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NUMERICAL SIMULATION OF SALT WATER UPCONING AND SALT WATER INTRUSION IN THE WADI SURDUD AREA

(Draft report)

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CONTENTS

LIST OF ANNEXES

LIST OF FIGURES

LIST OF TABLES

SUMMARY

Within the framework of the project 'Water Resources Assessment Yemen' numerical simulations have been performed to investigate the effect of various abstraction scenario's on both upconing of salt water underneath a well and salt water intrusion. The upconing of salt water merely is a local phenomenon, whereas saltwater intrusion is a regional process.

Upconing of salt water has been simulated for situations with combinations of various abstraction rates, well depths and anisotropy factors. The model code SWIP, developed by the United States Geological Survey (USGS), has been used to perform these simulations. The geohydrological schematization used for these simulations represent a more or less characteristic situation for the Wadi Surdud area.
The various simulations showed that upconing of salt water under abstraction wells can be retarded considerably by keeping the wells shallow and the rate of abstractions only small or moderate. Furthermore this study showed that upconing is in particular limited in situations with high anisotrophy factors ($k_h >> k_v$).

Next salt water intrusion has been simulated by means of the BADON-3 model, developed by prof. A. Verruijt. This model has first been calibrated. Available groundwater level maps have been used for this purpose. Next the calibrated model has been used to calculate on a regional scale the effects of various abstraction scenarios on the rate of salt water intrusion and the rate of drawdown of the groundwater level.
The model study shows that the drawdown of the phreatic table is maximum in case the groundwater abstractions take place from the eastern part of the aquifer. In that case, on the other hand, the rate of salt water intrusion is small. In case the groundwater abstractions predominantly take place from the western part of the aquifer the drawdowns of the phreatic table are reduced considerably. However, the rate of salt water intrusion increases as compared to the situation with abstractions in the eastern part of the aquifer. As the negative effects of drawdown seem to be more serious than the negative effects of salt water intrusion the abstraction scenario that results in limited drawdown of the phreatic table offers best potentials for future water supply. For this reason, from groundwater reservoir management point of view, it is promoted to retire wells in the eastern zone (to the extent possible) and to allow drilling new wells (if absolutely needed) in the western part of the aquifer, to arrive to a situation that can be sustained as long as possible.

1. INTRODUCTION

In this report the results of the groundwater modelling study on the Wadi Surdud Area, The Republic of Yemen are presented. The study especially aimed at understanding and quantification of spatial and temporal aspects of the salinization processes.
In the current situation the two major mechanisms to cause salinization in the Wadi Surdud Area are supposed to be:

A. Local salinization near groundwater abstraction wells. This so-called 'salt water upconing' from deeper salt water strata to shallow fresh water strata is a local phenomenon, caused by the local drawdown near an abstraction well.
B. Regional salinization near the shore. This so called salt water intrusion of seawater is caused by regional changes in the groundwater regime.

As both salinization processes do occur on completely different spatial and temporal scales they demand a different modelling approach.
In this particular case next two groundwater models have been used:

A. SWIP for simulation of upconing salt water near pumping wells.
B. BADON-3 for simulation of the saltwater intrusion near the shore.

The study has been performed within the framework of the third phase of the WRAY-programme. It is based on the results of the Water Resources Assessment Study (WRAY1) and the drilling programme (WRAY 2 and 3).
In turn the results of this study will be used as an input to the "Pilot Study Water Resources Wadi Surdud", which is being prepared currently.

It should be mentioned that during modeling the Wadi Surdud area various model code adaptions have been performed in cooperation with prof. A. Verruijt (Technical University, Delft). Furthermore, model interfaces have been made to use the program in combination with the SURFER contour package. Finally a user manual has been written (Elderhorst, 1990) and a course on modelling of fresh and salt groundwater flow has been given for the Yemeni counterparts in Sana'a, May 1990.

Numerical groundwater modelling can be used as an aid for the development and management of groundwater resources, to verify whether the resources are exploited rationally under a given abstraction regime. This study describes both a groundwater transport model (SWIP), and a salt/fresh interface model (BADON-3).

The first type of model provides an opportunity to calculate the local salt transport in an aquifer. For various moments of time this model will calculate the salt concentrations of the various selected model elements. The second type of model enables to calculate the changing position of the salt/fresh interface in a phreatic or a confined aquifer. In this case it is assumed that the transition zone between fresh and salt water is very thin, allowing a sharp interface approximation.
Both models can be used for both steady-state as well as for transient groundwater flow simulations.

2. CHARACTERISTICS OF THE WADI SURDUD AREA

This chapter is an adjusted reprint of "Water Resources of the Wadi Surdud Area", Main Report, Sections 3.1 and 3.2 (Van der Gun, 1986)

2.1 Location and topography

The Wadi Surdud project area is situated on the so-called "Western Escarpment" (fig. 1), in the western zone of the Yemen Republic. It lies between longitude 42 30' and 44 00' East and latitude 15 00' and 15 40' North. The extent of the area – including the Salif peninsula – is 4050 km^2.

The project area (fig. 2) is composed of a gently sloping western zone at low elevation and east of it a rugged, strongly dissected mountainous zone that reaches elevations of over 3000 meters. The lowland zone between the mountain front and the Red Sea forms part of the Tihama Plain and is called 'Wadi Surdud Coastal Plain' in this report. The regional salt water intrusion study covers approximately 2400 km^2 of this Plain.

2.2 Geology

Figure 2 shows the general geologic features of the project area and its immediate surroundings. The stratigraphy and lithology of the mapped units are presented in table 1. Yemen Volcanics and Tawilah Sandstones are dominant in the upper catchment of Wadi Surdud, but Tertiary granitic intrusions cover large areas further downstream, within a short distance from the Tihama Plain. The geologic units mentioned so far are not included in the model study.
The Tihama Plain is situated inside the Red Sea Rift Valley and is characterized by dominantly Quaternary unconsolidated deposits that form a smooth, gently sloping surface. It should be mentioned that figure 2 is based upon the 1 : 500000 geological map by Grolier and Overstreet (1978).
The Red Sea graben was formed during the Tertiary, initiated by fracturing, step-faulting and rifting along an anticlinal structure of the African-Arabian shield. The graben was filled by large amounts of clastic fluvial deposits and by marine or coastal sediments. The Red Sea lies in its deepest part (trough).
A schematic cross-section through the Wadi Surdud coastal plain is presented in figure 3. It extends over 60 - 70 km from east to west; the section represents a thickness of a few thousand meters. The quaternary deposits, modelled in this study, are most probably some 200 - 300 m thick in the central and western zones of the plain, but are shallower

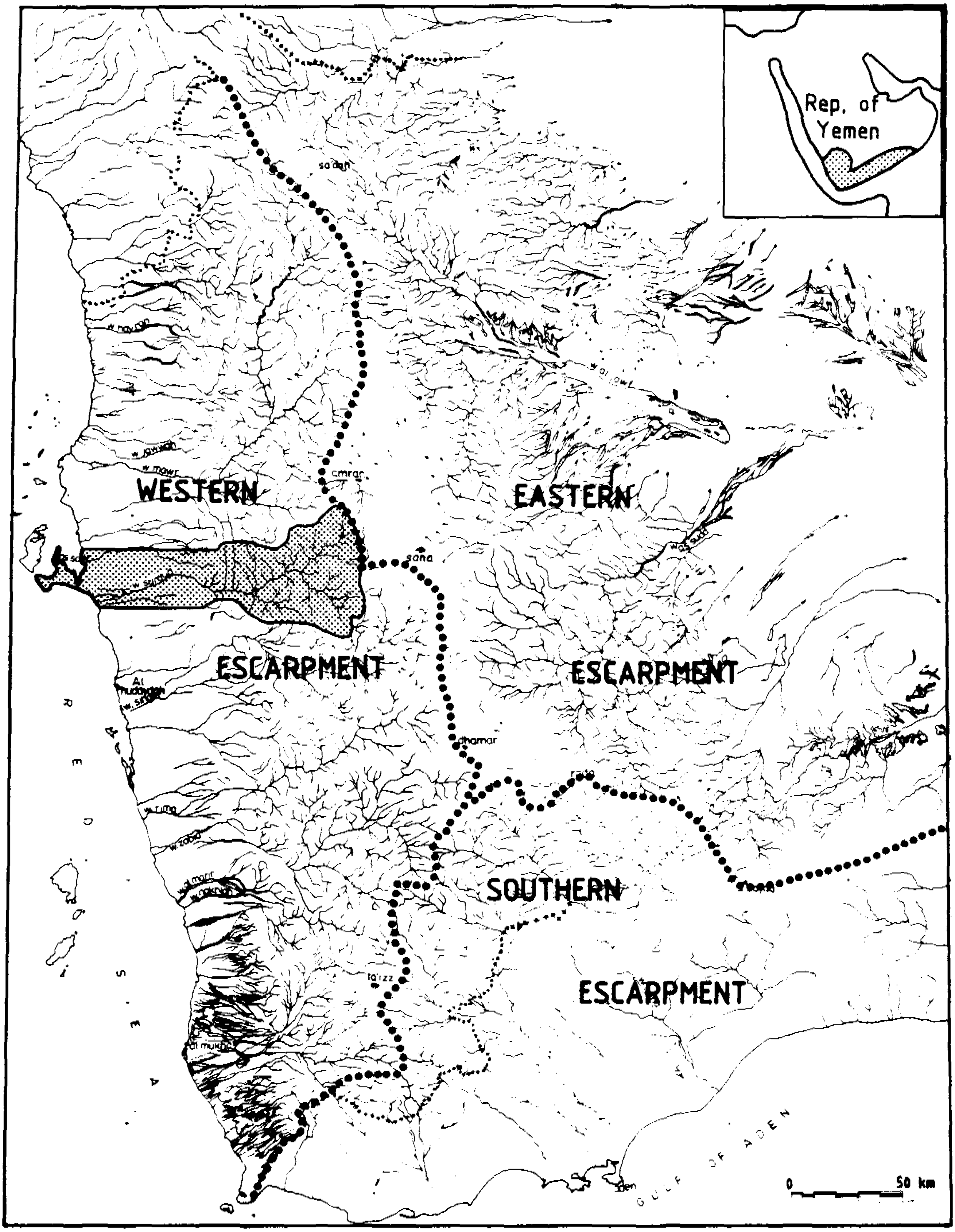


Figure 1: Location of the Wadi Surdud project area

GEOCHRONOLOGY		LITHOSTRATIGRAPHY	LITHOLOGY		HYDROGEOLOGY
			West	East	
Cainozoic	Quaternary	Recent alluvial aeolian, marine and evaporitic sediments	aeolian medium-fine sands coral reefs, limestone; sandstone; evaporites	alluvial boulders, pebbles and sands; low clay content	good aquifer, medium to high permeability, upper parts unsaturated
				alluvial pebbles and sands with much clay (often calcareous)	very heterogeneous formation (lateral facies changes) poor aquifer
	Tertiary	Baid formation / Yemen volcanics	shales sandstones carbonates anhydrites halite	siliceous shales tuffs volcanic flows sills intrusives	most rocks low hydraulic conductivity; wholly or mostly saturated with saline water
Mesozoic	Jurassic	Amran limestone	limestones with shales and marls		poor aquifer
	Triassic	Kohlan sandstone	cemented fine-grained quartz sands		potential aquifers, but, if present, only at great depths; probably little or no recharge
Paleozoic		probably absent in Wadi Surdud's coastal plain			
Precambrium		Basement complex	metamorphic rocks		impermeable bedrock, buried at great depths

Table 1: Lithostratigraphic table.

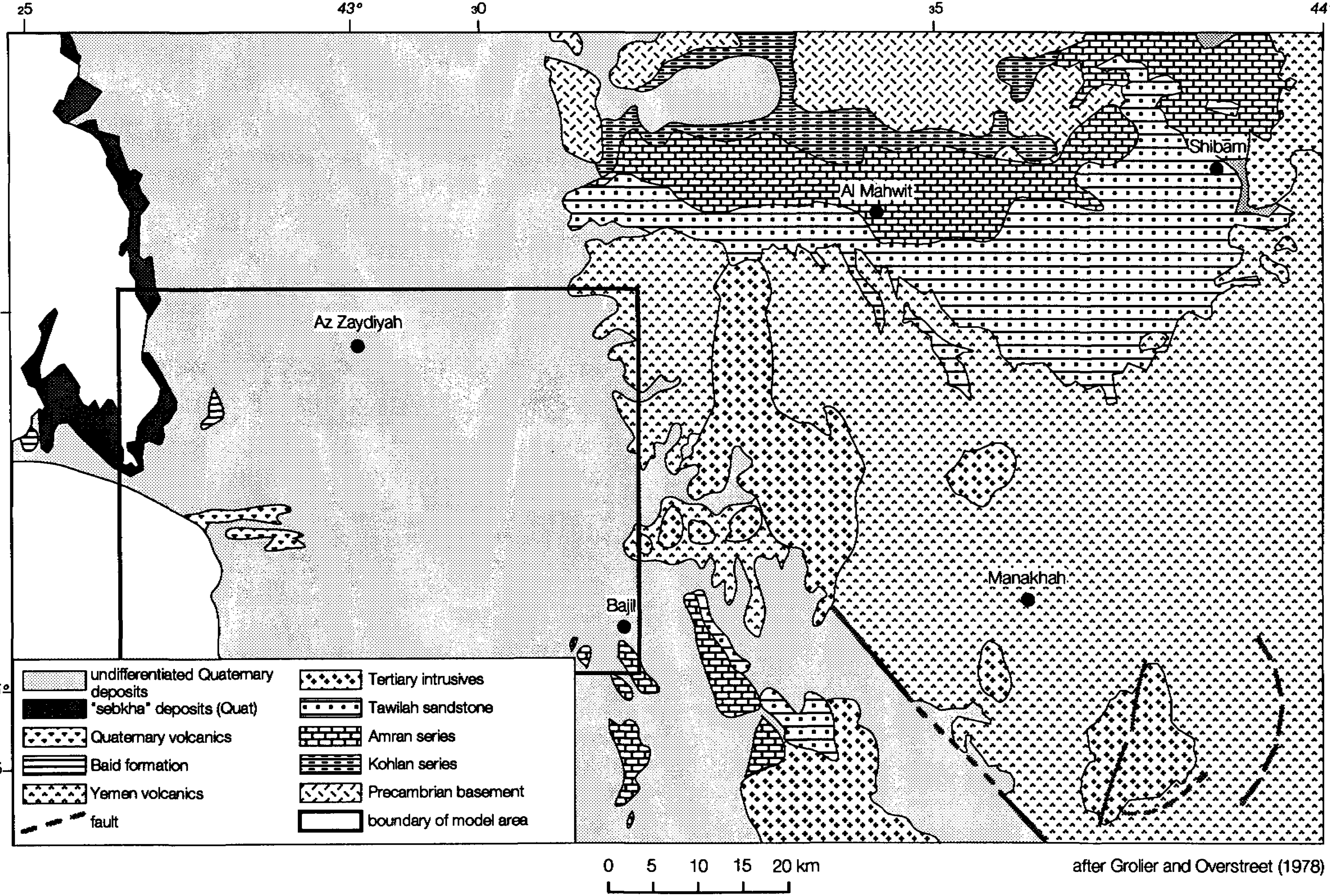
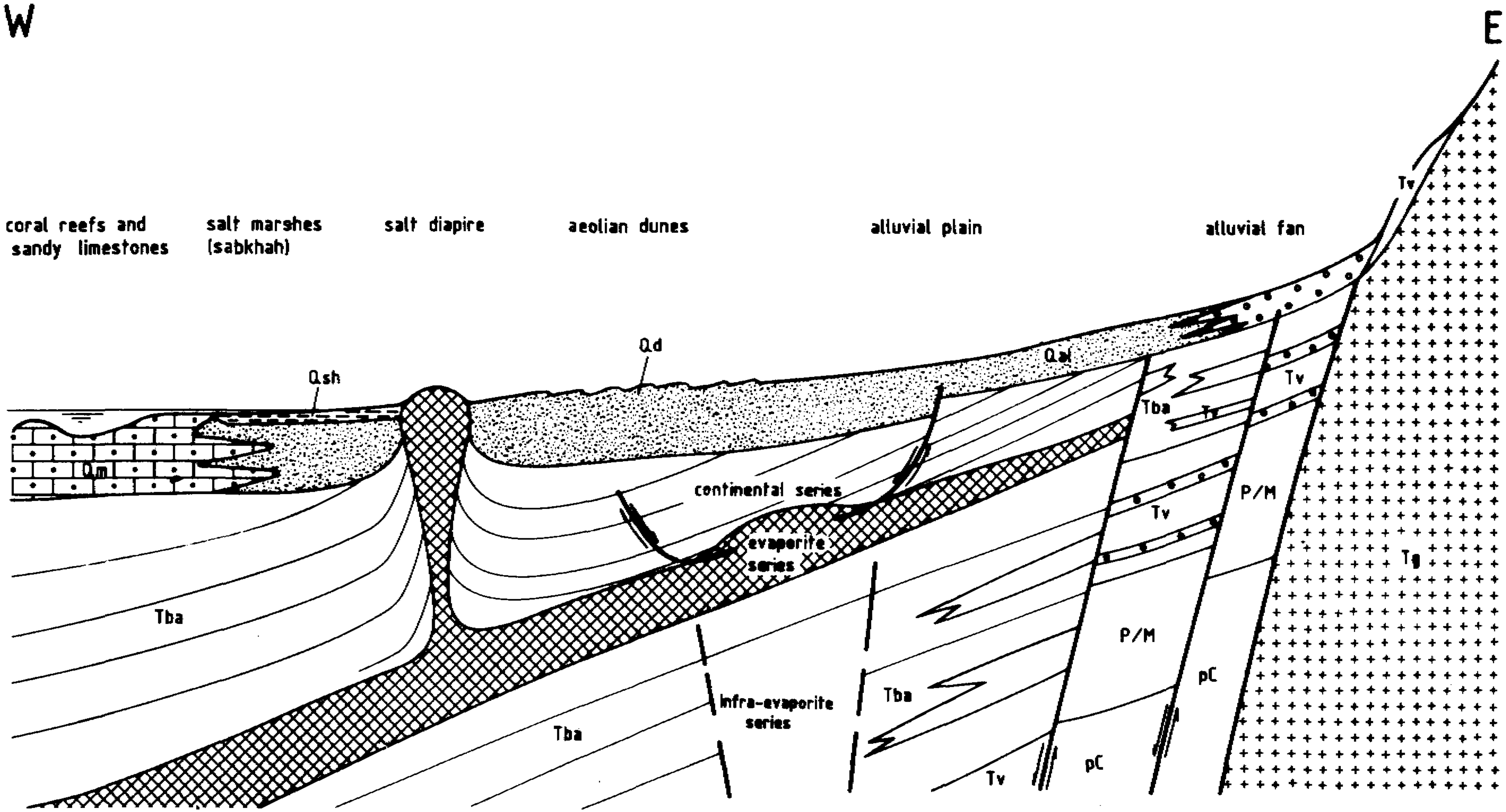


Figure 2: Geological setting.



LEGEND

- Q — Quaternary (alluvial, aeolian, sabkhah, marine)
- Tg — Tertiary granites
- Tba — Tertiary clastic-evaporites (Baid fm)
- rock salt
- Tv — Tertiary volcanics
- P/M — Paleozoic/Mesozoic
- pC — Precambrian

Figure 3: Schematic geological cross-section through the coastal plain of Wadi Surdud

along its eastern edges (Van Overmeeren, 1985). On the plain's surface they are present mainly as alluvial sediments in the eastern half and as aeolian deposits (dunes) west of Ad Dahi.

The alluvial sediments are poorly sorted and vary in grain size from blocks and boulders to sands, silts and clays. The aeolian deposits, on the other hand, are well-sorted fine- to medium-grained sands and form a generally homogeneous formation. Noteworthy is the occurrence of salt diapirs that locally penetrate the quaternary deposits (Jebel Qumah and Salif peninsula). Salt domes and also salt pillows might be present elsewhere underground.

2.3 Climate

In the Wadi Surdud Coastal Plain both temperature and relative air humidity are high throughout the year (1984 averages are 30 °C and 62% respectively at Ad Dahi). From the coast towards the mountainous front the daily temperature range increases slightly, and relative humidity decreases.

Rainfall shows a significant trend over the coastal plain: it varies from virtually zero at the coast to some hundreds of mm per year near the mountain front.

Potential evaporation far exceeds the monthly and annual rainfall. Recharge from rain does hardly occur at all in the Surdud area.

As the depth to the groundwater is quite large (5 - 50 m) no groundwater evaporation does occur either, except in some salt marches (sabkhahs) in the western part of the area near the coast. It is assumed that some 25 Mm^3/year is lost from the groundwater system this way.

2.4 Surface water

Wadi Surdud collects water from the mountainous area.The wadi system is composed of a few major branches. Stream beds are dry during most of the year, except for a permanent modest base flow in Wadi Surdud's bed in the foothill area. Where Wadi Surdud enters the coastal plain, its base flow disappears largely by infiltration into the permeable deposits and by diversion for irrigation. During rainstorms the water levels of the wadi rise quickly and the discharge increases fast too. Wadi Surdud hardly ever reaches the Red Sea, but instead loses all its water by infiltration in the plain.

From streamflow measurements an average inflow into the aquifer system (recharge) of ca. 50 Mm^3/year could be estimated. The annual variations of this recharge are large and the seasonal variations of the recharge might even vary orders of magnitude.

2.5 Groundwater

As mentioned before, Wadi Surdud is part of the Tihama Plain. The subsurface consists of unconsolidated sediments, which form a highly permeable aquifer. Recharge mainly is caused by runoff from a large mountainous catchment area. North and south of Wadi Surdud similar flow domains do occur, which are connected hydraulically. The transition zones between the various flow domains is supposed to be less pervious, though.

2.6 The aquifer system

Fresh groundwater occurs mainly in the pores of the upper unconsolidated strata. Lower and lateral boundaries of the aquifer system have been established by geophysical methods (Van Overmeeren, 1985) and are shown in figure 4. Tertiary layers of low permeability, filled with saline groundwater, are thought to underlie the aquifer system, except in the eastern zone (zone 1) where the aquifer rests on bedrock. Outcropping bedrock constitutes the eastern limit of the aquifer system; to the west, fresh groundwater ends as a tongue extending into a saline environment (zone 3).

According to the geo-electrical survey, zone 2 falls into two distinct zones. The most probable hypothesis to explain the differences observed is that there is a sharp transition from alluvial (east) to dominantly aeolian deposits (west).

There is not much information on the vertical stratification of the delineated aquifer system. However, the few lithological borehole descriptions available, the form of the geo-electrical field curves and published geological information (Skipwith, 1973, Kraft et al., 1971) suggest that the upper 20 - 50 metres of the aquifer system might constitute the main aquifer beds, overlying strata of higher clay or silt content (Van Overmeeren, 1985, Van der Gun, 1985a).
The groundwater variables described below were measured almost exclusively in the upper part of the aquifer system. If the hypothesis presented above holds true, they represent conditions in the 'main aquifer' only.

2.7 Groundwater levels and groundwater flow

Depth to groundwater was measured (Van der Gun, 1986) in 853 wells and is shown in figure 5. Depths are commonly between 10 and 30 metres, but depths more than 50 m are observed in the alluvial fan zone and - in contrast - shallow water tables (< 5 m) are found in the so-called 'sabkha' zones.

