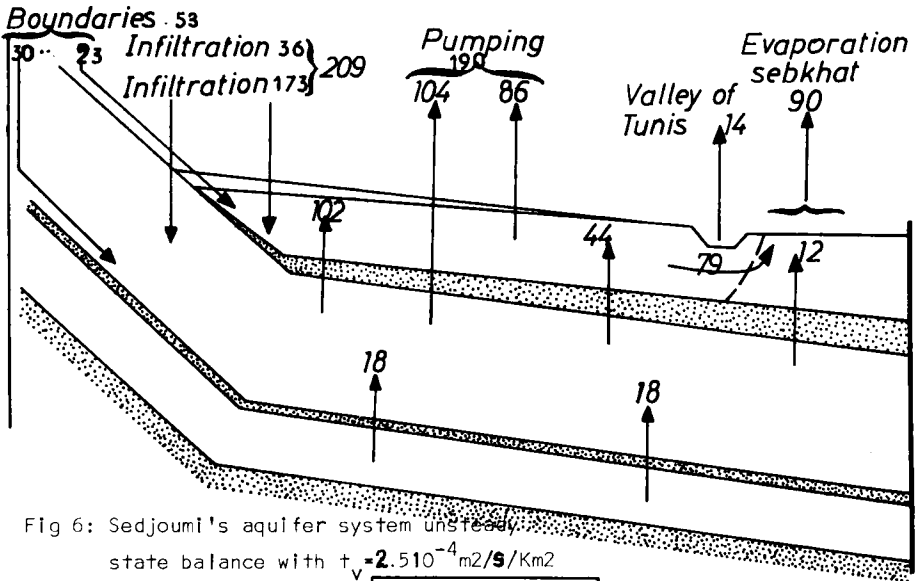


Fig 6: Sedjoui's aquifer system unsteady state balance with $\tau_v = 2.510^{-4} \text{ m}^2/\text{s}/\text{Km}^2$