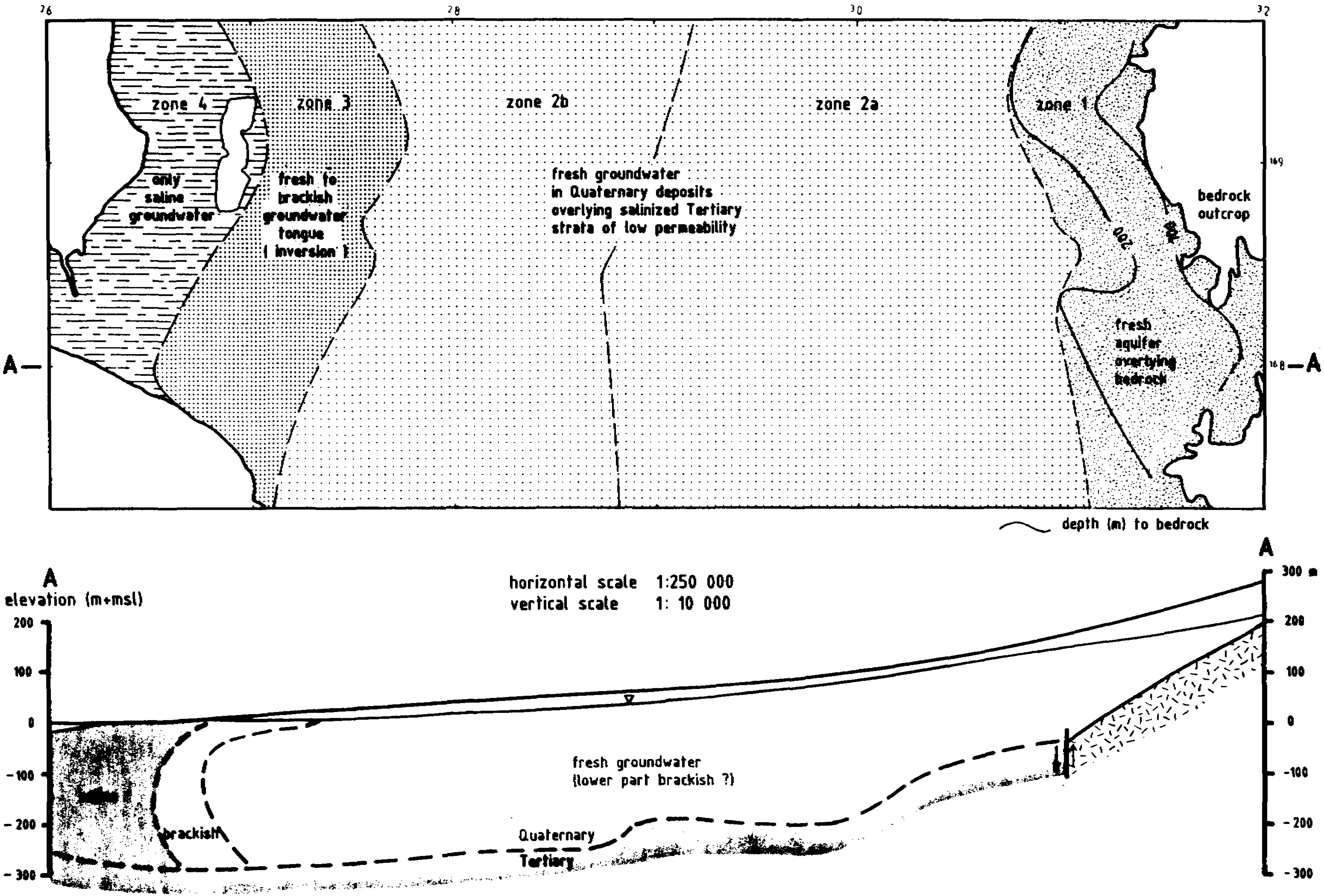


Figure 4: Delineation of the Wadi Surdud coastal plain aquifer

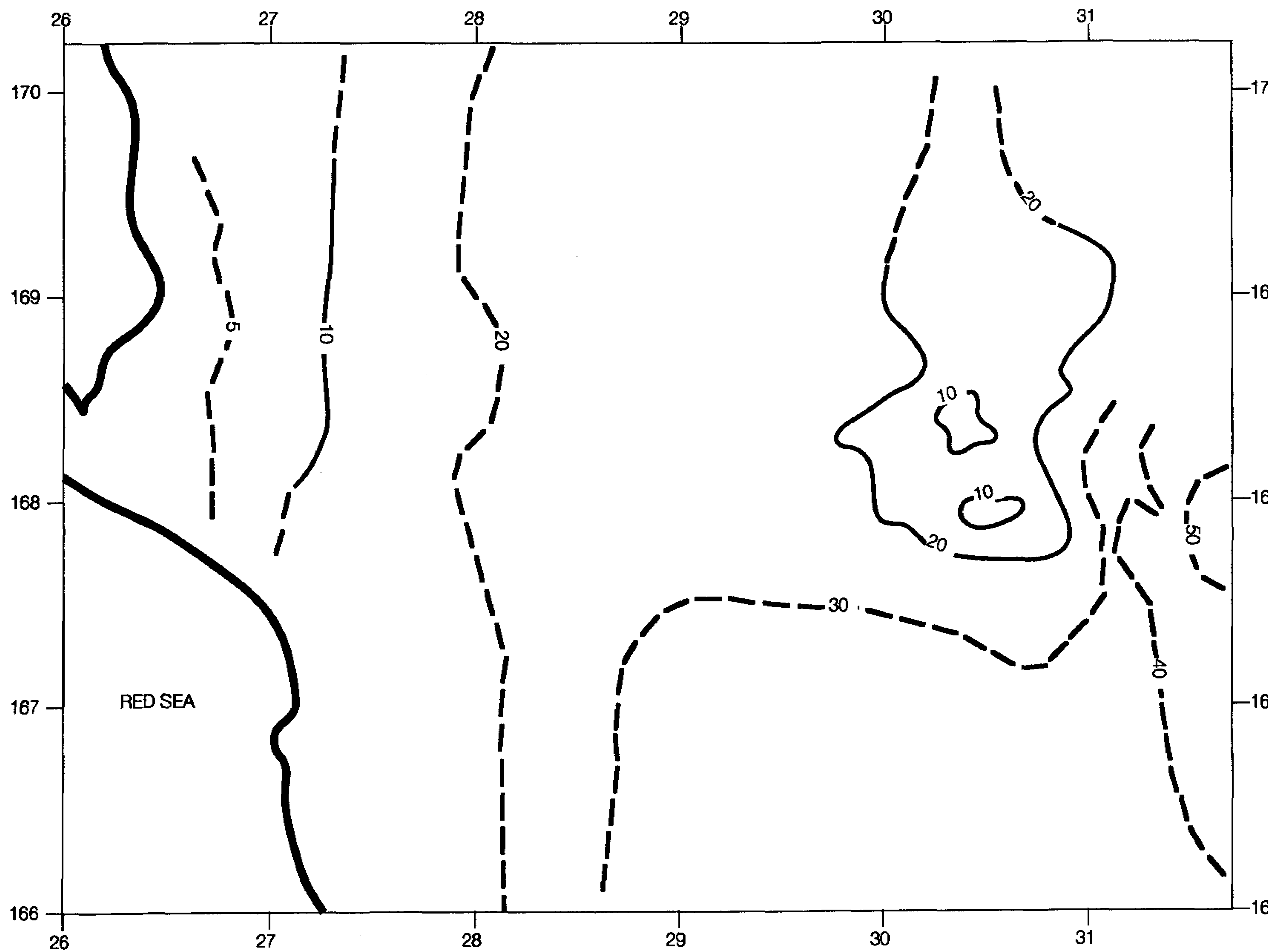


Figure 5: Depth to groundwater situation 1984.

Seasonal variations have been observed, in particular in the eastern-most zone, but they did not exceed 2 m during the period January 1984 - June 1985. Records at the Al Kadan State Farm indicate that groundwater levels have declined there by approximately 10 metres since the well field came into use (1967), possibly reflecting a composite but local 'cone of depression'. A slightly declining trend in groundwater level is to be expected for the entire area, as a response to the recently initiated groundwater pumping (section 2.9).

Figure 6 presents the piezometric groundwater level measured during the first half of 1984. It demonstrates a generally east-west flow, divergent in the alluvial fan zone, but elsewhere almost perpendicular to the coastline. Groundwater is recharged by Wadi Surdud - mainly east of Al Kadan - by return flow of irrigation water and by local rainfall. Discharge of groundwater proceeds by evaporation in the 'sabkhas', by outflow into the Red Sea (Al Urj zone) and by abstraction by means of wells.

The Jebel Qumah diapir forms an evident obstacle to groundwater flow: the piezometric surface shows it by a pronounced divergence of flow. Other irregularities in the piezometric map may be associated with lithological variations within the Quaternary deposits, e.g. the presence of buried, abandoned wadi channels more or less parallel to the actual wadi bed.

Worth special mention is the difference between the hydraulic gradients on either side of the 43" East meridian: west of this meridian the hydraulic gradients are much lower. A similar 'flattening' of the piezometric surface is observed all over the Tihama Plain at some distance from the coast. Fluxes do not decrease significantly here, and therefore it can be inferred that the hydraulic characteristics of the aquifer system change suddenly (greater transmissivity in the western zone). It is very likely that the observed phenomenon is caused by the same geological factor (lithological variation) that enables zone 2 to be subdivided into 2a and 2b (see preceding section).

2.8 Groundwater quality

Investigations indicate that the major part of the Quaternary aquifer system is filled with fresh water. The limits of the fresh groundwater body were already roughly outlined in figure 7. Approximately west of the line Al Munirah - Al Urj fresh groundwater becomes overlain by shallow brackish to saline groundwater and some 5 - 8 km further west there is no fresh groundwater any more.

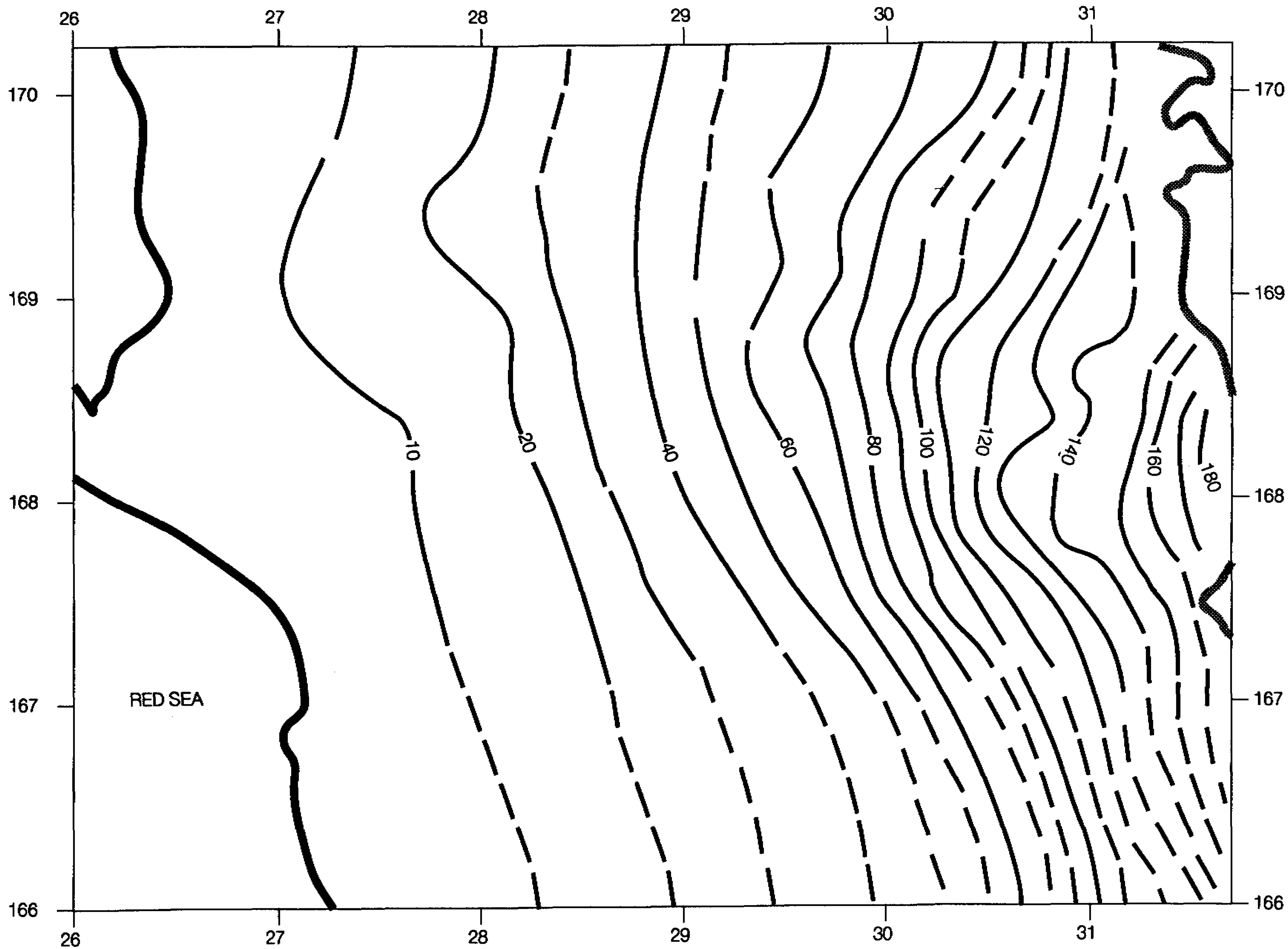


Figure 6: Groundwater level 1984, Wadi Surdud.

Electrical conductivity is commonly used to measure groundwater salinity. Figure 7 presents the electrical conductivity pattern based upon measurements in existing wells, thus representing the upper part of the Quaternary sequence ('main aquifer'). Groundwater electrical conductivities higher than 2000 micromho/cm will present limitations to groundwater suitability, whereas groundwater of some 3500 micromho/cm and more is considered unsuitable for drinking and irrigation.
The evolution of groundwater salinity at shallow depths is strongly associated with the groundwater flow pattern. Salinity increases down the flow paths and reaches local maxima in stagnation zones, such as east of Jebel Qumah and at the boundaries of the flow domain. Total residence time underground seems to be the main governing factor, which might also explain the westward protruding lobes of relatively fresh groundwater (preferential zones for groundwater flow).

Near the coast, however, salinization is not only a product of long residence time, enhanced by evaporation processes; water of another origin (seawater) has entered the aquifer as well, either during sedimentation or afterwards, by intrusion.

Groundwater is of the calcium bicarbonate to calcium sodium bicarbonate type in the alluvial fan zone of the aquifer. The relative importance of sodium and chloride ions increases quickly in downflow direction, in a way that suggests admixture of groundwater from sources other than Wadi Surdud; this could be caused by connate water of marin origin, recharge from coastal ($NaCl$ enriched) precipitation, or return flow from irrigation water. Groundwater samples from near the coast have a typical $NaCl$ composition.

2.9 Groundwater wells and abstraction

Approximately 965 wells were present in the Wadi Surdud area by mid-1984 (Van der Gun, 1986). The number of wells has increased considerably during the last 15 years (fig. 8), which is certainly related to the fact that motor-driven pumps have become available in the area. Though the area of investigation of Van der Gun does not exactly coincide with the model area, figure 8 presents a quite realistic impression of the increase of the number of wells in the model area as well.

It is clear from this figure that groundwater development is most intensive in the eastern part of the plain. This is not because the aquifer is less productive in the western part, but because of the scarcity of irrigable lands in that dune-covered zone and the less favourable groundwater quality found there. The areal distribution of groundwater abstraction (1984) is shown in annex A1.

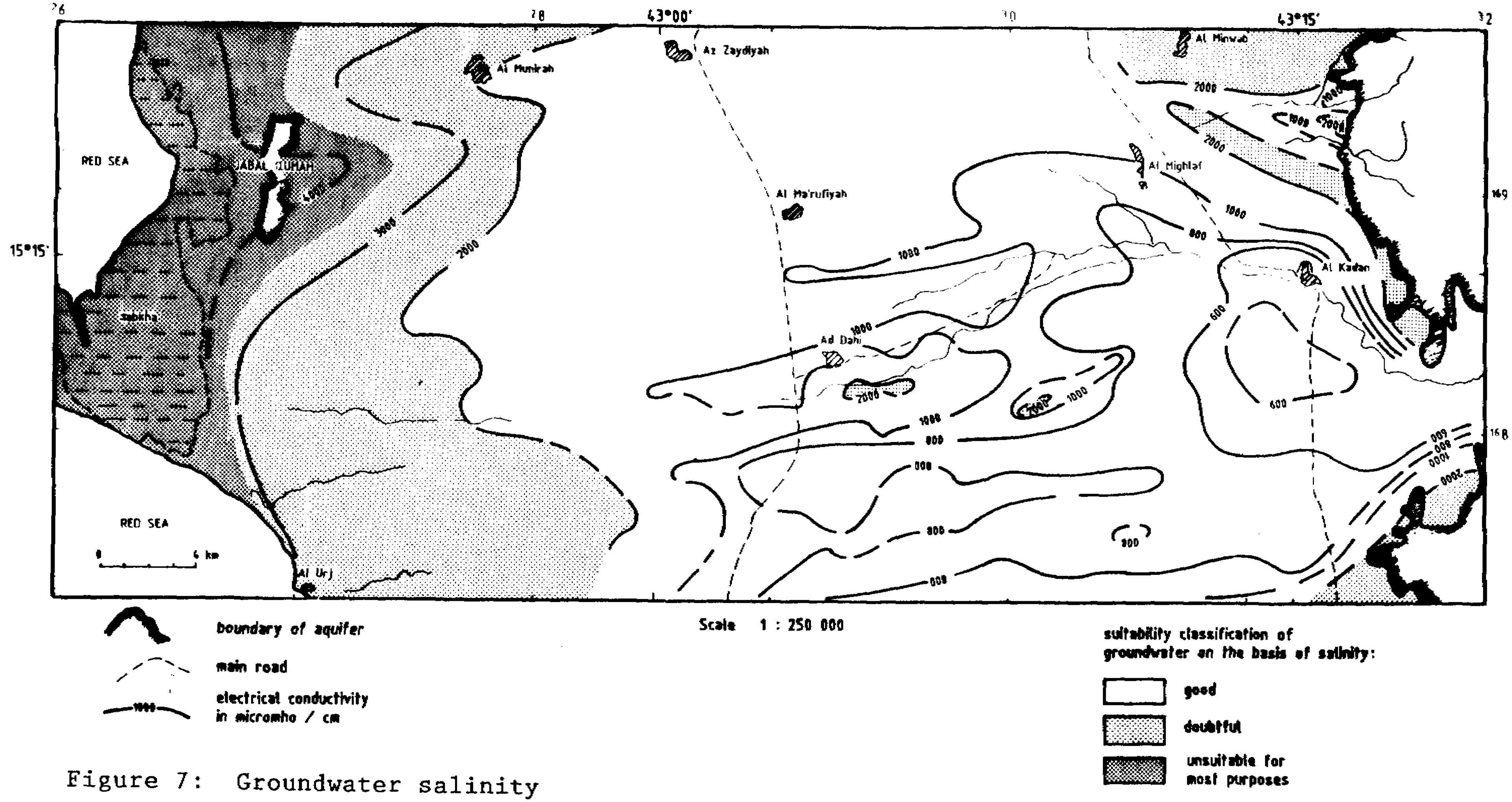


Figure 7: Groundwater salinity

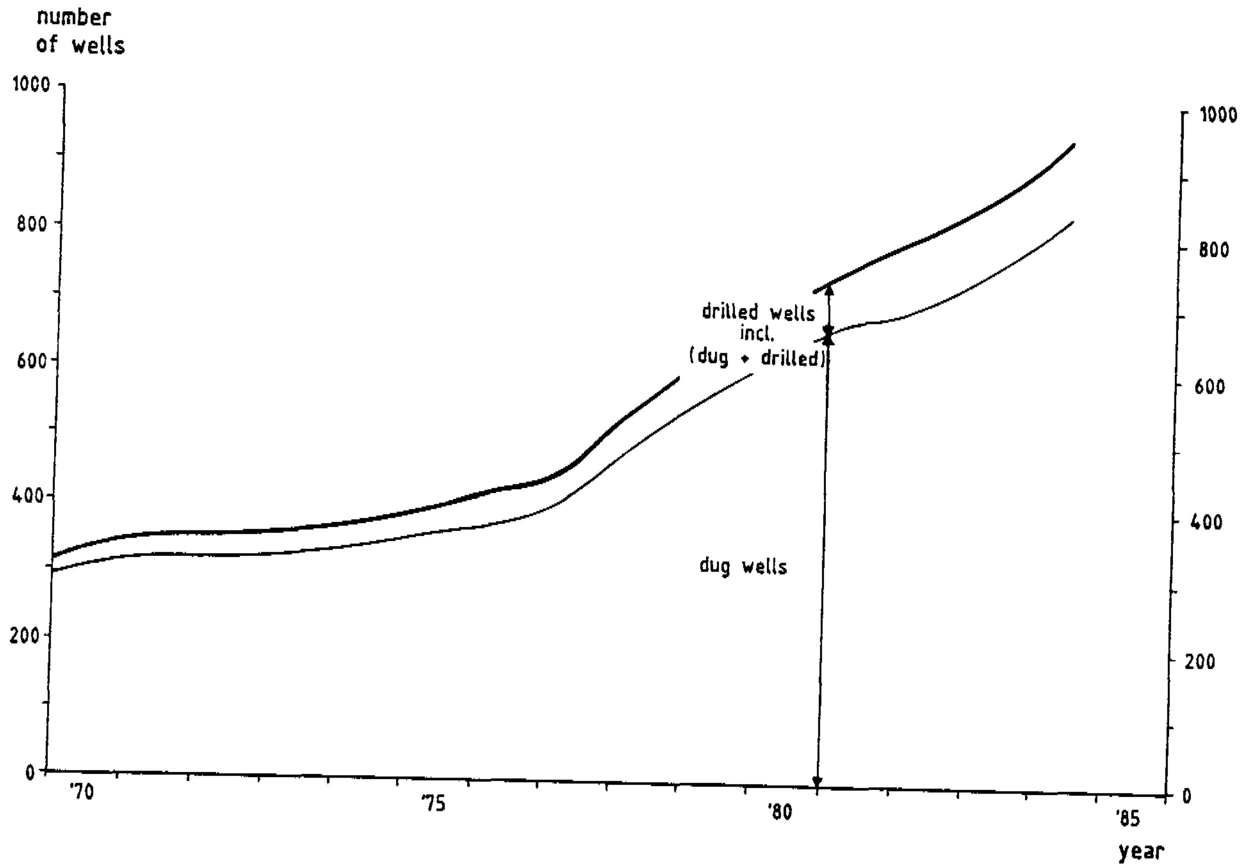


Figure 8: Increase of the number of wells, 1970 - 1984.

Table 2 shows that most wells have been dug. Hence, it is no surprise that wells are, in general, shallow and closely follow the variations in the depth to groundwater (figure 5).

Table 2 summarizes some relevant data on wells and groundwater abstraction for different zones in the area.

Table 2 Relevant data on wells and groundwater abstraction in Wadi Surdud's coastal plain (1984). These data do not cover the entire model area.

Zone	number of all wells	number of pumped wells	% drilled	average depth (m)	average pumped yield (l/s)	total abstraction ($x10^6$ m^3/yr)
east of 43°15'E	51	32	24	47	11	4.0
between 43°E and 43°15'E	754	568	4	29	14	76.1
west of 43°E	161	77	5	22	15	10.8
total or mean	966	677	5	29	14	90.9

2.10 Groundwater storage, recharge and discharge

It is estimated that approximately 100 x 10^9 m^3 of fresh groundwater is stored in the aquifer system of Wadi Surdud's coastal plain. Around one third of it potentially can be drained by gravity. If only the shallow 'main aquifer' beds are considered, a stored volume of some 15 x 10^9 m^3 of fresh groundwater remains.

The various recharge and discharge rates of the Wadi Surdud aquifer are based on information derived from an inventory study, situation 1984 (Van der Gun, 1986).

a. Inflow of groundwater in the eastern part of the model area: 30 x 10^6 m^3/year.

b. Infiltration of water from the Wadi to the aquifer system:
21.3×10^6 m^3/year.

c. Evaporation of water in the 'sabkha' zones near the coast
25×10^6 m^3/year.

d. Net groundwater abstraction rate. This is equal to the groundwater abstractions minus the return flow:
77.35×10^6 m^3/year.

From the above mentioned information it can be derived that in the initial steady-state situation, prior to groundwater abstractions, the natural groundwater discharge to the Red Sea was approximately
$30 + 21.3 - 25 = 26.3 \times 10^6$ m^3/year.
It should be mentioned that the data, presented here, slightly deviate from more recent information (Van der Gun & Wesseling, 1990), which was based on more detailed investigations.

Thus the total discharge of groundwater currently is approximately twice the average rate of recharge and, consequently, will cause storage depletion of around 0.5 m/year.
Natural discharge of groundwater will diminish only very slowly, because of inertial effects of the aquifer.

3. LOCAL STUDIES

This chapter contains the results of a local study on the upconing of the fresh/salt interface under variation of various parameters influencing the position of this interface.

3.1 Introduction

In many geohydrological situations a layer of fresh groundwater is present above a layer of salt groundwater. This might be the case in a situation where fresh infiltration water flushes the upper part of a saline marine aquifer. A stratification like this of fresh groundwater on top of salt groundwater is stable because the salt water has a higher density than the fresh groundwater. As a result this situation might continue to exist for a very long period of time.

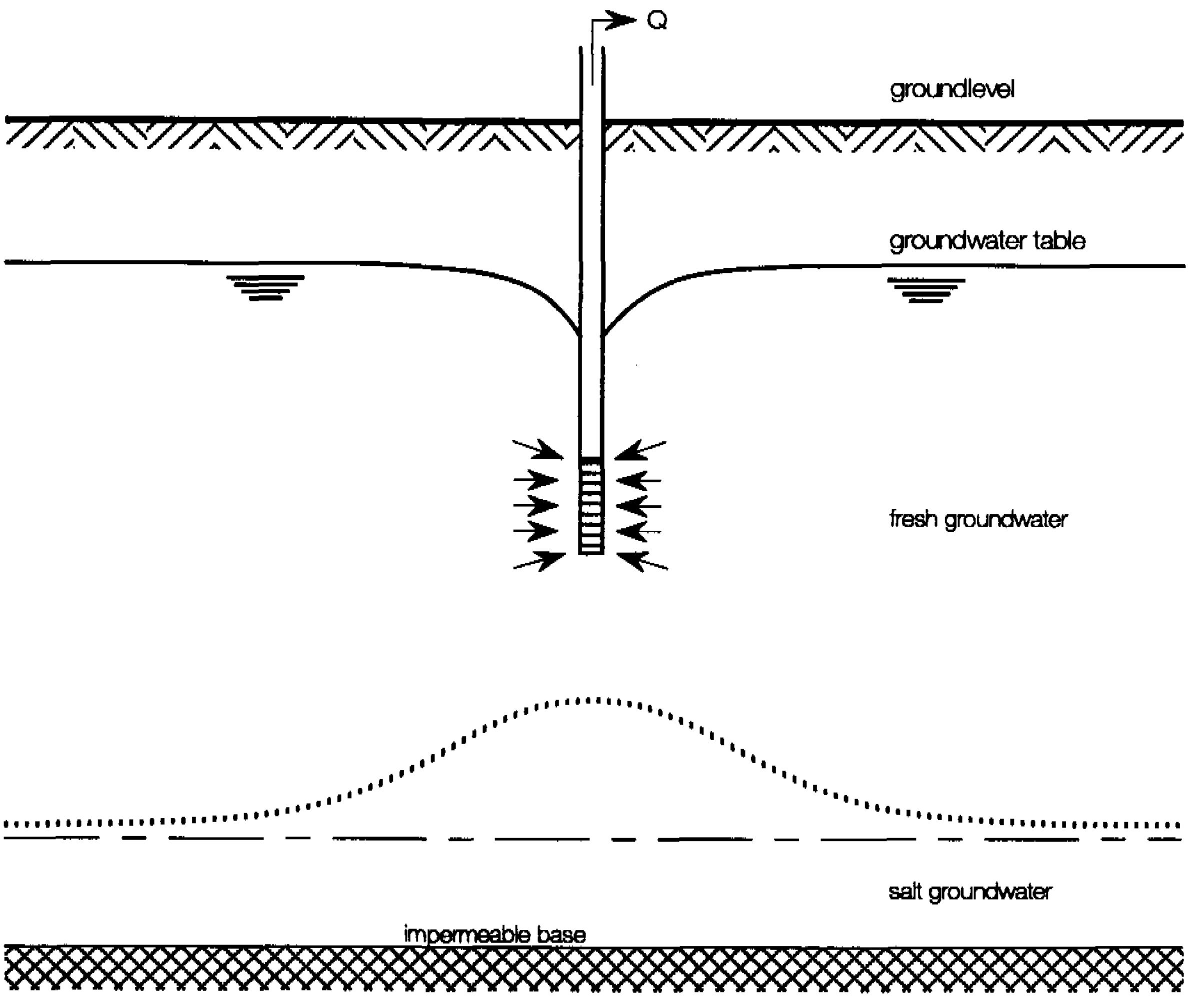
However, due to human interferences in these systems, the original stable situation may be disturbed. This may be the case, for example, when an abstraction well is installed to abstract fresh groundwater. Such a well, which is completed in the upper part of the aquifer, which contains the fresh groundwater, causes a decrease of the pressure around the well screen. As a result, groundwater will not only flow horizontally to the well screen, but also from below the screen in upward direction. This upward groundwater flow, just below the pumping well causes an upward movement of the fresh/salt interface (fig. 9).

Depending on the abstraction rate, depth of the fresh/salt interface, permeability characteristics and length and depth of the pump screen the salt/fresh interface will rise. Under unfavourable conditions, e.g. using high abstraction rates, the fresh/salt interface might even reach the lower part of the pump screen. In that case the salt water will enter the lower part of the screen and will mix with the fresh water that is abstracted with the upper part of the screen.

As the chloride concentration of the salt, marine formation water usually is very high, e.g. 15000 - 20000 mg/l, even a low ratio of abstracted salt water/fresh water will result in a chloride concentration of the abstracted water which is too high to be used for drinking- or irrigation purposes.

This has the practical consequence that a well has to be closed as soon as the fresh/salt interface reaches the well screen. For this reason, progressive upconing of the fresh/salt interface has to be prevented as much as possible especially because it is almost impossible to restore the original situation.

In order to prevent undesired effects of groundwater abstractions, such as upconing, a groundwater model can be used to predict the upconing of



——— — initial boundary between salt and fresh groundwater

·············· boundary between salt and fresh groundwater after a period of groundwater pumping

Figure 9: Upconing of salt water under pumping well.

the fresh/salt interface. Such a model enables the user to simulate various situations and to calculate the effects of various abstraction scenarios. In this way such a model can be a precious tool for water management purposes, and it enables water planning authorities to take into account these effects of groundwater abstractions in their long term planning.

3.2 The SWIP-model

In this particular case the SWIP-model (Vernon Ichimura, 1982) has been used for a series of local simulations. The SWIP-model is a three-dimensional transient solute transport model. It enables the user to calculate both groundwater head and solute concentrations, in this particular case salt concentrations. The computer code takes into account the effects of pressure, temperature and salt concentrations on fluid properties such as density and viscosity. In this case the solution is governed by two coupled partial differential equations that describe fluid pressure and salt concentration.
The differential equations are coupled, because on one hand the salt concentration influences the density and thus hydraulic head or pressure distribution, on the other hand does the head or pressure distribution influence groundwater flow and thus salt transport and salt concentration. In the computer code the partial differential equations are replaced by a finite difference approximation. By dividing the flow domain in a number of blocks or cells (discretization in space) the user can calculate both groundwater head and salt concentration in each node, which values are supposed to be representative for the whole grid block.

SWIP uses a direct solution technique (Gauss 3D) to solve the set of equations. This technique includes an optimum ordering scheme to obtain minimum computing time and storage (Vernon Ichimura, 1982).

The input of the SWIP-model merely contains information on fluid and aquifer characteristics, boundary conditions, initial conditions of salt concentration and pressure distribution, discretization in time and space, well characteristics and choice of solution technique. Furthermore, information should be included on output requirements.

3.3 Simulated cases

The SWIP-model has been used to simulate 12 different cases. The main variables in these simulations were: pumping rate, well depth and anisotropy factor. This factor is the ratio between horizontal- and vertical permeability. The well depth is measured with respect to the initial (static) water level. The various combinations of parameters for each specific case are listed in table 3.

Table 3 Simulated cases for local studies.

scenario nr.	well depth (m)	anisotropy factor	pumping rate (l/sec)
1	2	100	10
2	2	1	10
3	2	100	25
4	2	1	25
5	40	100	10
6	40	1	10
7	40	100	25
8	40	1	25
9	100	100	10
10	100	1	10
11	100	100	25
12	100	1	25

3.4 Geohydrological Schematization

The simulations are performed in a geohydrological system which is representative for the Wadi Surdud area. The groundwater flow near the well is supposed to be radial symmetric. This means that no neighbouring wells are regarded, that no inhomogeneities do occur and that both initial and boundary conditions are radially symmetric as well.
The simulated aquifer/aquitard system has a thickness of 600 m, and consists of 3 layers, each with its own permeability (hydraulic conductivity) (table 4).

Table 4 Permeability characteristics of radial symmetric model.

layer no	depth (m) below SWL	permeability (m/d)	transmissivity (m^2/d)
1	0 - 50	20	1000
2	50 - 300	1	250
3	300 - 600	0.002	0.6

The base of the system is supposed to be impervious. The initial salt distribution for each case is as follows:

- fresh water in the aquifer from 0 - 250 m depth
- salt water with chloride concentration 20000 mg/l at depth of 250 - 600 m

3.5 Discretization

The subdivision of the 3-dimensional space in a number of grid blocks is called spatial discretization. This discretization should be done taken into account the permeability distribution of the aquifer, well depth, initial depth of the fresh/salt interface, pumping rate and expected upconing. Moreover it should be noticed that that the discretization chosen should cover all simulated scenarios in order to facilitate comparison of the results of the different scenarios. In other words the discretization chosen should be applicable for each of the scenarios. In vertical direction a discretization into 28 blocks was made. The grid blocks have - from top to bottom - thicknesses (m) of respectively:

1	1	1	2	2	3	5	5	10	10
10	10	20	20	25	25	25	25	25	25
25	25	50	50	50	50	50	50		

The horizontal spatial discretization is a function of the distance to the pumping well. This distance (m) from the centre of the well to the centre of a grid block increases logarithmically and is respectively:

1.00	1.44	2.08	3.00	4.33	6.25
9.02	13.02	18.79	27.11	39.12	56.45
81.45	117.53	169.58	244.69	353.06	509.44
735.08	1060.66	1530.45	2208.31	3186.40	4597.70
6634.10					

for the successive blocks. The size of the successive grid blocks increases accordingly.
For the discretization in time, time steps of 1000 days have been used.

3.6 Results

The results of the various cases are presented in figure 10 through 16. For each case the position of the 1000 mg/l contourline after 100 years of abstraction is presented. To facilitate comparison of the various cases, each figure contains the results of comparable situations, in which only one of the variables is altered. This will enable the reader to get an fairly good impression of the influence of the various parameters on the process of upconing.
Figure 10 shows the position of the 1000 mg/l chloride contourline for scenarios 1, 5 and 9 after ca. 100 years of pumping at a rate of 10 l/sec (= ca. 315000 m^3/year), assuming an anisotropy factor of 100.

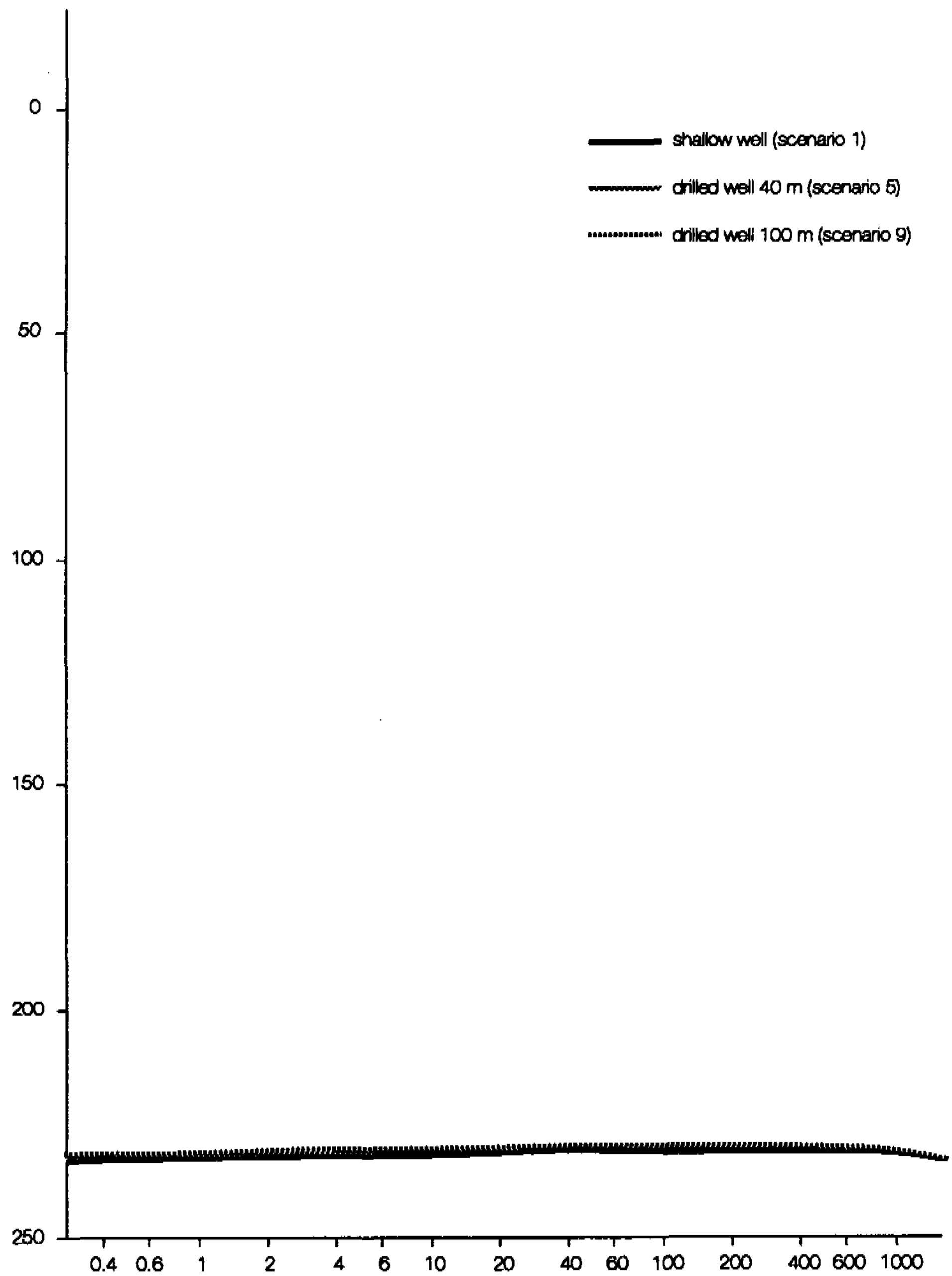


Figure 10: Location of 1000 mg/l contourline, with $\frac{k_h}{K_v} = 100$, and abstraction rate = 10 l/s, after 100 years of abstraction.

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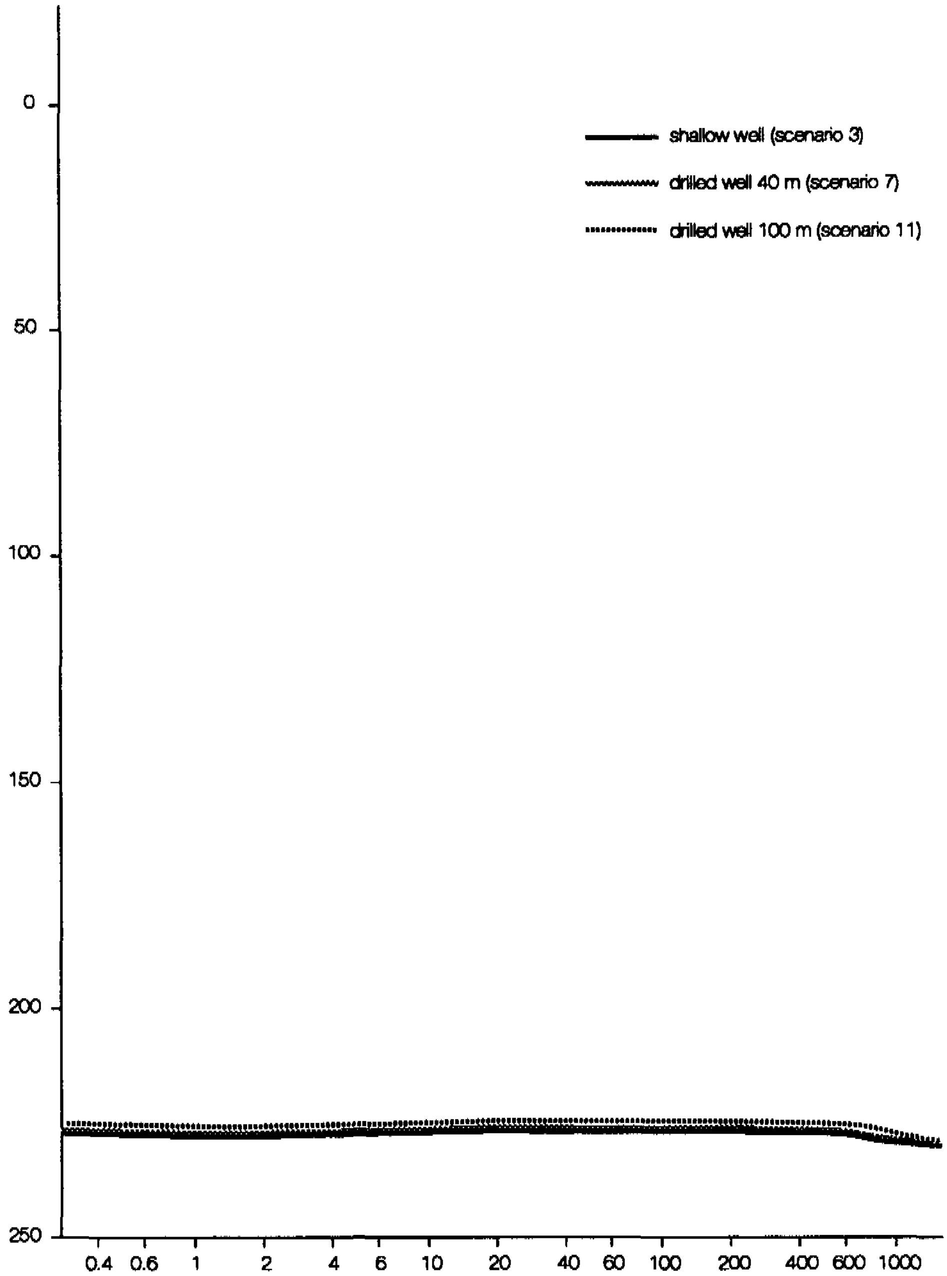

Figure 11: Location of 1000 mg/l contourline, with $\frac{k_h}{k_v} = 100$, and abstraction rate = 25 l/s, after 100 years of abstraction.

This figure shows that in these cases hardly any upconing does occur. The high anisotropy factor of 100 prevents upconing of the salt/fresh interface for each of the three well configurations, even after this long period of time.
Figure 11 shows the results of simulations with an abstraction rate of 25 l/sec. All other variables are identical to those presented in figure 10. Figure 11 shows that even with a high abstraction rate of 25 l/sec (= ca. 788000 m^3/year) the upconing of the fresh/salt interface is very much limited in case of an anisotropy factor of 100.
Figure 12 shows the isohaline of 1000 mg/l after 100 years of pumping at a rate of 10 l/sec from an isotrope aquifer (anisotropy factor =1). In this case the upconing of the fresh/salt interface is considerable, though for none of the three well configurations the salt water reached the well screen within 100 years. The well with the screen depth of 100 m causes a faster upconing of the fresh/salt interface than the other two wells. This combination of faster rising of the interface and the deeper location of the screen causes a considerable sooner breakthrough of the salt front in the well of 100 m depth than in both other wells.

Figure 13 through 16 show the transient upconing of the salt front in an isotope aquifer and an abstraction rate of 25 l/sec. The isohaline lines of 1000 mg/l chloride are shown after 11, 22, 55 and 100 years of pumping respectively. The pictures show a relatively fast rising of the salt front. After 22 years (fig. 14) none of the three wells will suffer inflow of salt water yet. This figure also shows that the salt front is lifted faster if the well screen is deeper.

Figure 15 shows that after 55 years the deep well of 100 m depth already is confronted with salt water inflow in a considerable part of the screen. This figure also shows that the fresh/salt interface did not yet reach the screen of the well of 40 m depth after 55 years.

For the various well configurations figure 16 shows a further upconing of the salt fronts after 100 years. It also shows that the breakthrough in the shallow well is about to begin after 100 years of abstraction.

It can be concluded that in a isotropic situation with an abstraction rate of 25 l/sec eventually for all well configurations a breakthrough of the salt front will occur. In case of a shallow well it will take ca. 100 years before the front breaks through, and it will take ca. 40 or 60 years for the wells with a depth of 100 or 40 m respectively.

Due to the stratified nature of the rock, anisotropy will be there; it is expected that an anisotropy factor of 100 is not exaggerated.
Hence salt water upconing seems not a serious hazard to groundwater abstractions in the Wadi Surdud Area, as long as the well screen is in the fresh domain and at rather great distance (>100 m) from underlying salt water.

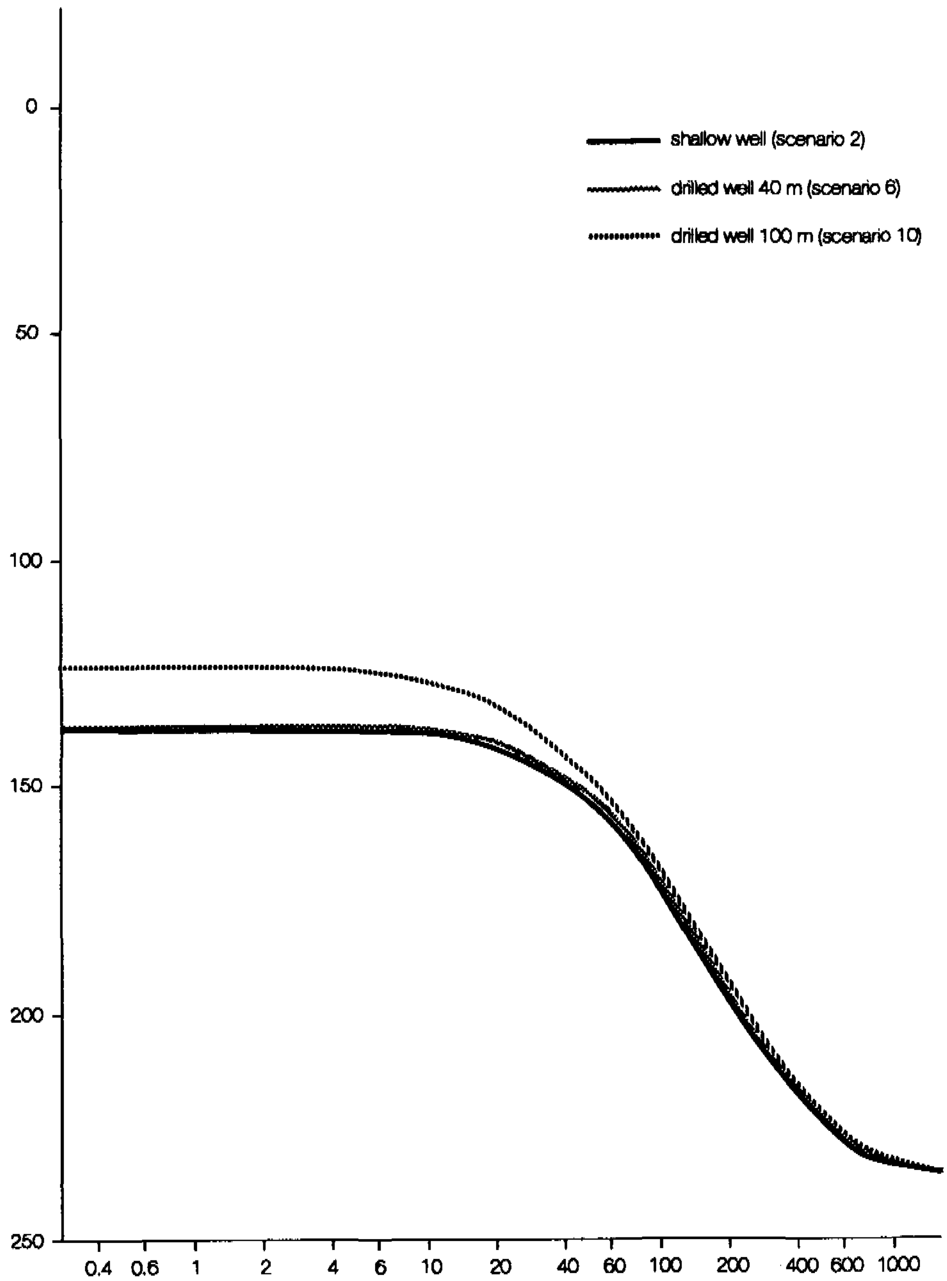

Figure 12: Location of 1000 mg/l contourline, with $\frac{k_h}{k_v} = 1$, and abstraction rate = 10 l/s, after 100 years of abstraction.

el. 83

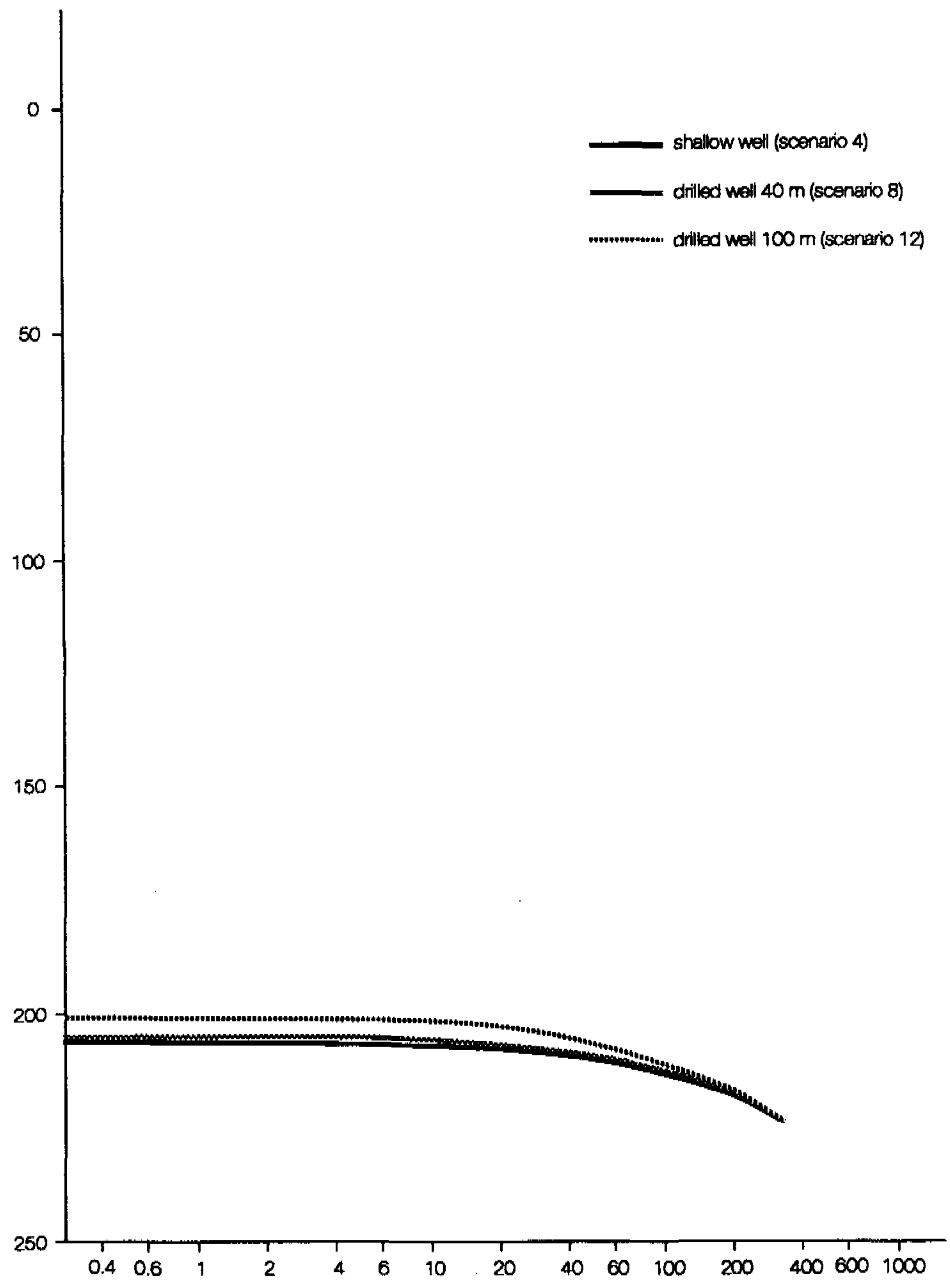

Figure 13: Location of 1000 mg/l contourline, with $\frac{k_h}{K_v} = 1$, and abstraction rate = 25 l/s, after 4.000 days (ca. 11 years).