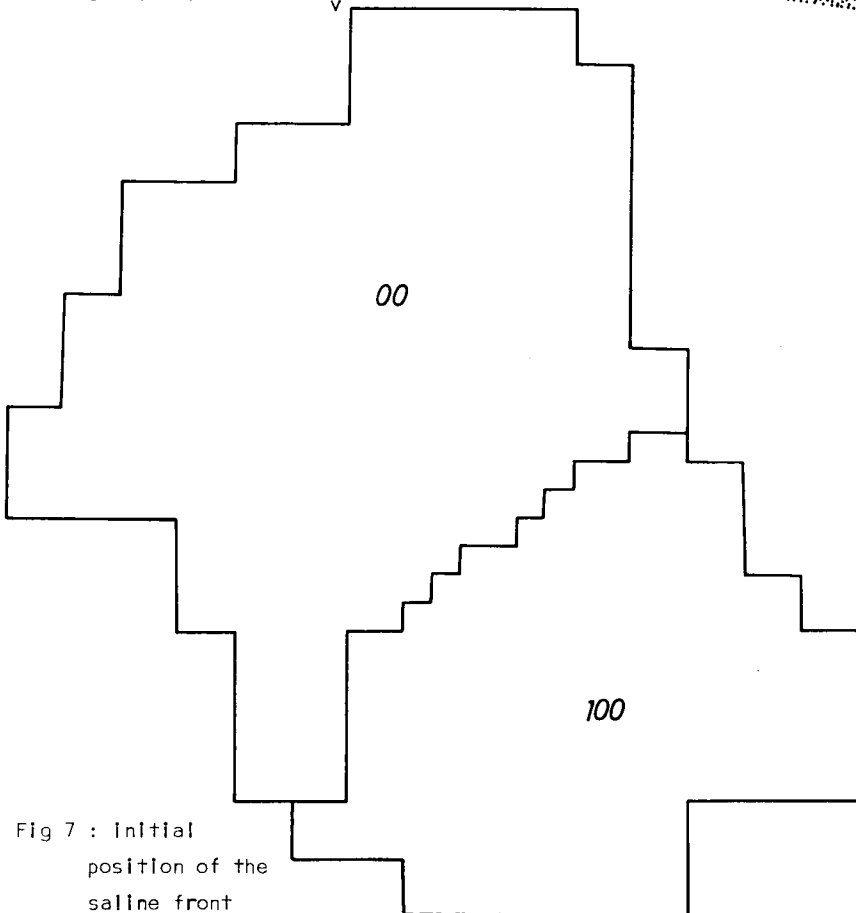


Fig 7 : Initial position of the saline front

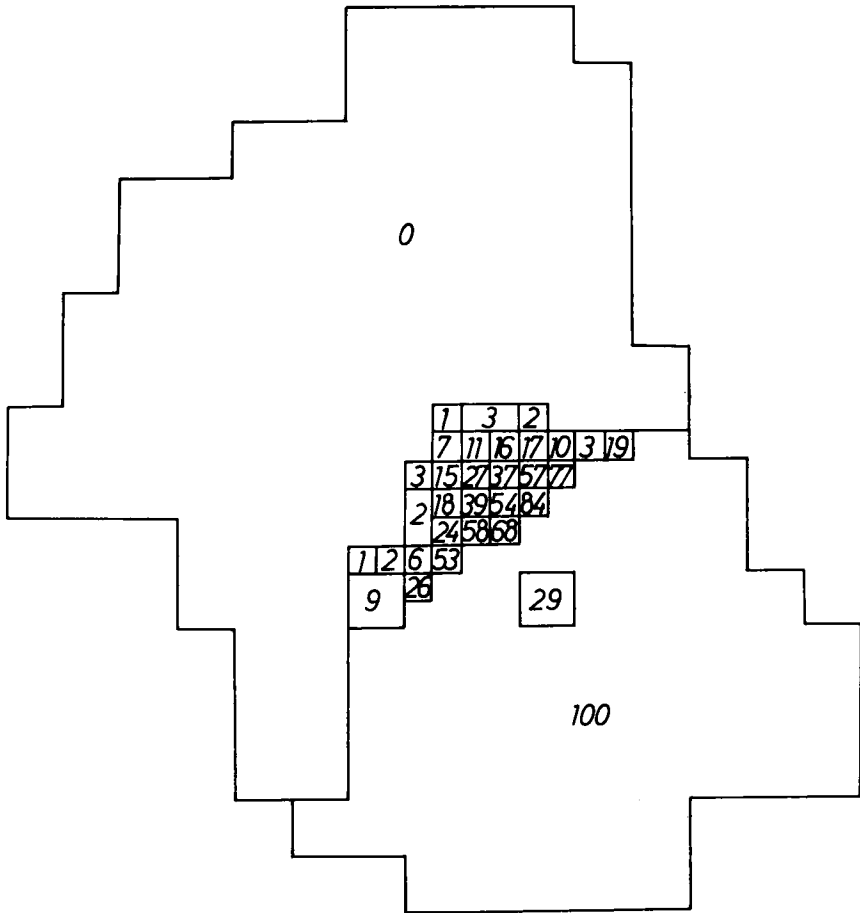


Fig 8 : exploitation effect by 20 years.
salt content in g/l

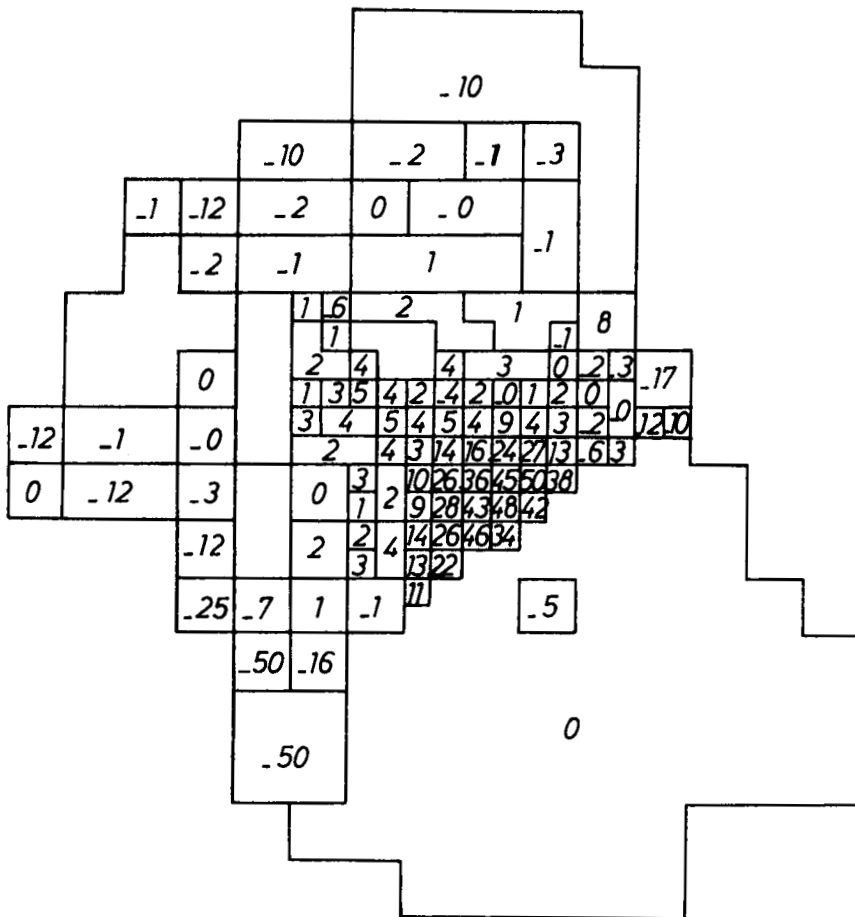