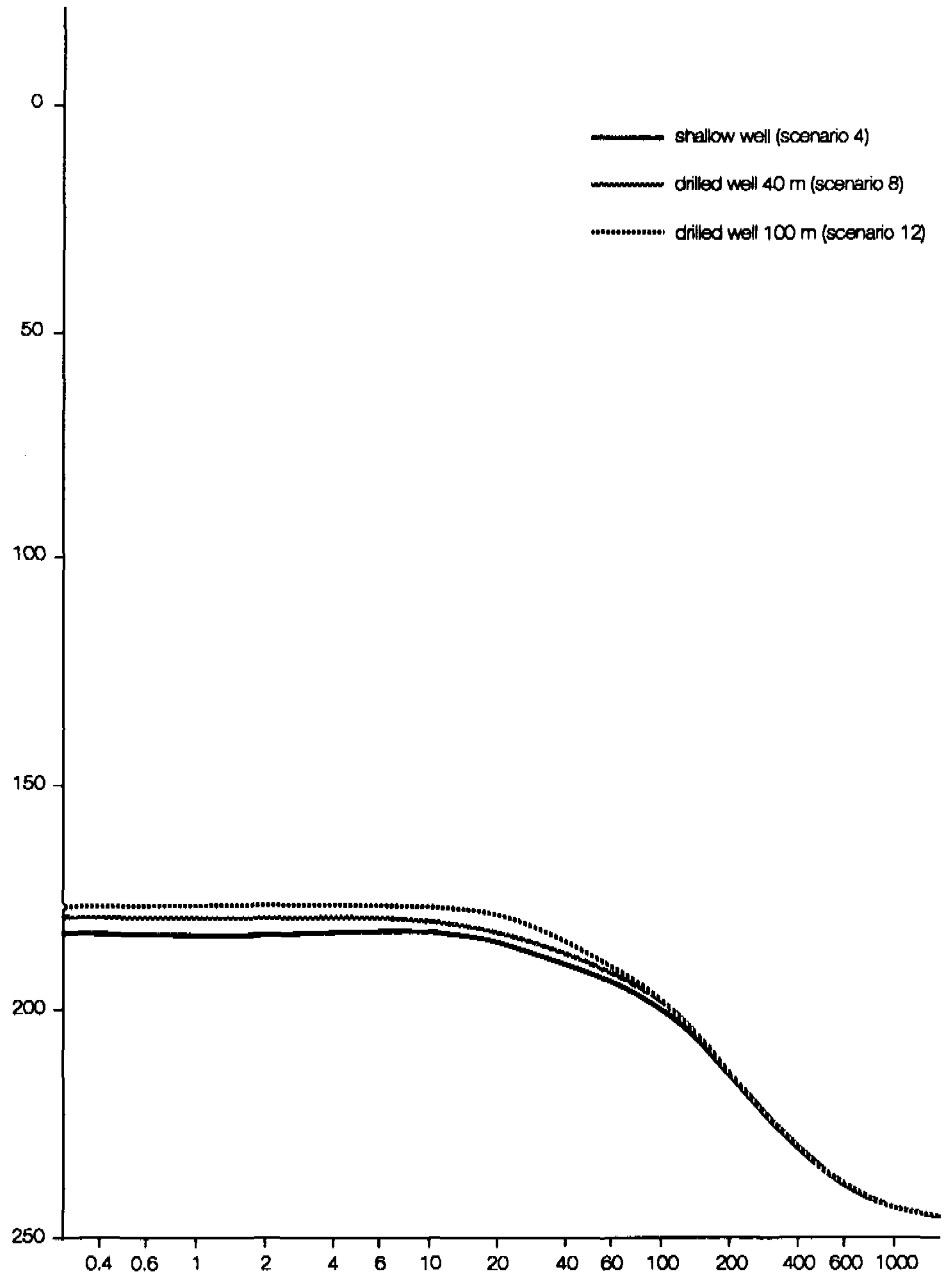

Figure 14: Location of 1000 mg/l contourline, with $\frac{k_h}{k_v} = 1$, and abstraction rate = 25 l/s, after 8.000 days (ca. 22 years).

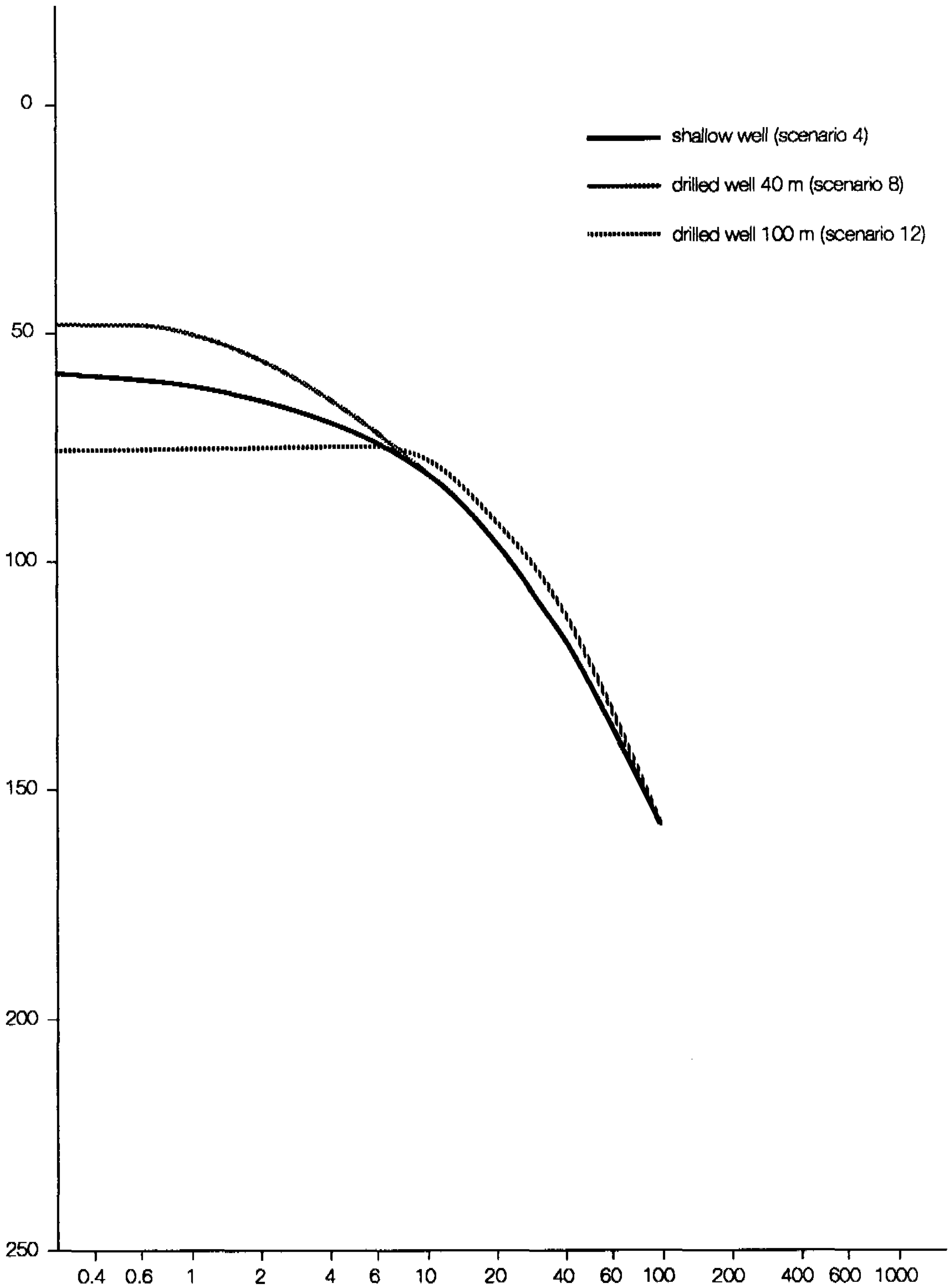

Figure 15: Location of 1000 mg/l contourline, with $\frac{k_h}{k_v} = 1$, and abstraction rate = 25 l/s, after 20.000 days (ca. 55 years).

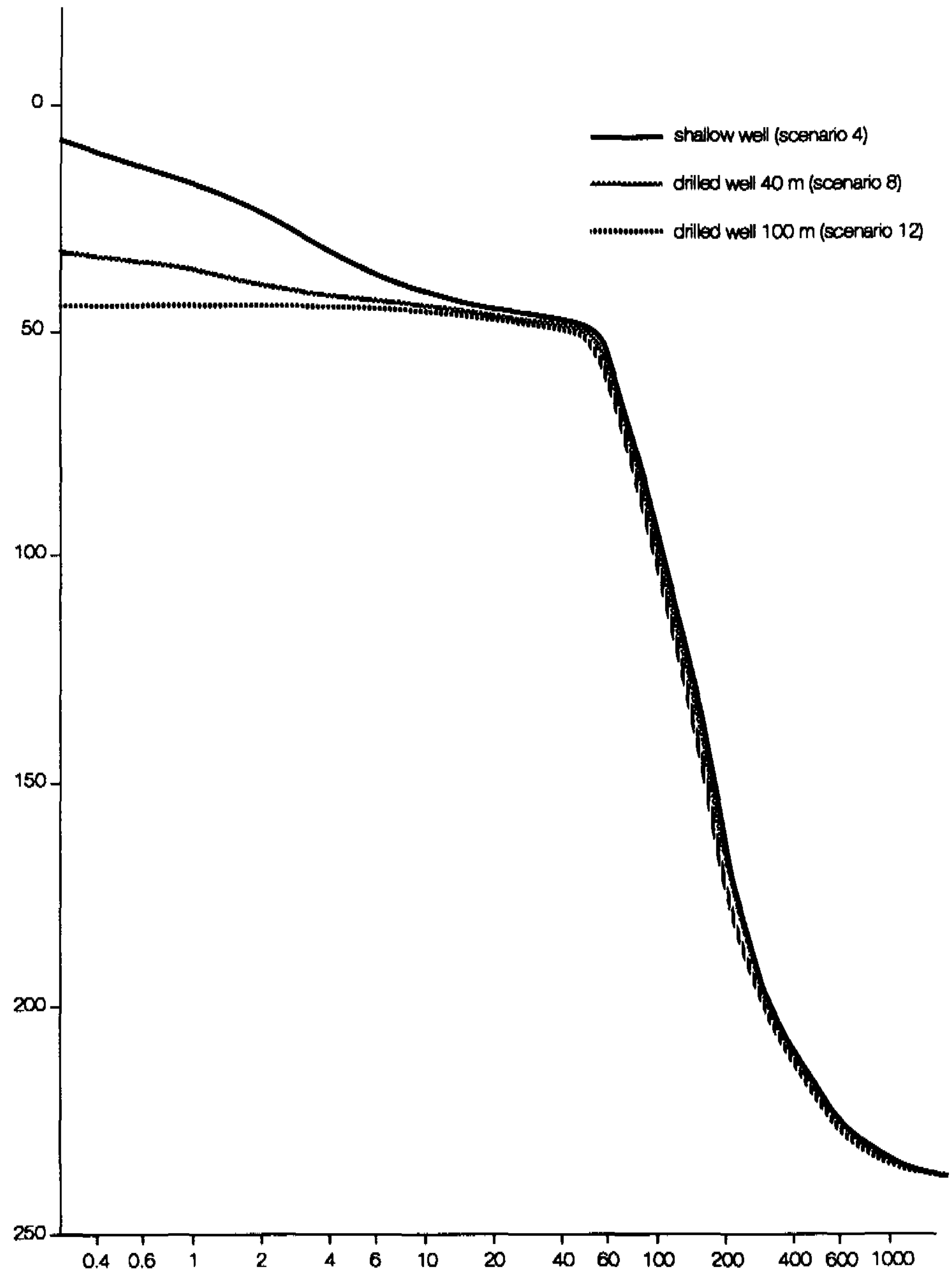

Figure 16: Location of 1000 mg/l contourline, with $\frac{k_h}{k_v} = 1$, and abstraction rate = 25 l/s, after ca. 100 years abstraction.

d. s6

4. REGIONAL STUDIES

This chapter describes the set-up of a regional groundwater flow and interface model for the Wadi Surdud area. The model has been calibrated and next has been applied for various simulations. The results and the various physical processes involved are described in detail. In addition water balance studies are presented.

4.1 The BADON-3 program

In this part of the study the BADON-3 model has been used to calculate the position of the salt/fresh interface.
This model, developed by prof. A. Verruijt, is particularly suited to calculate the effects of human interference in the natural groundwater flow regime, such as groundwater abstractions, irrigation or drainage. These kind of human activities might cause considerable salt water intrusion and/or salt water upconing in coastal areas. The use of BADON-3 is recommended in these situations in order to provide information needed for an optimum aquifer management.

The BADON-3 program assumes a sharp interface between the fresh water body and the salt groundwater. In many coastal areas such a sharp interface exists. The BADON-3 program is based on the Dupuit assumption, which states that only horizontal groundwater flow occurs in both the fresh and the salt part of the aquifer. The program can be used both in confined or unconfined aquifers, for steady state as well as non-steady state flow conditions. The position of the fresh/salt interface, as well as the phreatic level of the fresh water are calculated after each user-defined time step.
The model is 2-dimensional, which means that both the phreatic level and the depth of the fresh/salt interface are calculated for each nodal point in the horizontal plain.
Each input parameter can be defined separately in each nodal point, allowing the user to take fully into account lateral variability of all input parameters, such as recharge, evapotranspiration, permeability etc.

The program is interactive and menu-driven, and as a result is user friendly. Once the input data is entered in the system the data can be changed by means of a spreadsheet-type of feature, which is part of the program. The results of the calculations can either be printed or be plotted. Contourplots of the results can be made by means of the SURFER program.
The programming language of the BADON-3 programme is Fortran 77.

4.2 Conditions for applicability

The BADON-3 program can be used on a Personal Computer. It is required to have at least 640kram and a mathematical co-processor. A harddisk is recommended. In order to make contourmaps or 3-D images of the results, installation of a printer and a plotting program is required. Such a program might be SURFER from Golden software, Colorado, USA. The BADON-3 program package includes interfaces to enhance communication between the BADON-3 program and SURFER.

In order to be able to perform numerical groundwater flow simulations next data should be available:
-lateral extent and thickness of the aquifer
-permeability and transmissivity distribution
-recharge and discharge data
-evapotranspiration
-surface water head
-relation between surface water and groundwater
-inflow from mountainous catchment area
-groundwater abstractions
-groundwater level contours
-porosity of the sediments
-storage coefficient (only for non-steady-state simulations)
-density of both fresh and salt groundwater
-salt-content of the water
-initial position of salt/fresh interface

As already shown in Chapter 2, extensive fieldwork and inventory studies have been performed in the Wadi Surdud area (Van der Gun, 1985 and 1986, Van Overmeeren, 1985 and 1986), allowing application of the BADON-3 model.

4.3 Summary of input data

This paragraph shortly describes the main input data for the regional groundwater flow simulation. The project area is shown in figure 17. The total project area is 57.5 by 42.5 km. This figure also shows the spatial discretization. In this particular case a grid size of 2.5 by 2.5 km has been used.
The total number of nodes in the model is 432. The node numbering is shown in Annex 4. The number of elements is 391. The numbering of the elements is shown in Annex 5.
As will be explained in paragraph 4.6 the thickness of the aquifer in the model is 450 m, and the reference level in the model is 200 m + M.S.L.

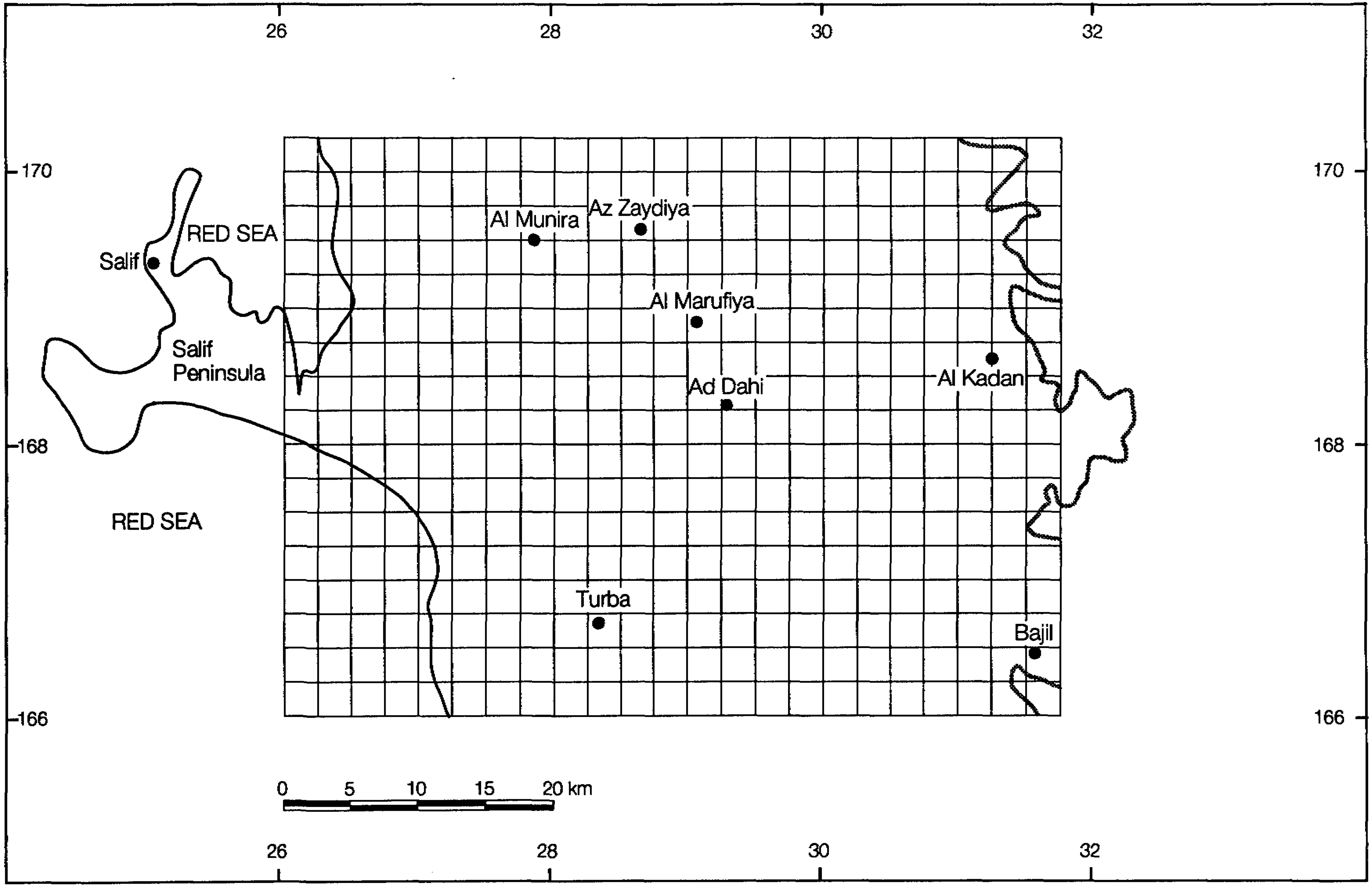

Figure 17: Project area with model discretization.

The density of fresh and salt water is 1000 and 1025 kg/m^3 respectively. These values are supposed to be representative for the entire flow domain. The effective porosity of the aquifer (near the interface) and the phreatic storage coefficient both are 0.15. The current version of the Badon-3 model does not make a destinction between both parameters. This is why one value has to be entered to represent both parameters.
Nodes that coincide with the Red Sea have a more or less fixed water level, which is independent of groundwater abstractions. These nodes are represented in the model by fixed head boundary conditions. These fixed head boundary nodes are presented in Annex 6. Apart from these fixed head boundaries in the west, all other lateral boundaries of the area are represented by no-flow boundary conditions.
At the eastern model boundary the aquifer is bounded by impermeable hardrocks, which is the reason why the no-flow boundary is realistic. At the northern and southern boundaries the groundwater flow is more or less parallel to the boundary edge. In these situations, too, a no-flow boundary is quite realistic from modelling point of view, though there is no impervious boundary in reality.

In Annex 7 the infiltration rates are presented. Notice that the negative infiltration rates in the Sabkha zone, near the Red Sea, actually represent evaporation.

The complete input data set is included in Annex 8. This annex consists of two sections.
In the first section information is presented per node. In eight columns next input parameters are printed for each node:

node number	(node)
x-coordinate (m)	(x)
y-coordinate (m)	(y)
node type	(F/Q)
initial condition for groundwater level (m)	(F_0)
initial condition for depth interface (m)	(h_0)
abstraction rate of fresh groundwater (m^3/day)	(Q_f)
abstraction rate of salt groundwater (m^3/day)	(Q_s)

The origin of the x- and y-axes is in the South-Western corner of the project area. This origin has the following coordinates: 42°45'35.4" east and 15°1'28.2" north.
In the second section next input parameters are presented per element:

element number	(element)
nodes (four columns)	(nodes)
permeability of the upper aquifer part (m/day)	(k)
infiltration rate of fresh water (m/day)	(I_f)
infiltration rate of salt water (m/day)	(I_s)

Apart from the numerical information given in Annex 8, the Annexes 1 through 3 provide mapped input data. These maps respectively represent:

Annex 1: Transmissivities (m^2/day)

Annex 2: Initial phreatic head (m)

Annex 3: Initial depth interface (m)

Time discretization

The groundwater level and the depth to the interface have been calculated at next moments of time (days):

50	100	150	200	300	400	500	700
900	1200	1500	1800	2200	2700	3300	4000
5000	6000	7000	8500	10000	12000	15000	18250
22000	26000	31000	36500	41000	45500	50000	54750
59000	63000	68000	73000				

If the simulation is done for all these time steps, a total period of 200 years has been covered.

At the beginning of the simulation small time steps have been chosen (50 days) to prevent numerical instabilities in the numerical calculations. During the simulation the time steps are gradually magnified, thus limiting the total number of time steps, and computation time.

4.4 Calibration

The hydraulic stress (recharge and discharge) of the aquifer system results in changes in hydraulic head that can be measured as groundwater heads in observation wells. When correct aquifer parameter values are used in the numerical model, the simulated groundwater levels should correspond with the measured ones. Calibration or "history matching" is the process by which the model parameter values are adjusted until the simulated and measured groundwater levels correspond. This type of calibration often is referred to as "trial and error".

Since the discrepancy between simulated and measured heads is not solely due to errors in aquifer parameter values, care is required in adjusting these parameters. Discrepancy may also be caused by:

- errors in aquifer schematization and discretization
- errors in measured and interpolated groundwater heads
- errors in other nodal parameters, such as recharge
- too great a model simplification of the real situation

The transmissivities derived during the calibration process are presented in Annex 1. At this map several sub-areas with distinct transmissivities

can be detected. First of all it should be noticed that the highest values (1000 - 5000 m^2/day) do occur in the western half of the aquifer. This area roughly coincides with the aeolean deposits (zone 2b of fig. 4). In the eastern half the aquifer transmissivity is less (500 - 2000 m^2/day). This part of the aquifer coincides approximately with the alluvial plain (zone 2a of fig. 4).
Pumping tests near the coast indicated maximum transmissivities of ca. 3000 m^2/day. The calibration, however, indicated considerable higher values. Due to the very small groundwater head gradient, the best fit in this part of the aquifer was obtained for transmissivities of ca. 7000 m^2/day. Finally it was decided to use a value of 5000 m^2/day, as a compromise between both pumping tests and model calibration runs.
During the calibration transmissivities of ca. 1000 m^2/day were derived in the eastern part of the aquifer, where Wadi Surdud infiltrates. These values very well confirmed the results of pumping tests performed in this part of the aquifer.

In the North/Western part of the aquifer very low transmissivities were found in the zone near the salt diapir (Jebel Qumah). Of course, this was to be expected.
Finally low transmissivities are found in the far North/East and South/East corners of the project area. These areas coincide with fine grained and silty parts of the aquifer, somewhat remote from the major sources of recent sediments (main wadis).

4.5 The "Flushing" of Tertiary Strata

It can be expected that the Tertiary Strata are far less permeable than the Quaternary Strata. However, no field data on the permeability of these Tertiary Strata are available. To overcome this lack of information, some numerical experiments have been performed, in order to obtain an indication of the permeability ratio between Quaternary and Tertiary Strata.
Knowledge of the permeability of Tertiary Strata will help in understanding of geohydrological system and its response to man-induced changes, like abstractions. It especially will provide information to be used in modeling of upconing. Furthermore boundary conditions for regional salt intrusion studies can be obtained.
From this information e.g. the justification of the assumption of an impervious boundary at the base of the Quaternary Strata could be checked.

The current three-dimensional distribution of fresh and salt groundwater has been investigated quite thoroughly. Field methods used are resistivity surveying, exploratory drilling, geophysical well-logging and water quality sampling (Van der Gun, 1986 and Van Overmeeren, 1985). It was found that the salt water front roughly coincides with the boundary between Quaternary and Tertiary Strata in the major part of the aquifer. Only in the coastal zone a salt water wedge penetrates the quaternary deposits.
The current location of the salt/fresh interface at the boundary of Quaternary and Tertiary Strata is, according to the Badon-Ghyben principle, not in equilibrium with the current groundwater head. In the steady-state position the fresh/salt interface should be positioned considerably deeper than the current location. This indicates that the "flushing" of the marine Tertiary Strata by fresh groundwater still continues, but is considerably retarded. The only explanation for this can be that the resistivity to flow in the Tertiary Strata is considerable. In other words: the permeability of these strata is very low.

To check this hypothesis several numerical simulations have been performed, using the Badon-3 program and the calibrated model of the Wadi Surdud area.
First, however, the Badon-3 program had to be adjusted to take into account horizontal layering. These model extensions have been performed in cooperation with prof. A. Verruijt, Technical University, Delft, The Netherlands.
Next the adjusted model has been applied to simulate the flushing of the Tertiary Strata during the entire Quaternary period.
In the initial condition the fresh/salt interface coincides with the boundary between Tertiary (marine) and Quaternary (terrestrial) deposits. For several permeability ratios between Quaternary and Tertiary sediments the transient process of flushing of the Tertiary sediments by fresh groundwater has been simulated for the entire Quaternary period, i.e. 2 million years.
The results of these simulations are shown in figure 18. It is evident that a permeability of zero for the Tertiary Strata will prevent any flushing of these strata. The higher the permeability of these strata the faster the flushing process will progress.
Comparing the results of the simulation with the actual position of the fresh/salt interface provides the indication that the permeability of the Quaternary deposits are at least a factor 25000 higher than the permeability of the Tertiary deposits.

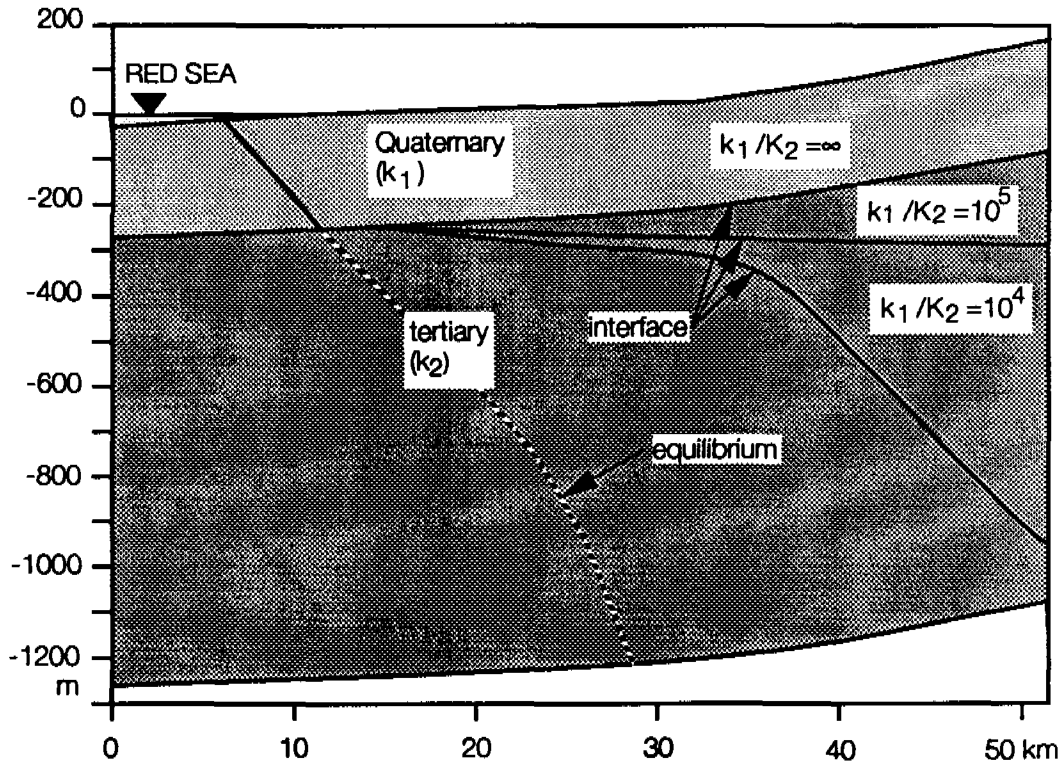

Figure 18: The displacement of the salt-fresh interface over the duration of the entire Quaternary period.