Fig 10 : Salt content increase due to the over exploitation by 20 years in the first deep aquifer in 10^{-1} g/l

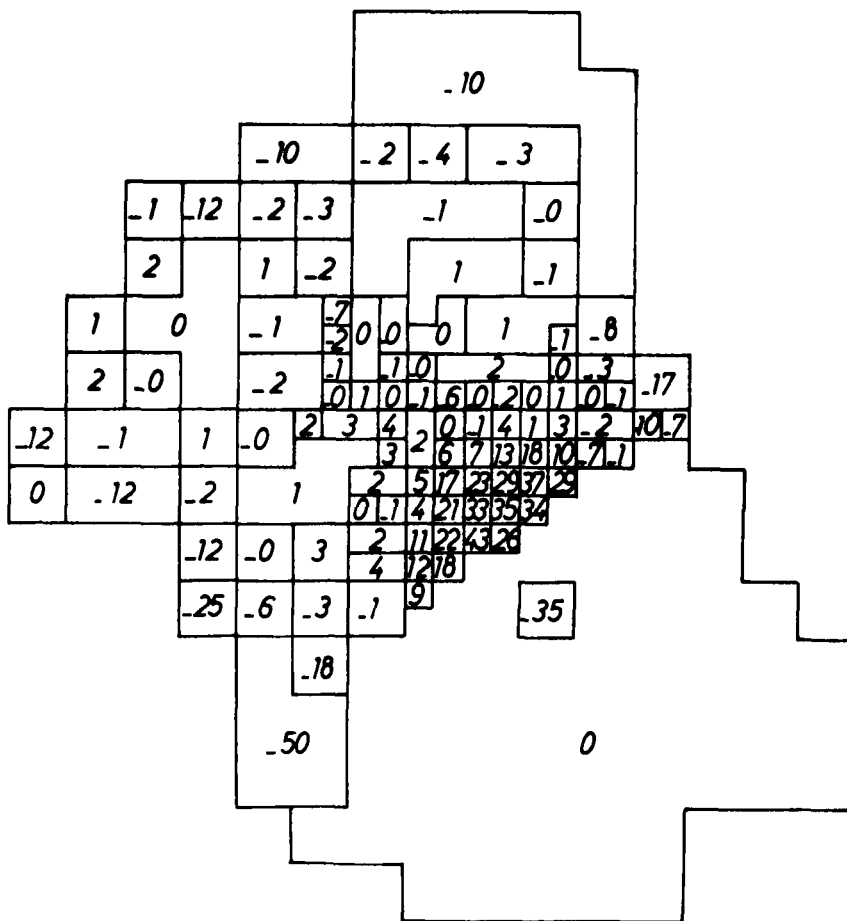


Fig 11 : salt content increase in the first deep aquifer in case of a better leakage from the phreatic aquifere in 10^{-1} g/l