It is true that the model neglects a large number of details and does not take into account factors such as the varying hydrological and climatological boundary conditions, the gradual deposition of the Quaternary strata and the tectonic events in the Red Sea Graben, which caused the top of the Tertiary strata to sink at a non-uniform rate. Nevertheless, the simulations clearly demonstrate, that the permeability of the Tertiary Strata must be very low. This means that discharge of fresh groundwater and sea water intrusion are almost completely restricted to the Quaternary strata.

4.5.1 Stability of the numerical simulations

At this point some remarks should be made on instability of the numerical calculations. Instability is the phenomenon that inaccuracies in the results are magnified in every successive timestep of the simulations. This might result in irrealistic solutions that don't make sense at all.
Though the program Badon-3 is provided with an option to suggest a time discretization, it was found that this does not guarantee that instabilities in the numerical process are prevented. Due to the extremely long period of the simulation (over 1 million year) the calculation process was very sensitive for the time discretization. It was found that the stability of the solution could be considerably improved by:

- proper calibration of the model
- proper initial conditions of the phreatic level
- proper initial conditions of the fresh/salt interface
- proper time discretization

Finally, results were obtained in which instabilities were suppressed.

4.6 The effects of different abstraction scenarios

In previous section the calibration of the Badon-3 model for the Wadi Surdud area is described in detail. This calibrated model now can be used to perform numerical simulations. In this way the effects of future groundwater abstractions can be made visible, offering groundwater management authorities the possibility to balance pros and cons of the different scenarios. Thus these simulations can help to delineate proper abstraction scenarios, to minimize negative effects and to promote adequate development and management of groundwater resources.

In order to arrive to a simulation as realistic as possible the quaternary deposits are divided in two separate layers with different permeabilities. The top layer in the east side of Wadi Surdud has a much higher permeability, than the lower part. In schematization this highly

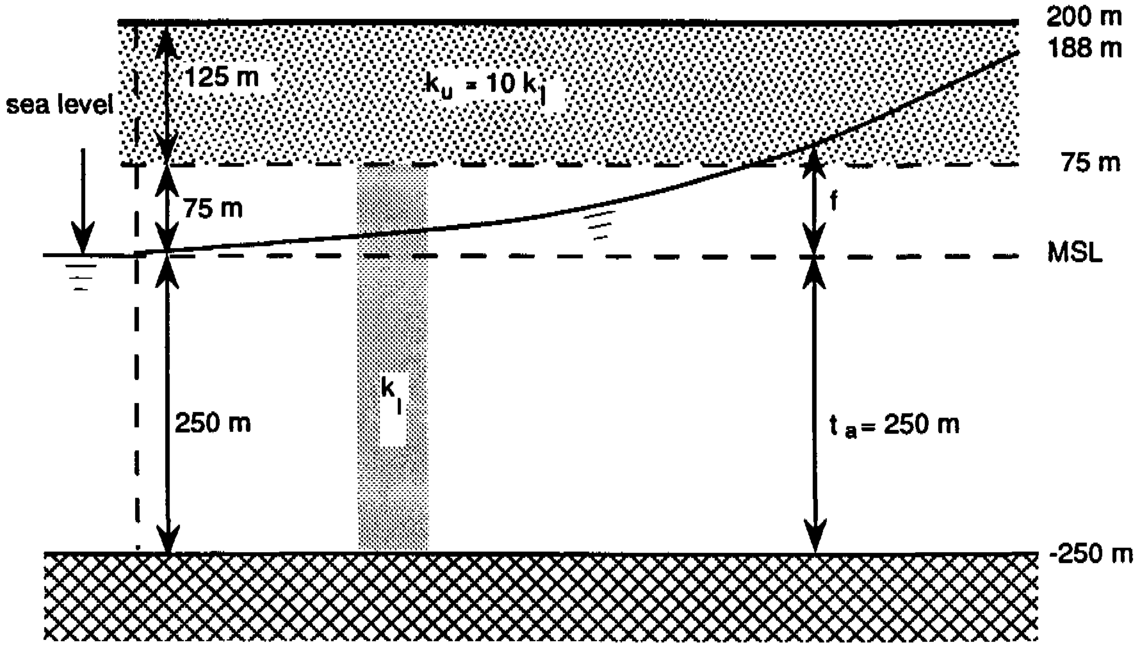

Figure 19: Schematization of layered Quaternary deposits.

permeable layer was introduced for the part of the aquifer situated above a level of 75 m +M.S.L. (fig. 19).

During the simulations a ratio of 10 has been used for the contrast in permeability (ku/kl). In each node the permeabilities were chosen such that the resulting transmissivities equal those used during calibration.
In Badon-3 only the permeability of the upper part and the permeability ratio have to be entered. Here two different cases should be distinguished: 1)phreatic level is below 75 m +M.S.L., and 2) phreatic level is above 75 m +M.S.L.
In case of phreatic levels below 75 m +M.S.L. the entire saturated zone is situated in the lower, less pervious aquifer. For these nodes a permeability of the upper part should be entered, which is 10 times as much as the permeability used for the case where no layered system is modeled.
In case of phreatic levels above 75 m +M.S.L. the permeability of the upper part can be derived from:

$$T(old) = T(new)$$

or:

$$(ta+f).ku(old) = (f-75).ku(new) + 0.1\ ku(new).(ta+75).$$

From this equation an expression for ku(new) can be derived:

$$ku(new) = \frac{(ta+f).ku(old)}{f-75 + 0.1\ ta + 75}$$

or:

$$ku(new) = \frac{(f+250).ku(old)}{f - 42.5}$$

In these expressions:

T = transmissivity (m^2/d)
ta = thickness aquifer from base until M.S.L.
ku = permeability upper part (m/d)
f = phreatic head in m above M.S.L.

After the permeabilities in all nodes had been adjusted according to above mentioned method the actual simulations could start. Three different abstraction scenarios have been analysed:

scenario 1: abstractions predominantly concentrated in the east (current situation)
scenario 2: abstractions predominantly concentrated in the west
scenario 3: abstractions predominantly concentrated in the central part

All abstractions were assumed to remain constant during the entire simulation period.
From a well inventory the total amount of abstractions could be estimated. For each of the above mentioned scenarios the total amount of

net abstractions is equal to 212000 m^3/day. The only difference between the various simulations is the spatial distribution of the abstraction wells.

The abstraction rates from each element are shown in Annex A1, B1 and C1 for the respective scenarios.

4.6.1 Total simulation time

The total period of time for which the calculations have been performed is 200 years for each scenario. A shorter time period has not been chosen, because the effects of fresh groundwater abstraction on drawdown and saltwater intrusion is a long term process, meaning that these effects especially will be evident on a long term time scale like this.

Though the situation with regard to both drawdown and saltwater intrusion will continue to get worse after 200 years a longer simulation period has not been chosen because it is not very likely that the abstraction schemes, as they will occur in reality, can be foreseen for such a long period. The simulations based on these schemes as a result would be considerably more uncertain, if longer simulation times would have been applied.

The 200 year time period seems to be an acceptable compromise. It is long enough to give an indication of long term effects, and it is not too long to come up with 'meaningless' predictions of abstraction schemes.

4.6.2 Results of the simulations

The results of the simulations are shown in Annex A2 - A17, B2 - B17 and C2 - C17 for each of the three mentioned scenarios. For each scenario contour maps of next four variables have been created:

- Groundwater level (phreatic head)
- Depth of the fresh/salt interface
- Drawdown of the phreatic head
- Rising of the fresh/salt interface

The contour maps of all of these variables have been created at the time intervals: 50, 100, 150 and 200 years. As a result a total number of sixteen maps have been created for each scenario. Examination of the successive maps allows the reader to derive a basic understanding of the rate at which the various physical processes do take place, and to derive insight in the various transient processes.

Moreover, comparison of the corresponding maps for the separate scenarios provides information on the effect of location of wells on these processes.

In this section the results of the simulations are discussed briefly.

Groundwater level

Annex A2 - A5 show the phreatic head after 50, 100, 150 and 200 years, if the current abstraction will be maintained. It is clear that the phreatic heads continue to drop. In the western part of the aquifer the groundwater gradient is decreasing considerably and the total area with groundwater levels between 0 and 10 m +M.S.L. is expanding rapidly. After 200 years in the central part of the aquifer even a small area develops with groundwater levels below mean sea level. These low phreatic levels are due to groundwater abstractions. It can be assumed that continuation of the abstractions will lead to expansion of this area. As soon as the outer boundary of this area reaches the coast line outflow of fresh groundwater to the Red Sea will stop and instead seawater will penetrate the aquifer over the entire saturated thickness.

In the eastern part of the aquifer the groundwater levels are also dropping. It can be seen from these maps that the groundwater gradients in this part of the aquifer are increasing.

The corresponding maps of scenario 2 (abstractions in the west), Annex B2 - B6, show that an area with groundwater levels below sealevel is developing faster than in previous case. In addition this area is located closer to the Red Sea, indicating that fresh groundwater flow to the Red Sea will terminate faster and salt water intrusion over the entire saturated thickness will occur earlier than in previous case. It also can be remarked that the groundwater heads in the eastern part of the aquifer are affected less by the abstractions than in previous case.

The corresponding maps of scenario 3 (abstractions in central part) show situations that are more or less in between both situations regarded before.

Drawdown of groundwater level

Annex A10 - A13 show the drawdown of the phreatic head after 50, 100, 150 and 200 years continuation of current abstractions (scenario 1). The various maps clearly show that the largest drawdowns do occur in the mid-eastern part of the aquifer. The position of the actual greatest drawdown is a combination of 'high' abstraction rates and 'low' transmissivity. The maximum drawdown increases from ca. 30m after 50 years to 75m after 200 years, indicating a decreasing rate of drawdown.

The smallest drawdowns do occur in the west. The groundwater head near the coast is in direct hydraulic contact with the Red Sea. As the sea level won't change, the groundwater head at the coastline is also stable and the drawdowns are zero.

The drawdowns in scenario 2 (abstractions in the west) show a completely different picture than in the former case. In the first place it is clear that the calculated drawdowns are far less than in previous case. Actually in scenario 2 the largest drawdowns do occur in the far north and the far south of the line x=47500m. Though this scenario is called 'west' still 25% of the abstractions is located in the east, at line x=47500m, so it is clear that these small abstraction rates from the east cause even greater drawdowns than 75% of the abstractions in the west. Furthermore it should be noted that in the far north and the far south of the line x=47500 the transmissivities are relatively low, and cause the great drawdowns. If all the abstractions would have taken place from the west the maximum drawdown probably would be reduced to ca. 20 m, which is of coarse considerably less than the maximum drawdown of 75 m in case of current abstractions.

The difference between these two cases can be explained as follows. In scenario 1 groundwater abstraction predominantly takes place from the east, causing depletion of groundwater in the east (figure 20a). As, initially, the groundwater gradient near the coast is not affected too much by the abstractions in the east, the groundwater discharge to the Red Sea initially stays more or less constant. In that case the aquifer system loses both water from depletion and from discharge.
In scenario 2 the groundwater abstractions take place in the west, causing drawdowns in the west (fig. 20b). As a result the groundwater head gradient near the coast will decrease considerable in an early stage of the simulations, causing a considerable reduction in the discharge to the Red Sea. One might say that in this scenario the bulk of the abstractions is taken from the groundwater that would otherwise have been discharged to the Red Sea, and only a small part is taken from groundwater storage. The depletion of the aquifer will thus take place much slower than in scenario 1.

Annex C10 - C13 show a maximum drawdown of ca. 50m after 200 years abstractions in the central part (scenario 3). This maximum drawdown is located central north. At this location the transmissivity is less than in the south.

Salt water intrusion

One of the main objectives of this model study was to get to know the rate of the salt water intrusion for the various abstraction scenarios.
Annex A6 - A9 show the depth to the fresh/salt interface after 50, 100, 150 and 200 years continuation of current abstractions. When we compare these four maps in combination with Annex 3, Initial depth of the interface, we are able to derive the rate of salt water intrusion.

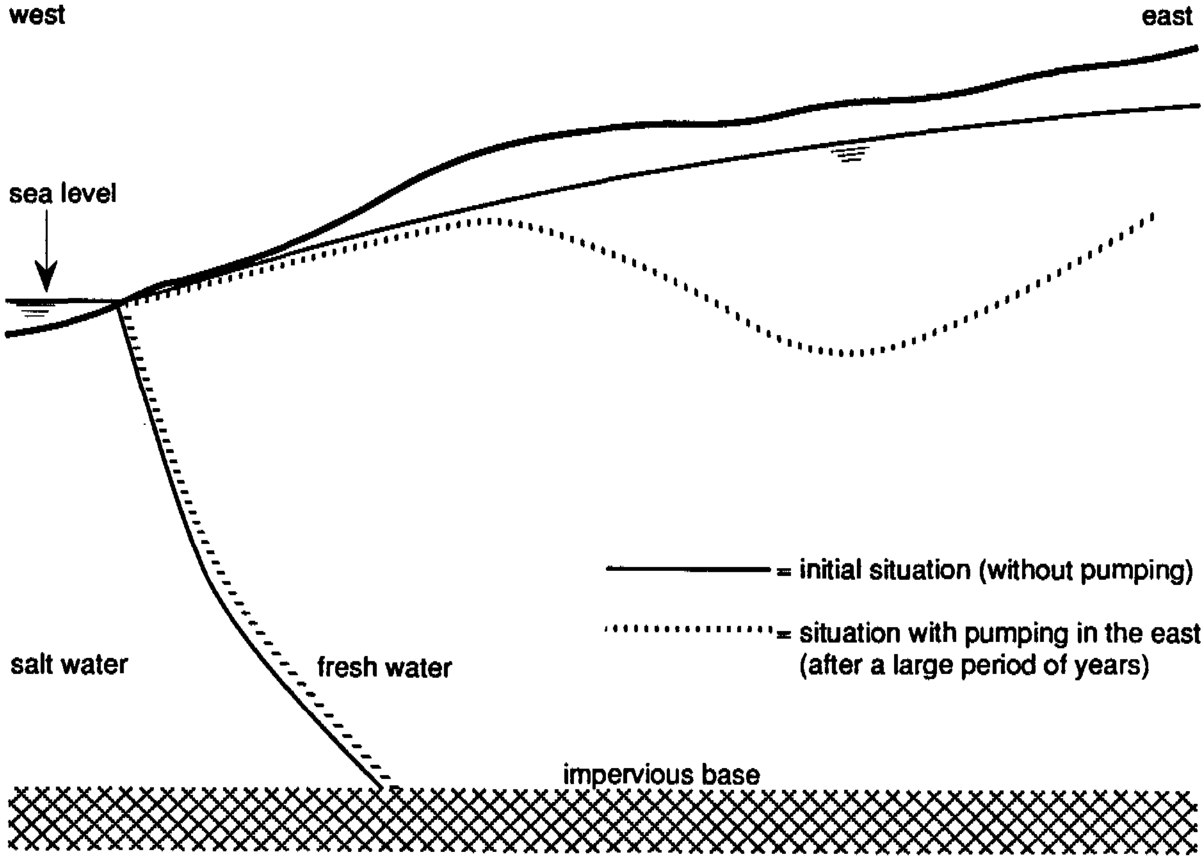

Figure 20a: Evolution of the watertable and salt water intrusion in case of abstraction wells located in the east.

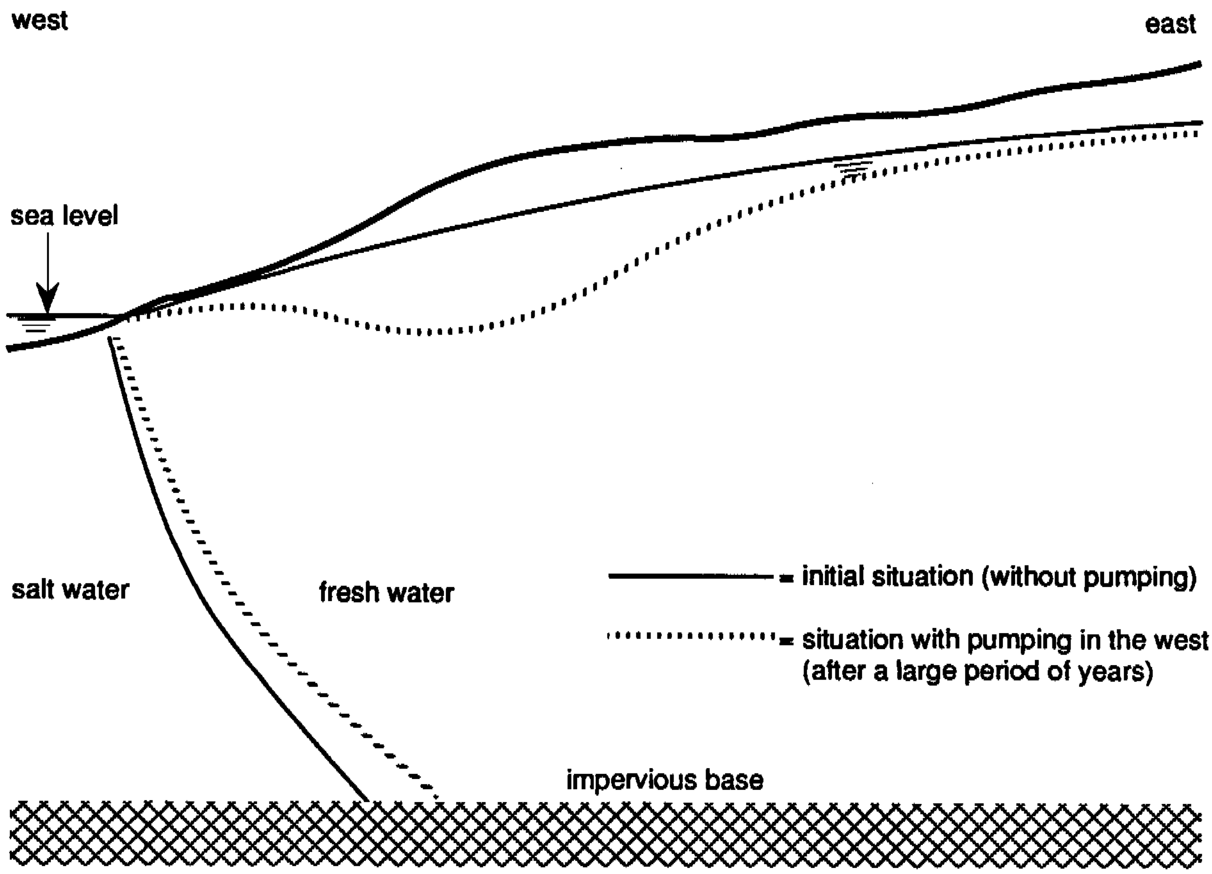

Figure 20b: Evolution of the watertable and salt water intrusion in case of abstraction wells located in the west.

We simply look how far the interface proceeded during the simulated time interval. When we divide this distance by the time interval we can derive the average rate of salt water intrusion during that interval.
It should be realised, however, that the actual rate of intrusion depends on:

1. Location along the coast. The rate of intrusion is larger in the southern part of the project area, as compared to the northern part.
2. The toe of the interface (deepest part) progresses considerably faster than the shallower parts of the same interface. For scenario 2 e.g. the toe progresses at an average rate of 40 m/year. At a depth of 160 m the rate of progress is 26 m/year. These are average rates for a period of 200 years at location y=10,000 m.
3. The rate of infiltration depends on the time elapsed since the beginning of the simulation. For scenario 2 e.g. the average rate of intrusion at the toe of the interface is 55 m/year during the first 50 years of the simulation for location y=10,000 m. During the last 50 years of the simulation the rate of intrusion at the same location is 25 m/year. The average rate during the 200 years simulation period is 40 m/year.

When comparing the rates of intrusion for the various abstraction scenarios we should, of course, consider the same conditions. In this report we will compare average rates of intrusion during a 200 year period, at y=10,000 m, for the toe of the interface.

Thus it can be derived that the rate of salt water intrusion for scenario 1 is 20 m/year for above mentioned conditions.
Annex B6 - B9 show the depth of the fresh/salt interface after 50, 100, 150 and 200 years for scenario 2 (abstractions in the west). It is obvious that the salt water front is progressing much faster than in scenario 1. The rate of progress of the interface toe is ca. 40 m/year, which is twice as fast as in scenario 1.

The difference in the rates of progress of the interface between scenario 1 and scenario 2 can be explained as follows. From Verruijt (1987) next expression for the specific discharge of salt water can be derived (1D-case):

$$qsalt = -k \cdot \frac{df}{dx} - ak \cdot \frac{dh}{dx} ,$$

in which:

qsalt = specific discharge of salt groundwater (m/d)
k = permeability (m/d)
f = head of fresh groundwater (m)
x = coordinate (m)

a = relative density difference (-)

h = depth of fresh/salt interface (m)

$$a = \frac{rs - rf}{rf}$$

rs = density of salt groundwater (kg/m^3)

rf = density of fresh groundwater (kg/m^3)

In above mentioned expression the positive z-direction has been chosen vertically upward for both f and h.
From this equation it can be seen that the salt water specific discharge consist of two components, the "head"-term and the "interface"-term. In the 1D-case (flow perpendicular to the coast) the initial gradients of the groundwater head (f) and the interface (h) are pointed downward in opposite directions. Both the "head"-term and the "interface"-term of the flow equation for qsalt are pointing in opposite directions. Initially these flow terms are of equal strength, indicating that qsalt is zero and that the fresh/salt interface stays at the same location .
In scenario 2 (abstractions in the west) the groundwater gradient near the coast decreases considerable as discussed before (figure 20b). As a result the initial equilibrium between the "head"-term and the "interface"-term of the expression for qsalt is disrupted. The "interface"-term considerably exceeds the "head"-term, indicating major salt water intrusion.
In scenario 1 (current situation) the groundwater head gradient is affected far less than in previous case, indicating that the "head"-term still is distinctly present (figure 20a). Though in this case too the "interface"-term will exceed the "head"-term, qsalt can not develop as strong as it did in previous case, resulting in far slower rates of intrusion.

As could be expected the progress rate of the interface toe in scenario 3 is in between the other two rates, discussed before. From Annexes C6 - C9 a progress rate of the interface was derived of ca. 34 m/year, which is only slightly less than in case of abstractions in the west.

The maps of Annexes A6 - A9 clearly show that the toe of the interface is progressing landinward much faster than the higher situated parts of the interface. When selecting the boundary conditions near the coastline it was assumed that a discharge of fresh groundwater would continue for the entire simulation period, and thus a more or less fixed depth to the fresh/salt interface would remain at the coast line during the entire simulation period. From the calculated drawdown it can be concluded that this is a fairly realistic assumption for the chosen simulation time of

200 years. For longer time periods this assumption is not correct anymore as soon as the groundwater gradient becomes negative indicating seawater intrusion in the entire saturated part of the aquifer.

Rise of the fresh/salt interface

Finally the regional rise of the fresh/salt interface will be discussed. This is the initial interface depth minus the interface depth at that location at a later moment of time. The rise as defined above should not be mixed up with the local upconing under an abstraction well. In the later case the salt water is really moving upward toward the well. In the regional study the fresh/salt interface moves horizontally landinward, resulting in shallower depths to the interface than in the initial situation.

Annexes A14 - A17 show the rise of the fresh/salt interface after 50, 100, 150 and 200 years continuation of current abstractions (scenario 1). As discussed previously the depth of the interface is kept constant at the coastline (boundary condition), resulting in a zero-rise at the coastline. At the toe of the interface the rise, of course, is also zero. The largest rise occurs somewhere in the middle part of the interface. In scenario 1 the maximum rise after 200 years is ca. 120 m.

Annexes B14 - B17 show the rise of the fresh/salt interface for scenario 2. Comparison with previous case clearly shows that the rise in scenario 2 does occur in a larger area than in scenario 1. In addition is the maximum rise considerably higher than in the other case. Now it is ca. 160 m.

Annexes C14 - C17 show the rise for scenario 3. The maximum rise here is 140 m, which is in between both other cases again.

4.7 Waterbalances

In previous section the results of the simulations have been discussed in terms of phreatic level, position of the fresh/salt interface and the transient variations of these two variables for each of the regarded scenarios.

In this section, however, the attention will be focussed on water quantities. More specifically, attention will be paid to changes in discharge of fresh water to the Red Sea, and to transient aspects of fresh water storage in the aquifer for the various scenarios. The storage is expressed as a quantity of water per time interval i.e. million cubic meter per year.

Above mentioned aspects have been analysed by means of a water balance. In a waterbalance the inflow, outflow and storage of a groundwater system are balanced. Basically a waterbalance expresses the law of conservation of mass. It states that the sum of all inflowing components is equal to the sum of all outflowing components plus the increase in groundwater storage. In formula:

In = Out + Storage

Here, again all terms of this equation are expressed in quantities of water per time interval.
In this specific case the only inflow component is the recharge. The outflow consists of evapotranspiration, abstractions and discharge to the Red Sea. The storage consists of two components: phreatic storage and interface storage. Phreatic storage is the decrease of stored fresh groundwater due to drawdown of the phreatic level. Interface storage is the decrease of fresh groundwater storage due to the moving salt/fresh interface. These quantities, too, are expressed in cubic meters per year. The above mentioned expression can thus be rewritten as follows:

Recharge = Evapotranspiration + Abstractions + Discharge + Interface Storage + Phreatic Storage.

For each scenario, waterbalances have been analysed for four successive periods of 50 years. Thus transient aspects of the various waterbalance components could be calculated and analysed. Comparison between the flow components for the various scenarios will contribute in understanding of the processes and phenomena involved.
During the numerical simulations several terms of above mentioned expression were kept constant. More specifically:

Recharge = 51.30 Mm^3/year
Evapotranspiration = 25.00 Mm^3/year
Abstractions = 77.35 Mm^3/year

With these values the above mentioned expression could be rewritten as:

Discharge = 51.3 - 25.0 - 77.35 + Phreatic Storage + Interface Storage.

The phreatic storage after each time period can be obtained by subtraction of the phreatic level from the initial phreatic level, and next determine the sum of these values for all of the nodes.
The interface storage could be obtained in a similar way by subtraction of the interface depth from the initial interface depth, and next determine the sum of these values for all of the nodes.
As the discharge is the only unknown term left in above mentioned expression it is possible to derive the discharge in this way. The results of the various waterbalance calculations are summarized in figures 21 - 23.

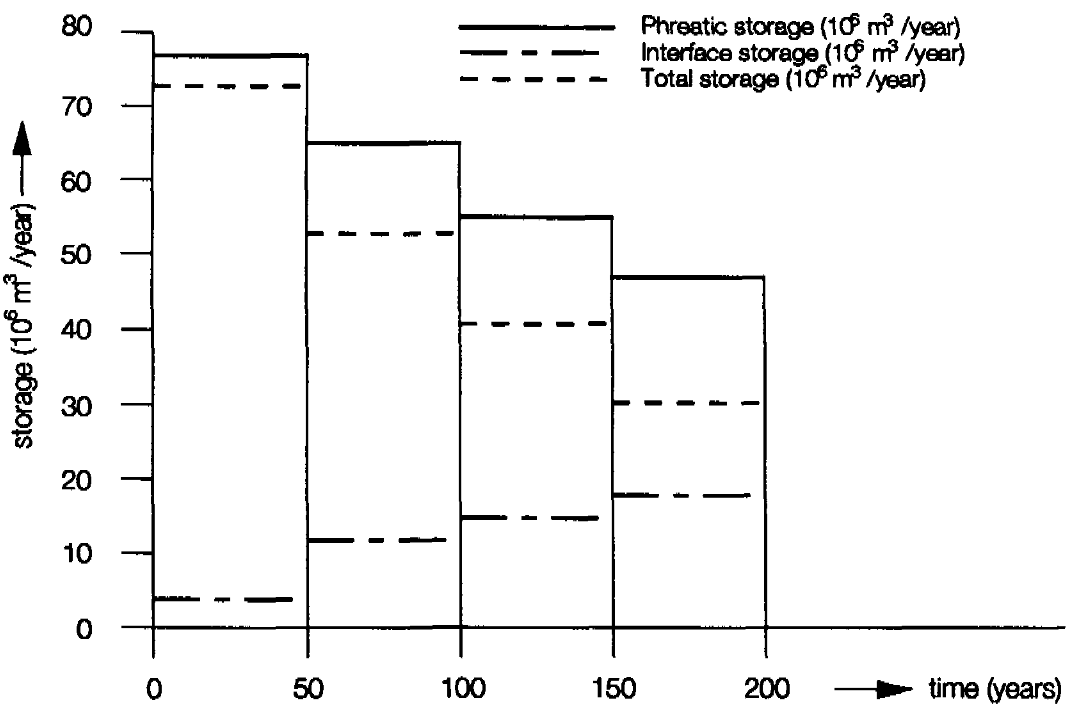

Figure 21a: Waterbalance terms for successive periods of time for abstractions (scenario 1).

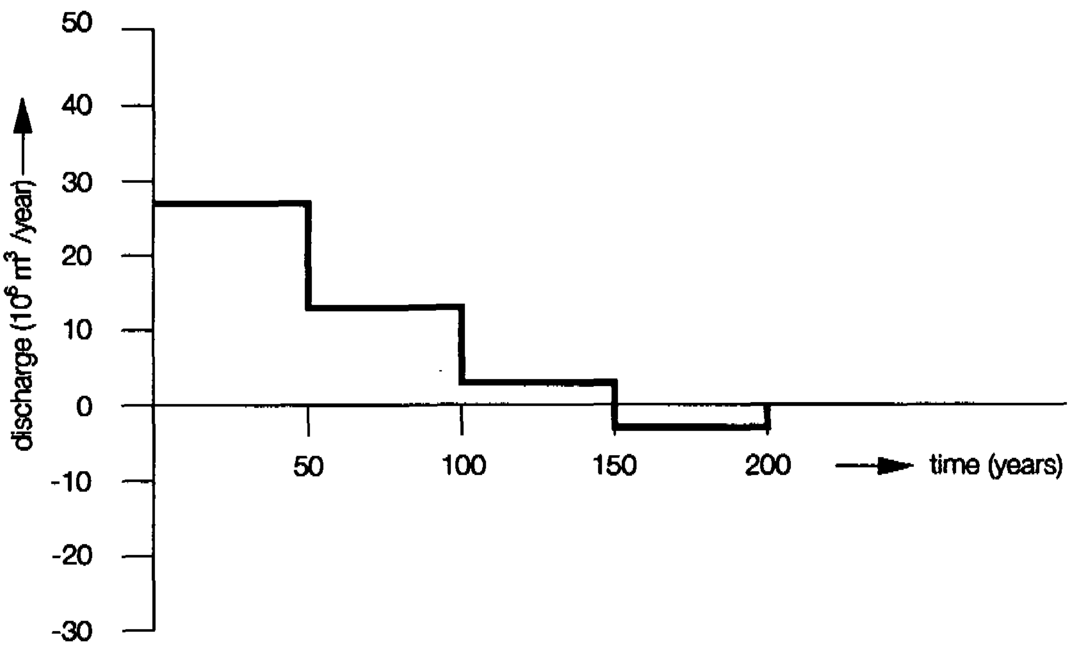

Figure 21b: Discharge of fresh groundwater to the Red Sea (scenario 1).

Figure 21a and 21b show the results of the simulations for the scenario with the current abstractions. It is clear that during the first 50 years of the simulations almost all abstracted water is taken from phreatic storage. As these abstractions take place in the eastern part of the aquifer the salt water intrusion during that period is limited, as discussed in previous chapter, and thus the interface storage is very small. In addition it should be noticed that the discharge of fresh water to the Red Sea hardly did not reduce at all. In the next time periods a gradual reduction of discharge to the Red Sea can be noticed. This was to be expected, because the drawdown will result in decreasing groundwater head gradients. According to Darcy's law this will cause decreasing discharge.
As, according to above mentioned equation, the total change in storage minus the discharge is constant (51.05 Mm^3/year), the total storage decreases at the same rate. The separate storage terms, however, show different characteristics. The interface storage increases as the salt water intrusion continues, whereas the phreatic storage decreases. The rate of decreasing phreatic storage is higher than the rate of increasing interface storage.

When we look at the results of the scenario with abstractions in the western part of the aquifer (fig. 22a and 22b), we notice the same characteristics of the various processes, however, the rate at which they take place differ considerable from previous case. In this scenario the groundwater head gradient near the coast will be reduced considerable in an early stage of the simulations, causing a large reduction of discharge to the Red Sea. In addition, the amount of groundwater taken from storage will be reduced at the same high rate. The total amount of fresh water taken from storage was 74 Mm^3/year in previous case, and is 63 Mm^3/year in this case. The differences of the separate storage terms for both scenarios are even bigger. The phreatic storage term reduces from 64 to 46 Mm^3/year and the interface storage term increases from 4 to ca. 17 Mm^3/year during the first 50 year period. From these figures the effect of well location on both fresh groundwater storage and salt water intrusion can be seen clearly. By location of wells in the western part of the aquifer we can reduce the amount of water taken from phreatic storage by ca. 18 Mm^3/year. The price we have to pay for that is an increase in salt groundwater intrusion of ca. 13 Mm^3/year. These values are averages over the first 50 years.
Figure 22b shows that during the last 100 year of the simulation the interface storage even exceeds the phreatic storage term in case of abstractions in the western part of the aquifer.

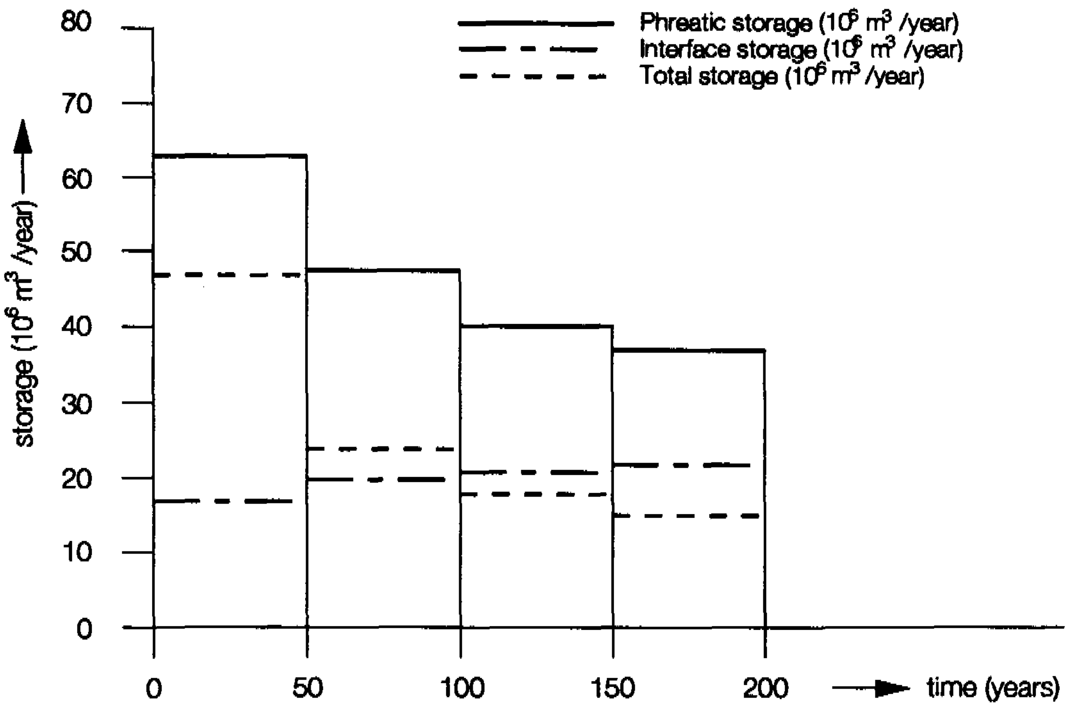

Figure 22a: Waterbalance terms for successive periods of time for abstractions in the West (scenario 2).

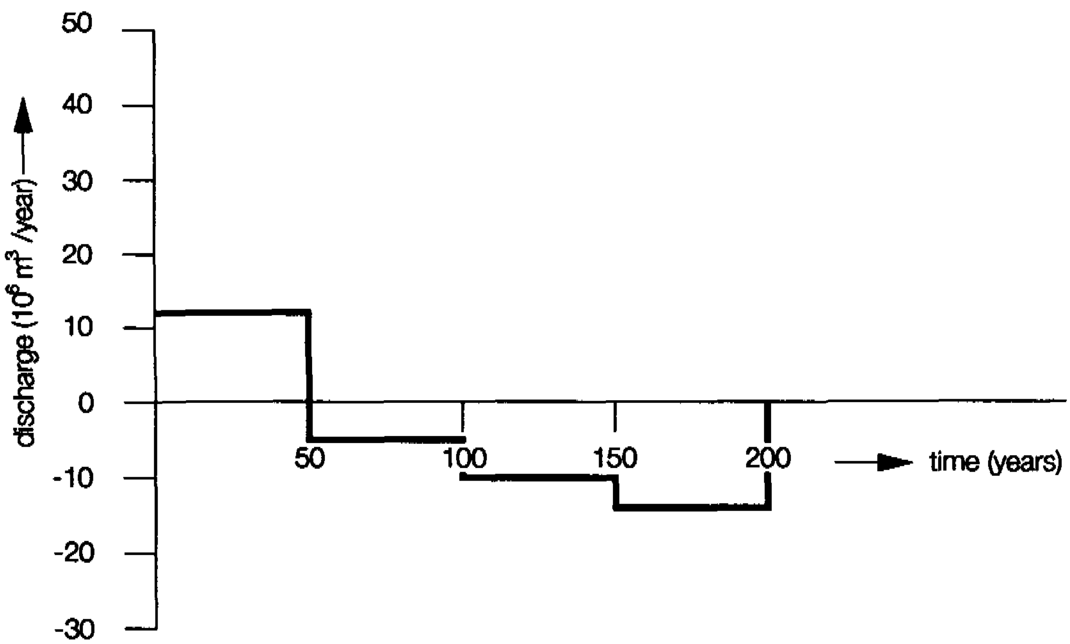

Figure 22b: Discharge of fresh groundwater to the Red Sea (scenario 2).

Figure 23a and 23b show the results of the waterbalance calculations for the situation of abstractions in the central part of the aquifer. Evidently, the results will be in between those of the two scenarios mentioned before and won't need any further comments.

Finally a remark should be made on the negative discharge to the Red Sea. A negative discharge to the Red Sea actually means an inflow of water from the Red Sea. Such an inflow of salt water near the salt marches (sabkhah) from the Red Sea already existed in the natural situation. In case of abstractions in the western part of the aquifer the drawdown in the salt marches will be intensified, causing an increased inflow of water from the Red Sea. Combined with the fact that discharge of groundwater to the Red Sea in the northern and especially the southern part of the coastline considerably reduces, this will result in a net inflow of water, indicating that the inflow near the salt marches exceeds the outflow in the northern and southern coastal areas.
Due to limited flexibility of the boundary conditions in the numerical simulations, and thus also in the water balance, this inflow of water near the salt marches partly appears as an fresh water term, where it should be salt in reality. As this effect is limited to a minor area, which, in addition, is not important for water resources activities at all, no attempts were made to overcome these model limitations during this stage of the project.

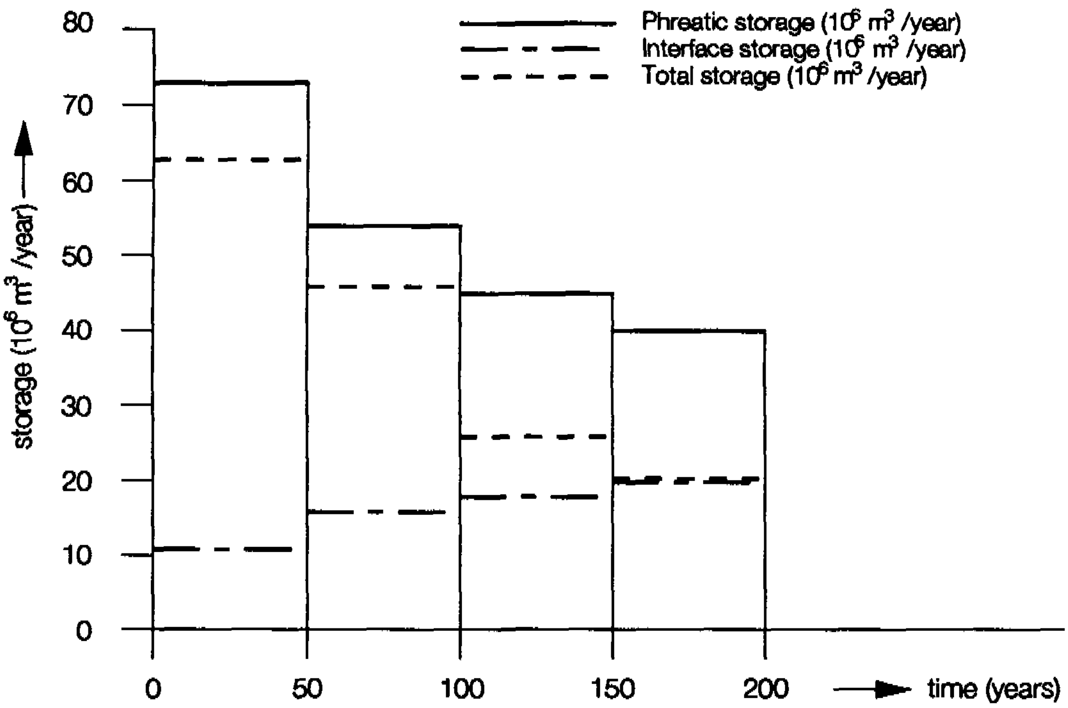

Figure 23a: Waterbalance terms for successive periods of time for abstractions in the central part of the aquifer (scenario 3).

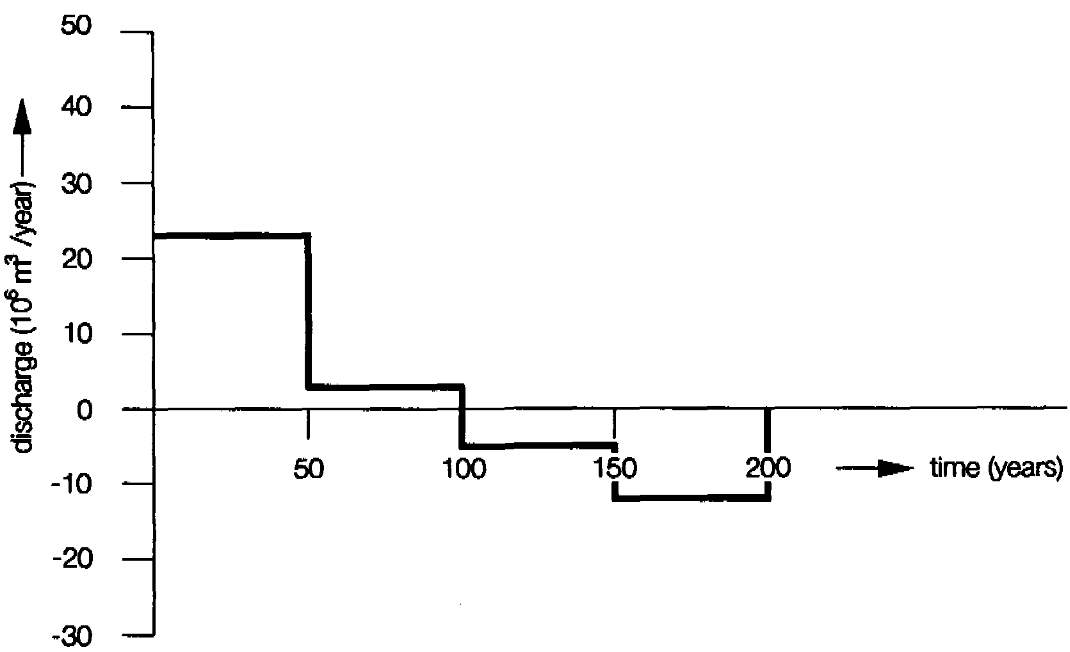

Figure 23b: Discharge of fresh groundwater to the Red Sea (scenario 3).

5. DISCUSSION

In previous section the results of the numerical calculations have been presented and some phenomena have been explained. In this section the results of the simulations will be discussed and the attention will be focussed on opportunities and items of interest for groundwater resources management.

5.1 Important aspects for (ground)water management

From previous section it will be clear that the main factors to be considered are drawdown of the phreatic head and intrusion of salt water. For both items spatial and temporal considerations should be regarded.
The drawdown of the phreatic head is important because:

- existing wells will fall dry
- new replacing wells have to be drilled deeper
- more energy per m^3 abstracted groundwater is required
- high powered pumps are required
- environmental aspects (desertification as a result of abandoning groundwater pumping
- reduction of the saturated zone means reduction of the transmissivity.

Especially in areas with high permeable layers in the upper part of the aquifer the reduction of the transmissivity might be considerable.

Salt water intrusion is important because salt water can not be used for either drinking water or irrigation water. This basically means that deep wells in the western part of the aquifer have to be closed as soon as the toe of the fresh/salt interface passes. Shallow wells can continue their abstraction longer, but eventually, also might have to be closed.

When comparing the results of the various scenarios it should be realized that the abstraction rates far exceed the natural recharge of the aquifer. This means that eventually for each scenario the aquifer will be depleted almost completely, and the fresh/salt interface will reach the far east side of the aquifer. In other words, the abstractions far exceed the sustainable yield. Sustainable yield is an abstraction rate that can be maintained for indefinite time, because negative effects like drawdown and salt intrusion stabilize at an acceptable level.
Though none of the presented scenarios will lead to a sustainable situation, the rate at which the various negative effects progress differ distinctly from one scenario to another. Due to this consideration groundwater resources management provides an opportunity to delay the collapse of the water supply system as long as possible. This, however,

does not mean that continuation of such an exceedence of the sustainable yield is promoted in this report. On the contrary. It merely provides information on how to come to an optimum planning of groundwater abstractions and how to select optimum abstraction locations, so a chosen abstraction rate can be maintained as long as possible.
Delay of the negative effects of overexploitation might help to change to a sustainable yield more gradually than in case of a sudden appearance of these negative effects. This allows groundwater authorities more time to take the right decisions at the right time.

In previous section it has been shown, that with current abstraction rates at current locations the drawdown in the eastern part of the aquifer will be considerable: up to 75 m after 200 years. Many wells will fall dry in this period. As in this part of the aquifer the layers with the highest permeability are located in the top of the aquifer and in addition the saturated part of the aquifer already is relatively thin, the aquifer transmissivity will decrease considerable, and there will hardly be any possibility to drill new wells in this part of the aquifer. So once wells fall dry, the new, replacing wells should be drilled further to the west. Thus continuation of abstractions in the eastern part of the aquifer will lead to a gradual shift of wells to the west. In the end the wells can not be shifted any further to the west, because the saline zone is progressing landinward. At that time no replacement of wells fallen dry is possible anymore, and the water supply system gradually will collapse for a major part.

When the abstractions will be located in the western part of the aquifer (scenario 2), the drawdowns will be smaller. However, the rate of intrusion of salt water will be twice as much compared with the previous scenario. As soon as the fresh/salt interface reaches the wells, these wells will have to be closed because of the salinity of the abstracted water. Replacing wells will have to be drilled further to the eastern part of the aquifer to obtain groundwater of good quality again. This gradual shifting of the wells to the east will continue until the wells reach the hard rock area or until the depth-to-groundwater will disencourage further eastward groundwater development. Here the wells can not be replaced by new wells anymore and here again the water supply system will gradually collapse.

Ultimately both abstraction scenarios can not be sustained and both will lead to collapsing systems. However the rate at which this will take place is considerable different. The falling dry of wells in scenario 1 will take place significantly sooner than the salinization of the wells in scenario 2. For this reason it is promoted to retire wells in the eastern zone (to the extent possible) and to allow drilling new wells (if absolutely needed) only in the western part of the area, to arrive to a situation that can be sustained as long as possible.

Of course above mentioned recommendation follows only from groundwater reservoir management point of view. Other considerations, like rural developments, agriculture, siting of new villages and arable land, economics etc. might lead to a more balanced view.
With regard to these aspects it should be mentioned that the WRAY-project is currently undertaking a multidisciplinary water resources management study for the Wadi Surdud area. Disciplines involved are: surface water management, groundwater management, agriculture and economics. This study tries to combine information of these disciplines in order to derive an optimum water resources management strategy (Van der Gun and Wesseling, 1990). The present groundwater modelling study was carried out to provide one of the building stones.

6. CONCLUSIONS AND RECOMMANDATIONS

From the aforementioned simulations next conclusions can be drawn:

- Both the SWIP model for simulation of local salt water upconing under a well and the BADON-3 model for simulation of regional salt water intrusion and drawdown of the phreatic head proved to be well applicable in the Wadi Surdud Area.

- In the regional studies the rate of drawdown of the phreatic head and the rate of salt water intrusion depend substantially on the location of the abstraction wells.

- Continuation of present abstractions for indefinite time will lead to a depleted aquifer, only containing salt intrusion water. In other words: The present pumping rate is exceeding maximum sustainable yield no matter where the abstraction wells are located.

- The rate of drawdown of the phreatic head is maximum in case the abstraction wells are located in the eastern part of the Wadi Surdud area (current situation). In that case the rate of drawdown is ca. 0.35 m per year in the eastern part of the aquifer.

- The rate of drawdown is considerably reduced if abstraction predominantly takes place from the western part of the aquifer. In that case the rate of drawdown is limited to ca. 0.15 m per year.

- The rate of salt water intrusion is maximum in case the abstraction wells are located in the western part of the aquifer. In that case the rate of salt water intrusion at the toe of the interface is ca. 40 m per year.

- The rate of salt water intrusion at the toe of the interface will be limited to ca. 20 m per year if the abstractions take place from the eastern part of the aquifer.

- The drawdown of the groundwater table will considerably sooner yield serious problems than salt water intrusion. As a result, mitigating measures should mainly be focussed on the reduction of drawdown of the phreatic groundwater table.

- Upconing of salt water under abstraction wells can be retarded considerably by keeping the wells shallow and the rate of abstraction only small or moderate.

- Upconing is in particular very limited in aquifers with high anisotrophy factors ($k_h >> k_v$).

- Some indication of the ratio between the permeability of the Quaternary and the Tertiary deposits can be obtained by calculating the rate of flushing of the Tertiary deposits by fresh water for various alternative assumptions on this ratio. It thus was found that the permeability of the Tertiary deposits is at least a factor 25000 less than that of the Quaternary deposits.

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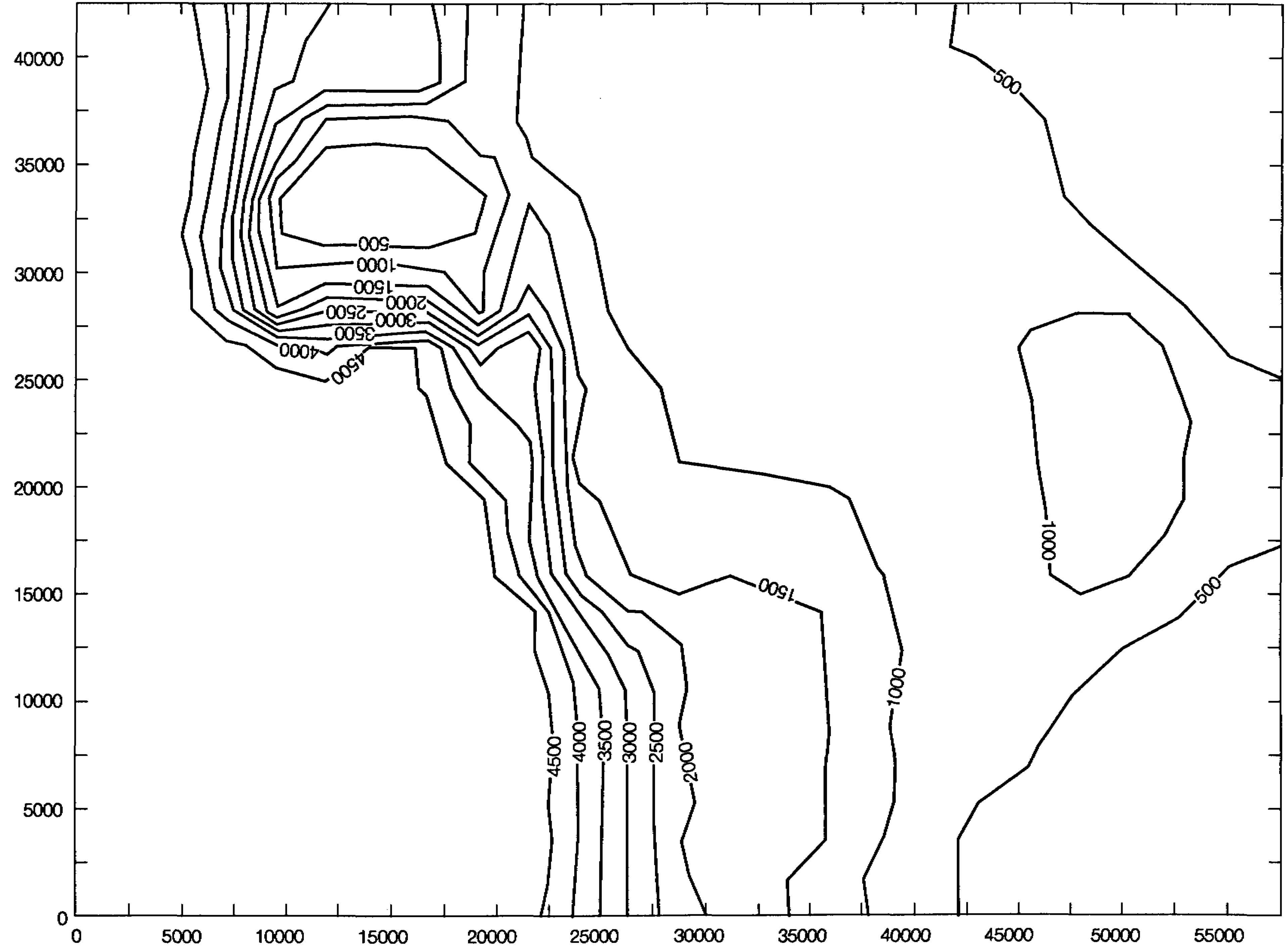
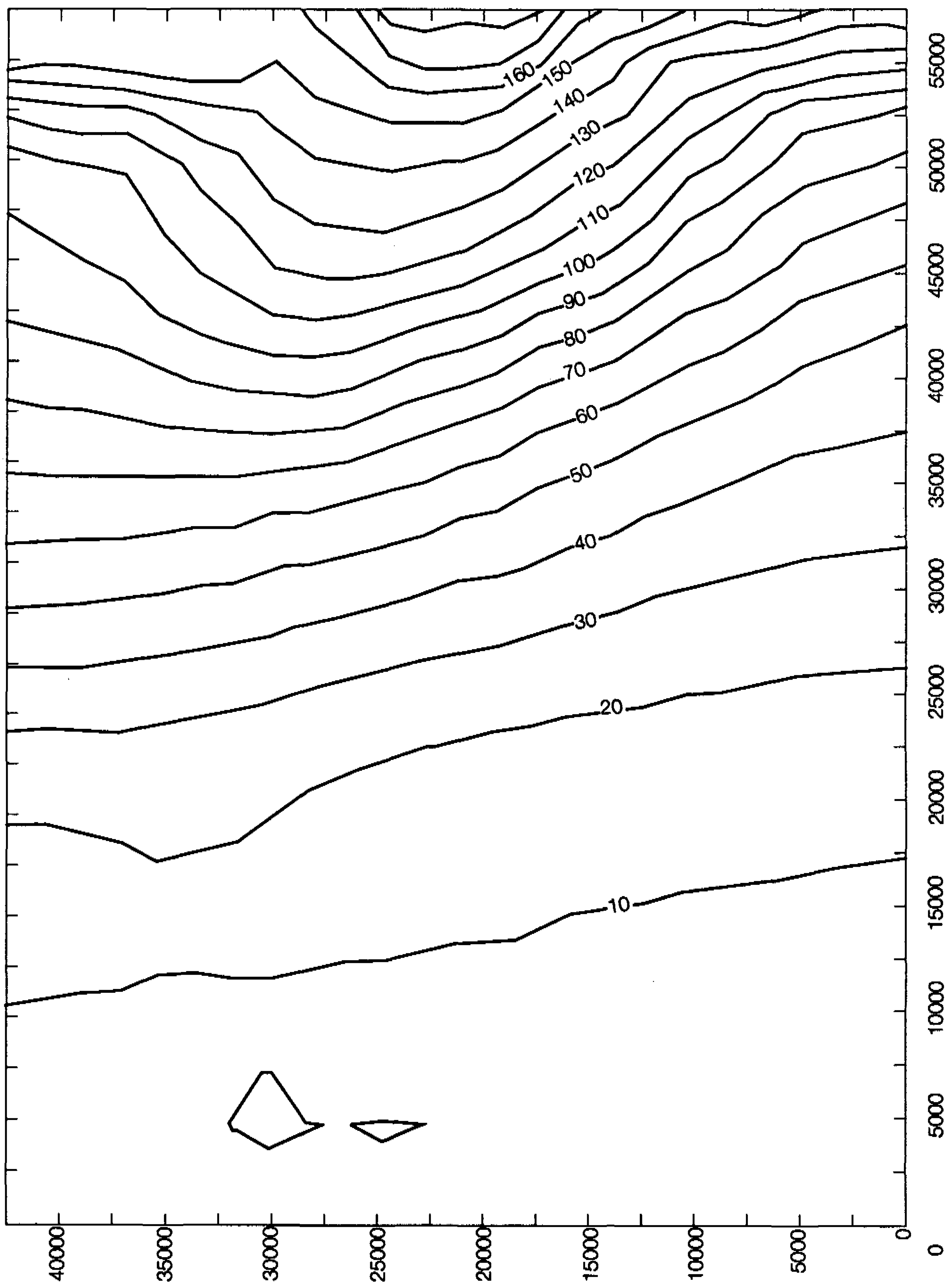
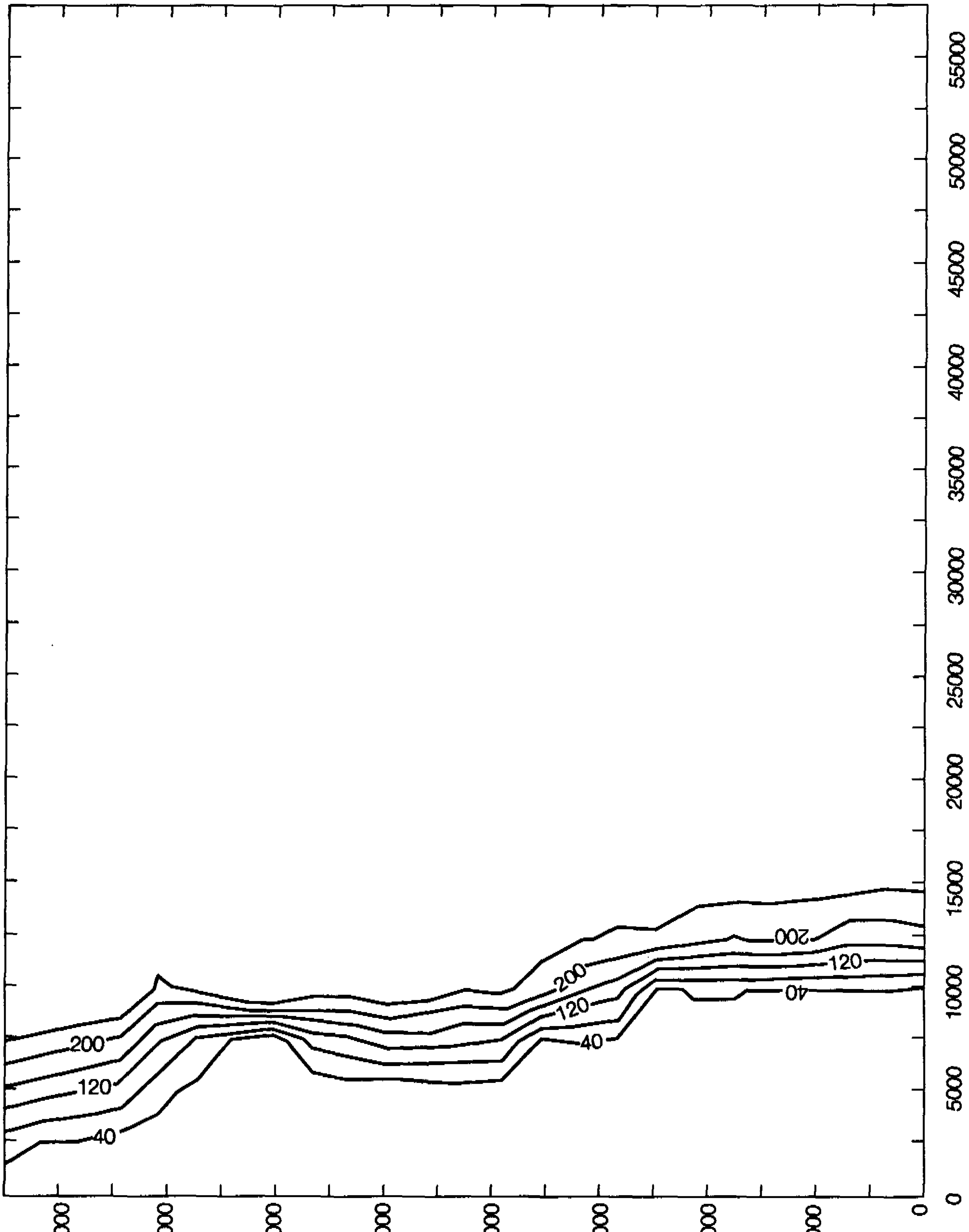


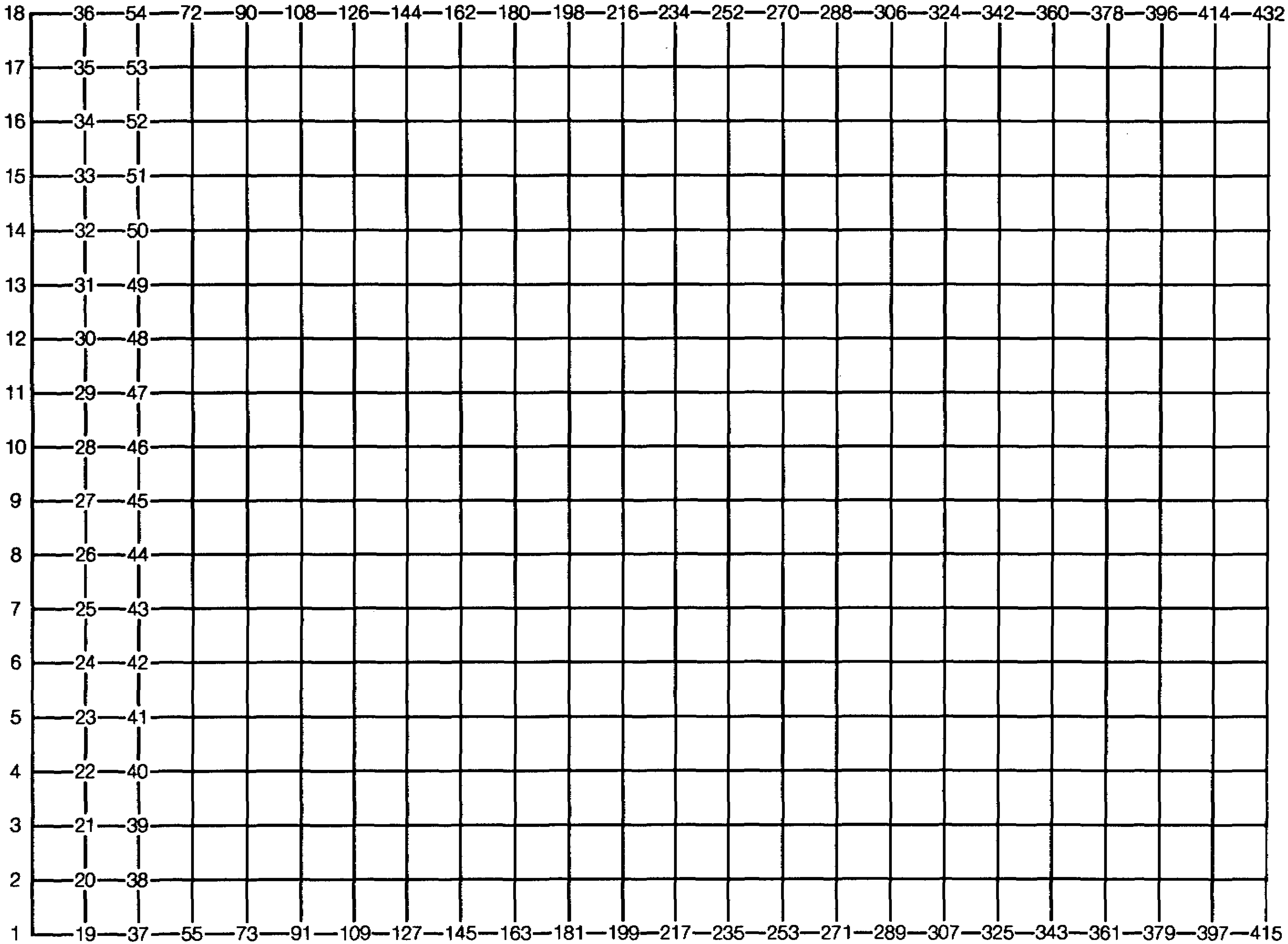
annex 1: Transmissivities (m^2 /day)



Annex 2: Initial phreatic head (m).



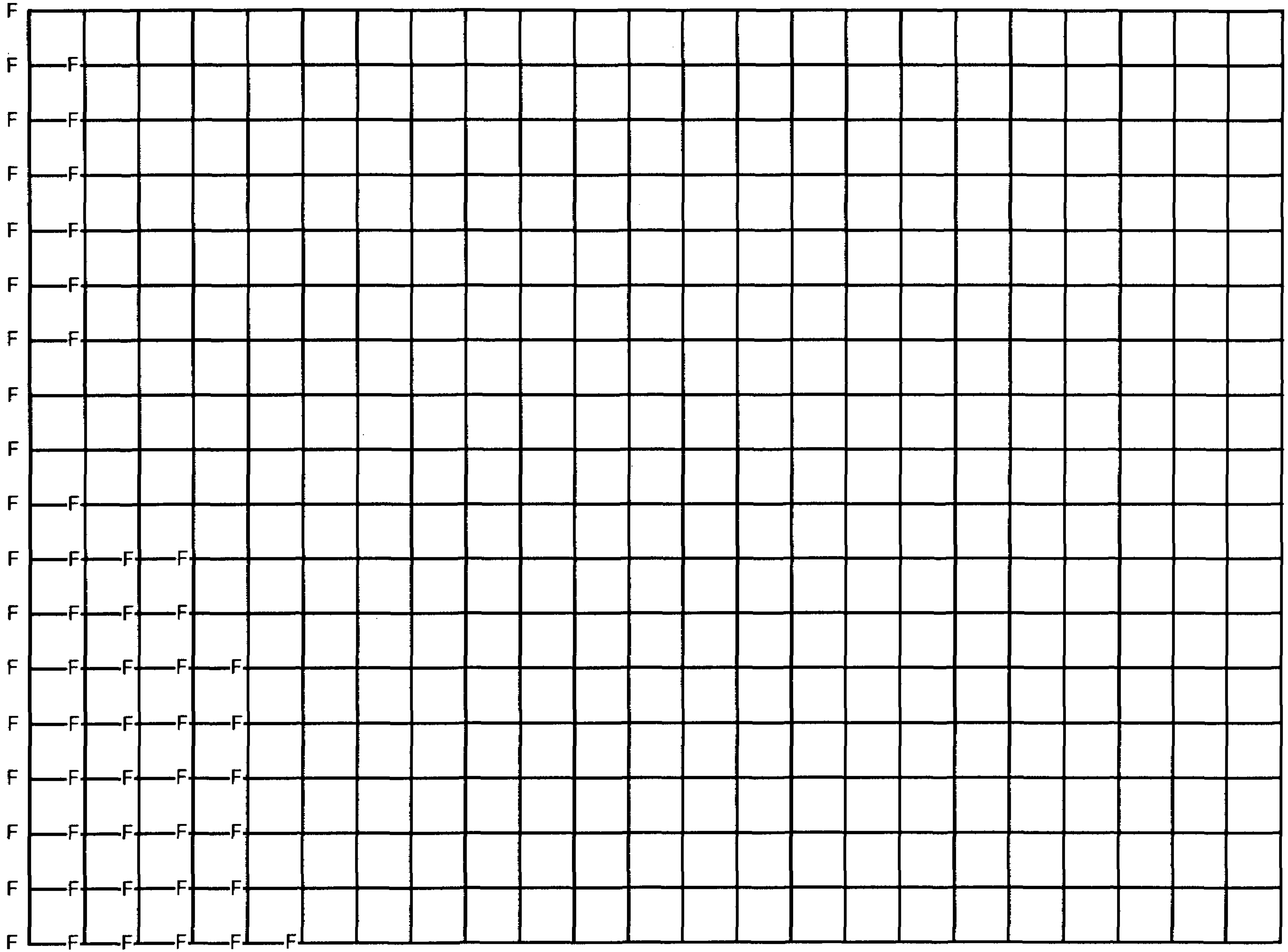
Annex 3: Initial depth to the fresh/salt interface (m).



Annex 4: Numbering of the nodes

17	34	51	68	85	102	119	136	153	170	187	204	221	238	255	272	289	306	323	340	357	374	391
16	33																					390
15	32																					389
14	31																					388
13	30																					387
12	29																					386
11	28																					385
10	27																					384
9	26																					383
8	25																					382
7	24																					381
6	23																					380
5	22																					379
4	21																					378
3	20																					377
2	19																					376
1	18	35	52	69	86	103	120	137	154	171	188	205	222	239	256	273	290	307	324	341	358	375

Annex 5: Numbering of the elements.



Annex 6: Fixed-head boundary conditions.

																					5	
																					5	
																					5	
	-64																				5	
		-88													32	64	48	16			5	
	-80	-96													80	64	48	48	64	32	5	
	-144	-32																56	80	72	48	
-128	-144	-48																72	56			384
-80	-144	-48																				547
																						384
																						4
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Annex 7: Infiltration rate x 10^{-5} m/d.

Annex 8: Input data for the BADON-3 numerical model of the Wadi Surdud Area, Yemen Republic.

===== BADON 3 =====

General data

Number of nodes	432
Number of elements	391
Density of fresh water	1000.00000
Density of salt water	1025.00000
Thickness of aquifer	450.00000
Thickness of upper part	125.00000
Permeability ratio lower/upper	0.10000
Storativity	0.15000
Problem title	curab

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
1	0.000	0.000	F	-199.500	220.000	0.000	0.000
2	0.000	2500.000	F	-199.500	220.000	0.000	0.000
3	0.000	5000.000	F	-199.500	220.000	0.000	0.000
4	0.000	7500.000	F	-199.500	220.000	0.000	0.000
5	0.000	10000.000	F	-199.500	220.000	0.000	0.000
6	0.000	12500.000	F	-199.500	220.000	0.000	0.000
7	0.000	15000.000	F	-199.500	220.000	0.000	0.000
8	0.000	17500.000	F	-199.500	220.000	0.000	0.000
9	0.000	20000.000	F	-199.500	220.000	0.000	0.000
10	0.000	22500.000	F	-199.500	220.000	0.000	0.000
11	0.000	25000.000	F	-199.500	220.000	0.000	0.000
12	0.000	27500.000	F	-199.500	220.000	0.000	0.000
13	0.000	30000.000	F	-199.500	220.000	0.000	0.000
14	0.000	32500.000	F	-199.500	220.000	0.000	0.000
15	0.000	35000.000	F	-199.500	220.000	0.000	0.000
16	0.000	37500.000	F	-199.500	220.000	0.000	0.000
17	0.000	40000.000	F	-199.500	220.000	0.000	0.000
18	0.000	42500.000	F	-199.500	220.000	0.000	0.000
19	2500.000	0.000	F	-199.500	220.000	0.000	0.000
20	2500.000	2500.000	F	-199.500	220.000	0.000	0.000

Node	x	y	F/Q	Fo	ho	Qf	Qs
21	2500.000	5000.000	F	-199.500	220.000	0.000	0.000
22	2500.000	7500.000	F	-199.500	220.000	0.000	0.000
23	2500.000	10000.000	F	-199.500	220.000	0.000	0.000
24	2500.000	12500.000	F	-199.500	220.000	0.000	0.000
25	2500.000	15000.000	F	-199.500	220.000	0.000	0.000
26	2500.000	17500.000	F	-199.500	220.000	0.000	0.000
27	2500.000	20000.000	F	-199.500	220.000	0.000	0.000
28	2500.000	22500.000	Q	-199.400	220.000	0.000	0.000
29	2500.000	25000.000	Q	-199.400	220.000	0.000	0.000
30	2500.000	27500.000	F	-199.500	220.000	0.000	0.000
31	2500.000	30000.000	F	-199.500	220.000	0.000	0.000
32	2500.000	32500.000	F	-199.500	220.000	0.000	0.000
33	2500.000	35000.000	F	-199.500	220.000	0.000	0.000
34	2500.000	37500.000	F	-199.500	220.000	0.000	0.000
35	2500.000	40000.000	F	-199.500	220.000	0.000	0.000
36	2500.000	42500.000	Q	-198.500	258.700	0.000	0.000
37	5000.000	0.000	F	-199.500	220.000	0.000	0.000
38	5000.000	2500.000	F	-199.500	220.000	0.000	0.000
39	5000.000	5000.000	F	-199.500	220.000	0.000	0.000
40	5000.000	7500.000	F	-199.500	220.000	0.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
41	5000.000	10000.000	F	-199.500	220.000	0.000	0.000
42	5000.000	12500.000	F	-199.500	220.000	0.000	0.000
43	5000.000	15000.000	F	-199.500	220.000	0.000	0.000
44	5000.000	17500.000	F	-199.500	220.000	0.000	0.000
45	5000.000	20000.000	Q	-199.900	203.500	0.000	0.000
46	5000.000	22500.000	Q	-200.400	200.000	0.000	0.000
47	5000.000	25000.000	Q	-200.400	200.000	0.000	0.000
48	5000.000	27500.000	Q	-200.400	200.000	0.000	0.000
49	5000.000	30000.000	Q	-200.500	200.000	0.000	0.000
50	5000.000	32500.000	Q	-200.200	200.000	0.000	0.000
51	5000.000	35000.000	Q	-198.300	251.500	0.000	0.000
52	5000.000	37500.000	Q	-197.200	311.000	0.000	0.000
53	5000.000	40000.000	Q	-196.500	340.000	0.000	0.000
54	5000.000	42500.000	Q	-196.100	355.000	0.000	0.000
55	7500.000	0.000	F	-199.500	220.000	0.000	0.000
56	7500.000	2500.000	F	-199.500	220.000	0.000	0.000
57	7500.000	5000.000	F	-199.500	220.000	0.000	0.000
58	7500.000	7500.000	F	-199.500	220.000	0.000	0.000
59	7500.000	10000.000	F	-199.500	220.000	0.000	0.000
60	7500.000	12500.000	F	-199.500	220.000	0.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
61	7500.000	15000.000	F	-199.500	220.000	0.000	0.000
62	7500.000	17500.000	F	-199.500	220.000	0.000	0.000
63	7500.000	20000.000	Q	-196.800	328.000	0.000	0.000
64	7500.000	22500.000	Q	-196.400	345.000	0.000	0.000
65	7500.000	25000.000	Q	-196.400	343.000	-250.000	0.000
66	7500.000	27500.000	Q	-197.600	293.900	0.000	0.000
67	7500.000	30000.000	Q	-200.500	200.000	0.000	0.000
68	7500.000	32500.000	Q	-200.200	200.000	0.000	0.000
69	7500.000	35000.000	Q	-197.000	319.000	0.000	0.000
70	7500.000	37500.000	Q	-195.100	396.000	0.000	0.000
71	7500.000	40000.000	Q	-194.200	432.000	0.000	0.000
72	7500.000	42500.000	Q	-193.900	443.000	0.000	0.000
73	10000.000	0.000	F	-199.500	220.000	0.000	0.000
74	10000.000	2500.000	F	-199.500	220.000	0.000	0.000
75	10000.000	5000.000	F	-199.500	220.000	0.000	0.000
76	10000.000	7500.000	F	-199.500	220.000	0.000	0.000
77	10000.000	10000.000	F	-199.500	220.000	0.000	0.000
78	10000.000	12500.000	F	-199.500	220.000	0.000	0.000
79	10000.000	15000.000	Q	-195.400	385.000	0.000	0.000
80	10000.000	17500.000	Q	-194.100	436.000	0.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
81	10000.000	20000.000	Q	−193.200	473.000	−965.000	0.000
82	10000.000	22500.000	Q	−192.700	491.000	0.000	0.000
83	10000.000	25000.000	Q	−192.500	498.000	0.000	0.000
84	10000.000	27500.000	Q	−192.200	513.000	0.000	0.000
85	10000.000	30000.000	Q	−190.900	565.000	0.000	0.000
86	10000.000	32500.000	Q	−190.800	565.000	0.000	0.000
87	10000.000	35000.000	Q	−194.000	438.000	0.000	0.000
88	10000.000	37500.000	Q	−191.800	529.000	0.000	0.000
89	10000.000	40000.000	Q	−190.800	565.000	0.000	0.000
90	10000.000	42500.000	Q	−190.600	575.000	0.000	0.000
91	12500.000	0.000	F	−199.500	400.000	0.000	0.000
92	12500.000	2500.000	Q	−195.700	400.000	0.000	0.000
93	12500.000	5000.000	Q	−194.500	430.000	0.000	0.000
94	12500.000	7500.000	Q	−193.900	446.000	0.000	0.000
95	12500.000	10000.000	Q	−193.500	459.000	0.000	0.000
96	12500.000	12500.000	Q	−193.100	459.000	0.000	0.000
97	12500.000	15000.000	Q	−192.100	459.000	0.000	0.000
98	12500.000	17500.000	Q	−191.400	459.000	0.000	0.000
99	12500.000	20000.000	Q	−190.900	459.000	−250.000	0.000
100	12500.000	22500.000	Q	−190.500	459.000	−965.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
101	12500.000	25000.000	Q	−190.200	459.000	0.000	0.000
102	12500.000	27500.000	Q	−189.900	459.000	−500.000	0.000
103	12500.000	30000.000	Q	−189.600	459.000	0.000	0.000
104	12500.000	32500.000	Q	−189.400	459.000	0.000	0.000
105	12500.000	35000.000	Q	−189.500	459.000	−250.000	0.000
106	12500.000	37500.000	Q	−188.200	459.000	0.000	0.000
107	12500.000	40000.000	Q	−188.200	459.000	0.000	0.000
108	12500.000	42500.000	Q	−188.000	459.000	0.000	0.000
109	15000.000	0.000	Q	−193.400	459.000	0.000	0.000
110	15000.000	2500.000	Q	−192.500	459.000	0.000	0.000
111	15000.000	5000.000	Q	−191.900	459.000	0.000	0.000
112	15000.000	7500.000	Q	−191.400	459.000	0.000	0.000
113	15000.000	10000.000	Q	−191.000	459.000	0.000	0.000
114	15000.000	12500.000	Q	−190.600	459.000	0.000	0.000
115	15000.000	15000.000	Q	−190.000	459.000	0.000	0.000
116	15000.000	17500.000	Q	−189.500	459.000	0.000	0.000
117	15000.000	20000.000	Q	−189.000	459.000	0.000	0.000
118	15000.000	22500.000	Q	−188.700	459.000	−1442.000	0.000
119	15000.000	25000.000	Q	−188.400	459.000	−250.000	0.000
120	15000.000	27500.000	Q	−188.200	459.000	−250.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
121	15000.000	30000.000	Q	−187.000	459.000	0.000	0.000
122	15000.000	32500.000	Q	−187.600	459.000	−250.000	0.000
123	15000.000	35000.000	Q	−187.000	459.000	0.000	0.000
124	15000.000	37500.000	Q	−185.100	459.000	0.000	0.000
125	15000.000	40000.000	Q	−185.300	459.000	0.000	0.000
126	15000.000	42500.000	Q	−185.400	459.000	0.000	0.000
127	17500.000	0.000	Q	−190.200	459.000	0.000	0.000
128	17500.000	2500.000	Q	−189.900	459.000	0.000	0.000
129	17500.000	5000.000	Q	−189.500	459.000	0.000	0.000
130	17500.000	7500.000	Q	−189.100	459.000	0.000	0.000
131	17500.000	10000.000	Q	−188.700	459.000	0.000	0.000
132	17500.000	12500.000	Q	−188.300	459.000	0.000	0.000
133	17500.000	15000.000	Q	−187.900	459.000	0.000	0.000
134	17500.000	17500.000	Q	−187.500	459.000	0.000	0.000
135	17500.000	20000.000	Q	−187.200	459.000	−965.000	0.000
136	17500.000	22500.000	Q	−186.800	459.000	−3574.000	0.000
137	17500.000	25000.000	Q	−186.400	459.000	−3122.000	0.000
138	17500.000	27500.000	Q	−186.300	459.000	0.000	0.000
139	17500.000	30000.000	Q	−186.000	459.000	0.000	0.000
140	17500.000	32500.000	Q	−179.400	459.000	0.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
141	17500.000	35000.000	Q	−178.800	459.000	−500.000	0.000
142	17500.000	37500.000	Q	−181.600	459.000	0.000	0.000
143	17500.000	40000.000	Q	−182.700	459.000	0.000	0.000
144	17500.000	42500.000	Q	−182.900	459.000	0.000	0.000
145	20000.000	0.000	Q	−187.500	459.000	0.000	0.000
146	20000.000	2500.000	Q	−187.400	459.000	0.000	0.000
147	20000.000	5000.000	Q	−187.100	459.000	0.000	0.000
148	20000.000	7500.000	Q	−186.700	459.000	0.000	0.000
149	20000.000	10000.000	Q	−186.400	459.000	0.000	0.000
150	20000.000	12500.000	Q	−186.000	459.000	0.000	0.000
151	20000.000	15000.000	Q	−185.800	459.000	0.000	0.000
152	20000.000	17500.000	Q	−185.500	459.000	0.000	0.000
153	20000.000	20000.000	Q	−185.000	459.000	−500.000	0.000
154	20000.000	22500.000	Q	−184.100	459.000	−2860.000	0.000
155	20000.000	25000.000	Q	−183.000	459.000	−3110.000	0.000
156	20000.000	27500.000	Q	−181.300	459.000	0.000	0.000
157	20000.000	30000.000	Q	−178.100	459.000	0.000	0.000
158	20000.000	32500.000	Q	−176.100	459.000	0.000	0.000
159	20000.000	35000.000	Q	−176.300	459.000	0.000	0.000
160	20000.000	37500.000	Q	−177.800	459.000	0.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
161	20000.000	40000.000	Q	−178.600	459.000	0.000	0.000
162	20000.000	42500.000	Q	−178.800	459.000	0.000	0.000
163	22500.000	0.000	Q	−185.100	459.000	0.000	0.000
164	22500.000	2500.000	Q	−185.000	459.000	0.000	0.000
165	22500.000	5000.000	Q	−184.700	459.000	0.000	0.000
166	22500.000	7500.000	Q	−184.400	459.000	0.000	0.000
167	22500.000	10000.000	Q	−184.000	459.000	0.000	0.000
168	22500.000	12500.000	Q	−183.700	459.000	0.000	0.000
169	22500.000	15000.000	Q	−183.500	459.000	0.000	0.000
170	22500.000	17500.000	Q	−183.200	459.000	0.000	0.000
171	22500.000	20000.000	Q	−182.600	459.000	−715.000	0.000
172	22500.000	22500.000	Q	−181.700	459.000	0.000	0.000
173	22500.000	25000.000	Q	−180.500	459.000	−2395.000	0.000
174	22500.000	27500.000	Q	−178.700	459.000	0.000	0.000
175	22500.000	30000.000	Q	−176.200	459.000	0.000	0.000
176	22500.000	32500.000	Q	−174.300	459.000	−250.000	0.000
177	22500.000	35000.000	Q	−173.600	459.000	0.000	0.000
178	22500.000	37500.000	Q	−173.800	459.000	0.000	0.000
179	22500.000	40000.000	Q	−174.100	459.000	0.000	0.000
180	22500.000	42500.000	Q	−174.200	459.000	0.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
181	25000.000	0.000	Q	−182.400	458.500	0.000	0.000
182	25000.000	2500.000	Q	−182.200	458.500	0.000	0.000
183	25000.000	5000.000	Q	−181.900	458.500	0.000	0.000
184	25000.000	7500.000	Q	−181.400	458.500	0.000	0.000
185	25000.000	10000.000	Q	−180.800	458.500	0.000	0.000
186	25000.000	12500.000	Q	−180.300	458.500	0.000	0.000
187	25000.000	15000.000	Q	−179.500	458.500	−500.000	0.000
188	25000.000	17500.000	Q	−178.300	458.500	−500.000	0.000
189	25000.000	20000.000	Q	−176.800	458.500	−250.000	0.000
190	25000.000	22500.000	Q	−175.300	458.500	−500.000	0.000
191	25000.000	25000.000	Q	−174.000	458.500	−500.000	0.000
192	25000.000	27500.000	Q	−172.700	458.500	0.000	0.000
193	25000.000	30000.000	Q	−171.300	458.500	−250.000	0.000
194	25000.000	32500.000	Q	−169.600	458.500	0.000	0.000
195	25000.000	35000.000	Q	−167.700	458.500	0.000	0.000
196	25000.000	37500.000	Q	−165.900	458.500	−250.000	0.000
197	25000.000	40000.000	Q	−165.400	458.500	0.000	0.000
198	25000.000	42500.000	Q	−165.300	458.500	0.000	0.000
199	27500.000	0.000	Q	−179.000	458.000	0.000	0.000
200	27500.000	2500.000	Q	−178.800	458.000	0.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
201	27500.000	5000.000	Q	-178.300	458.000	0.000	0.000
202	27500.000	7500.000	Q	-177.600	458.000	0.000	0.000
203	27500.000	10000.000	Q	-176.700	458.000	0.000	0.000
204	27500.000	12500.000	Q	-175.400	458.000	0.000	0.000
205	27500.000	15000.000	Q	-173.900	458.000	0.000	0.000
206	27500.000	17500.000	Q	-172.200	458.000	-1191.000	0.000
207	27500.000	20000.000	Q	-170.300	458.000	-1442.000	0.000
208	27500.000	22500.000	Q	-168.600	458.000	-1001.000	0.000
209	27500.000	25000.000	Q	-166.700	458.000	-1716.000	0.000
210	27500.000	27500.000	Q	-164.200	458.000	-1430.000	0.000
211	27500.000	30000.000	Q	-161.500	458.000	-751.000	0.000
212	27500.000	32500.000	Q	-159.100	458.000	-250.000	0.000
213	27500.000	35000.000	Q	-157.600	458.000	-500.000	0.000
214	27500.000	37500.000	Q	-156.700	458.000	-1906.000	0.000
215	27500.000	40000.000	Q	-156.300	458.000	0.000	0.000
216	27500.000	42500.000	Q	-156.100	458.000	0.000	0.000
217	30000.000	0.000	Q	-174.300	457.500	0.000	0.000
218	30000.000	2500.000	Q	-174.000	457.500	0.000	0.000
219	30000.000	5000.000	Q	-173.300	457.500	0.000	0.000
220	30000.000	7500.000	Q	-172.300	457.500	0.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
221	30000.000	10000.000	Q	-170.900	457.500	0.000	0.000
222	30000.000	12500.000	Q	-169.100	457.500	-250.000	0.000
223	30000.000	15000.000	Q	-166.800	457.500	0.000	0.000
224	30000.000	17500.000	Q	-163.700	457.500	-250.000	0.000
225	30000.000	20000.000	Q	-161.900	457.500	0.000	0.000
226	30000.000	22500.000	Q	-160.000	457.500	-500.000	0.000
227	30000.000	25000.000	Q	-157.600	457.500	-250.000	0.000
228	30000.000	27500.000	Q	-155.400	457.500	-1430.000	0.000
229	30000.000	30000.000	Q	-153.200	457.500	-500.000	0.000
230	30000.000	32500.000	Q	-151.400	457.500	-1442.000	0.000
231	30000.000	35000.000	Q	-150.200	457.500	-1680.000	0.000
232	30000.000	37500.000	Q	-148.900	457.500	-500.000	0.000
233	30000.000	40000.000	Q	-147.100	457.500	0.000	0.000
234	30000.000	42500.000	Q	-146.400	457.500	0.000	0.000
235	32500.000	0.000	Q	-169.500	457.000	0.000	0.000
236	32500.000	2500.000	Q	-169.000	457.000	0.000	0.000
237	32500.000	5000.000	Q	-168.000	457.000	0.000	0.000
238	32500.000	7500.000	Q	-166.500	457.000	0.000	0.000
239	32500.000	10000.000	Q	-164.600	457.000	0.000	0.000
240	32500.000	12500.000	Q	-162.400	457.000	0.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
241	32500.000	15000.000	Q	−160.000	457.000	0.000	0.000
242	32500.000	17500.000	Q	−157.100	457.000	0.000	0.000
243	32500.000	20000.000	Q	−154.400	457.000	−1215.000	0.000
244	32500.000	22500.000	Q	−151.000	457.000	−4301.000	0.000
245	32500.000	25000.000	Q	−148.400	457.000	−715.000	0.000
246	32500.000	27500.000	Q	−146.600	457.000	−4099.000	0.000
247	32500.000	30000.000	Q	−144.300	457.000	−1215.000	0.000
248	32500.000	32500.000	Q	−142.100	457.000	−1716.000	0.000
249	32500.000	35000.000	Q	−140.500	457.000	−4301.000	0.000
250	32500.000	37500.000	Q	−139.400	457.000	−1442.000	0.000
251	32500.000	40000.000	Q	−138.900	457.000	0.000	0.000
252	32500.000	42500.000	Q	−138.800	457.000	0.000	0.000
253	35000.000	0.000	Q	−164.800	456.500	0.000	0.000
254	35000.000	2500.000	Q	−164.300	456.500	0.000	0.000
255	35000.000	5000.000	Q	−163.000	456.500	0.000	0.000
256	35000.000	7500.000	Q	−161.100	456.500	0.000	0.000
257	35000.000	10000.000	Q	−158.700	456.500	0.000	0.000
258	35000.000	12500.000	Q	−155.800	456.500	−250.000	0.000
259	35000.000	15000.000	Q	−152.700	456.500	−1430.000	0.000
260	35000.000	17500.000	Q	−148.800	456.500	0.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
261	35000.000	20000.000	Q	−145.400	456.500	−2169.000	0.000
262	35000.000	22500.000	Q	−141.200	456.500	−3860.000	0.000
263	35000.000	25000.000	Q	−138.300	456.500	−1680.000	0.000
264	35000.000	27500.000	Q	−135.500	456.500	−1466.000	0.000
265	35000.000	30000.000	Q	−132.700	456.500	−2633.000	0.000
266	35000.000	32500.000	Q	−131.800	456.500	−4766.000	0.000
267	35000.000	35000.000	Q	−131.200	456.500	−2872.000	0.000
268	35000.000	37500.000	Q	−131.100	456.500	−250.000	0.000
269	35000.000	40000.000	Q	−131.100	456.500	0.000	0.000
270	35000.000	42500.000	Q	−131.100	456.500	0.000	0.000
271	37500.000	0.000	Q	−160.400	456.000	0.000	0.000
272	37500.000	2500.000	Q	−159.700	456.000	0.000	0.000
273	37500.000	5000.000	Q	−158.000	456.000	0.000	0.000
274	37500.000	7500.000	Q	−155.400	456.000	0.000	0.000
275	37500.000	10000.000	Q	−152.200	456.000	0.000	0.000
276	37500.000	12500.000	Q	−148.600	456.000	0.000	0.000
277	37500.000	15000.000	Q	−144.400	456.000	0.000	0.000
278	37500.000	17500.000	Q	−139.900	456.000	−2169.000	0.000
279	37500.000	20000.000	Q	−134.900	456.000	0.000	0.000
280	37500.000	22500.000	Q	−128.600	456.000	−1716.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
281	37500.000	25000.000	Q	-123.400	456.000	-4063.000	0.000
282	37500.000	27500.000	Q	-119.000	456.000	-2395.000	0.000
283	37500.000	30000.000	Q	-116.600	456.000	-1215.000	0.000
284	37500.000	32500.000	Q	-117.200	456.000	-3360.000	0.000
285	37500.000	35000.000	Q	-119.100	456.000	-5016.000	0.000
286	37500.000	37500.000	Q	-120.800	456.000	-965.000	0.000
287	37500.000	40000.000	Q	-122.500	456.000	0.000	0.000
288	37500.000	42500.000	Q	-123.300	456.000	0.000	0.000
289	40000.000	0.000	Q	-155.100	455.500	0.000	0.000
290	40000.000	2500.000	Q	-154.200	455.500	0.000	0.000
291	40000.000	5000.000	Q	-151.500	455.500	0.000	0.000
292	40000.000	7500.000	Q	-147.600	455.500	0.000	0.000
293	40000.000	10000.000	Q	-143.200	455.500	0.000	0.000
294	40000.000	12500.000	Q	-138.200	455.500	-250.000	0.000
295	40000.000	15000.000	Q	-132.800	455.500	-2157.000	0.000
296	40000.000	17500.000	Q	-127.200	455.500	-500.000	0.000
297	40000.000	20000.000	Q	-120.700	455.500	-965.000	0.000
298	40000.000	22500.000	Q	-114.700	455.500	-751.000	0.000
299	40000.000	25000.000	Q	-109.700	455.500	-1215.000	0.000
300	40000.000	27500.000	Q	-105.300	455.500	-500.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
301	40000.000	30000.000	Q	-103.900	455.500	-250.000	0.000
302	40000.000	32500.000	Q	-107.200	455.500	-2645.000	0.000
303	40000.000	35000.000	Q	-111.000	455.500	-2407.000	0.000
304	40000.000	37500.000	Q	-114.000	455.500	-1430.000	0.000
305	40000.000	40000.000	Q	-116.600	455.500	0.000	0.000
306	40000.000	42500.000	Q	-117.000	455.500	0.000	0.000
307	42500.000	0.000	Q	-151.500	455.000	0.000	0.000
308	42500.000	2500.000	Q	-149.900	455.000	0.000	0.000
309	42500.000	5000.000	Q	-144.900	455.000	0.000	0.000
310	42500.000	7500.000	Q	-139.400	455.000	0.000	0.000
311	42500.000	10000.000	Q	-133.400	455.000	0.000	0.000
312	42500.000	12500.000	Q	-126.900	455.000	-1430.000	0.000
313	42500.000	15000.000	Q	-119.900	455.000	-3860.000	0.000
314	42500.000	17500.000	Q	-113.000	455.000	-4790.000	0.000
315	42500.000	20000.000	Q	-106.000	455.000	-1906.000	0.000
316	42500.000	22500.000	Q	-100.000	455.000	-965.000	0.000
317	42500.000	25000.000	Q	-95.000	455.000	-2169.000	0.000
318	42500.000	27500.000	Q	-91.000	455.000	-250.000	0.000
319	42500.000	30000.000	Q	-90.000	455.000	-965.000	0.000
320	42500.000	32500.000	Q	-94.000	455.000	-1942.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
321	42500.000	35000.000	Q	-100.200	455.000	-3360.000	0.000
322	42500.000	37500.000	Q	-104.700	455.000	-2383.000	0.000
323	42500.000	40000.000	Q	-108.000	455.000	0.000	0.000
324	42500.000	42500.000	Q	-109.600	455.000	0.000	0.000
325	45000.000	0.000	Q	-141.400	454.500	0.000	0.000
326	45000.000	2500.000	Q	-139.200	454.500	0.000	0.000
327	45000.000	5000.000	Q	-133.500	454.500	0.000	0.000
328	45000.000	7500.000	Q	-127.900	454.500	0.000	0.000
329	45000.000	10000.000	Q	-120.500	454.500	0.000	0.000
330	45000.000	12500.000	Q	-111.400	454.500	0.000	0.000
331	45000.000	15000.000	Q	-101.900	454.500	-965.000	0.000
332	45000.000	17500.000	Q	-94.000	454.500	-2407.000	0.000
333	45000.000	20000.000	Q	-87.000	454.500	-2860.000	0.000
334	45000.000	22500.000	Q	-81.000	454.500	-1001.000	0.000
335	45000.000	25000.000	Q	-77.000	454.500	-3574.000	0.000
336	45000.000	27500.000	Q	-76.000	454.500	-715.000	0.000
337	45000.000	30000.000	Q	-79.000	454.500	-250.000	0.000
338	45000.000	32500.000	Q	-86.000	454.500	-965.000	0.000
339	45000.000	35000.000	Q	-93.000	454.500	-965.000	0.000
340	45000.000	37500.000	Q	-98.000	454.500	-250.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
341	45000.000	40000.000	Q	-102.300	454.500	0.000	0.000
342	45000.000	42500.000	Q	-103.600	454.500	0.000	0.000
343	47500.000	0.000	Q	-133.600	454.000	0.000	0.000
344	47500.000	2500.000	Q	-132.000	454.000	0.000	0.000
345	47500.000	5000.000	Q	-127.400	454.000	0.000	0.000
346	47500.000	7500.000	Q	-121.400	454.000	0.000	0.000
347	47500.000	10000.000	Q	-111.100	454.000	0.000	0.000
348	47500.000	12500.000	Q	-99.000	454.000	-250.000	0.000
349	47500.000	15000.000	Q	-89.000	454.000	-500.000	0.000
350	47500.000	17500.000	Q	-81.000	454.000	-1454.000	0.000
351	47500.000	20000.000	Q	-75.000	454.000	-4790.000	0.000
352	47500.000	22500.000	Q	-69.000	454.000	-7387.000	0.000
353	47500.000	25000.000	Q	-66.000	454.000	-1680.000	0.000
354	47500.000	27500.000	Q	-67.000	454.000	-4540.000	0.000
355	47500.000	30000.000	Q	-72.000	454.000	-1466.000	0.000
356	47500.000	32500.000	Q	-80.000	454.000	-3860.000	0.000
357	47500.000	35000.000	Q	-89.000	454.000	-3098.000	0.000
358	47500.000	37500.000	Q	-94.000	454.000	-1430.000	0.000
359	47500.000	40000.000	Q	-99.000	454.000	0.000	0.000
360	47500.000	42500.000	Q	-100.300	454.000	0.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
361	50000.000	0.000	Q	-122.600	453.500	0.000	0.000
362	50000.000	2500.000	Q	-120.800	453.500	0.000	0.000
363	50000.000	5000.000	Q	-115.500	453.500	0.000	0.000
364	50000.000	7500.000	Q	-108.300	453.500	0.000	0.000
365	50000.000	10000.000	Q	-99.000	453.500	0.000	0.000
366	50000.000	12500.000	Q	-88.000	453.500	0.000	0.000
367	50000.000	15000.000	Q	-78.000	453.500	-715.000	0.000
368	50000.000	17500.000	Q	-70.000	453.500	-1430.000	0.000
369	50000.000	20000.000	Q	-64.000	453.500	-250.000	0.000
370	50000.000	22500.000	Q	-60.000	453.500	-3837.000	0.000
371	50000.000	25000.000	Q	-59.000	453.500	-2157.000	0.000
372	50000.000	27500.000	Q	-60.000	453.500	-1692.000	0.000
373	50000.000	30000.000	Q	-64.000	453.500	-500.000	0.000
374	50000.000	32500.000	Q	-73.000	453.500	-500.000	0.000
375	50000.000	35000.000	Q	-84.000	453.500	0.000	0.000
376	50000.000	37500.000	Q	-90.000	453.500	0.000	0.000
377	50000.000	40000.000	Q	-94.000	453.500	0.000	0.000
378	50000.000	42500.000	Q	-95.000	453.500	0.000	0.000
379	52500.000	0.000	Q	-115.000	453.000	0.000	0.000
380	52500.000	2500.000	Q	-113.300	453.000	0.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
381	52500.000	5000.000	Q	-108.100	453.000	0.000	0.000
382	52500.000	7500.000	Q	-100.000	453.000	0.000	0.000
383	52500.000	10000.000	Q	-84.000	453.000	0.000	0.000
384	52500.000	12500.000	Q	-74.000	453.000	0.000	0.000
385	52500.000	15000.000	Q	-66.000	453.000	0.000	0.000
386	52500.000	17500.000	Q	-57.000	453.000	-500.000	0.000
387	52500.000	20000.000	Q	-51.000	453.000	-1466.000	0.000
388	52500.000	22500.000	Q	-48.000	453.000	-1716.000	0.000
389	52500.000	25000.000	Q	-48.000	453.000	-965.000	0.000
390	52500.000	27500.000	Q	-52.000	453.000	-8841.000	0.000
391	52500.000	30000.000	Q	-58.000	453.000	-715.000	0.000
392	52500.000	32500.000	Q	-64.000	453.000	-250.000	0.000
393	52500.000	35000.000	Q	-69.000	453.000	0.000	0.000
394	52500.000	37500.000	Q	-74.000	453.000	0.000	0.000
395	52500.000	40000.000	Q	-77.000	453.000	0.000	0.000
396	52500.000	42500.000	Q	-78.000	453.000	0.000	0.000
397	55000.000	0.000	Q	-87.000	452.500	0.000	0.000
398	55000.000	2500.000	Q	-86.000	452.500	0.000	0.000
399	55000.000	5000.000	Q	-82.000	452.500	0.000	0.000
400	55000.000	7500.000	Q	-77.000	452.500	0.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
401	55000.000	10000.000	Q	-75.000	452.500	0.000	0.000
402	55000.000	12500.000	Q	-68.000	452.500	0.000	0.000
403	55000.000	15000.000	Q	-57.000	452.500	0.000	0.000
404	55000.000	17500.000	Q	-39.000	452.500	0.000	0.000
405	55000.000	20000.000	Q	-28.000	452.500	0.000	0.000
406	55000.000	22500.000	Q	-26.000	452.500	0.000	0.000
407	55000.000	25000.000	Q	-32.000	452.500	-250.000	0.000
408	55000.000	27500.000	Q	-43.000	452.500	-250.000	0.000
409	55000.000	30000.000	Q	-50.000	452.500	0.000	0.000
410	55000.000	32500.000	Q	-39.000	452.500	0.000	0.000
411	55000.000	35000.000	Q	-39.000	452.500	0.000	0.000
412	55000.000	37500.000	Q	-42.000	452.500	0.000	0.000
413	55000.000	40000.000	Q	-45.000	452.500	0.000	0.000
414	55000.000	42500.000	Q	-46.000	452.500	0.000	0.000
415	57500.000	0.000	Q	-61.000	452.000	0.000	0.000
416	57500.000	2500.000	Q	-60.000	452.000	0.000	0.000
417	57500.000	5000.000	Q	-57.000	452.000	0.000	0.000
418	57500.000	7500.000	Q	-52.000	452.000	0.000	0.000
419	57500.000	10000.000	Q	-49.000	452.000	0.000	0.000
420	57500.000	12500.000	Q	-43.000	452.000	0.000	0.000

===== BADON 3 =====

Node	x	y	F/Q	Fo	ho	Qf	Qs
421	57500.000	15000.000	Q	-38.000	452.000	0.000	0.000
422	57500.000	17500.000	Q	-19.000	452.000	0.000	0.000
423	57500.000	20000.000	Q	-13.000	452.000	0.000	0.000
424	57500.000	22500.000	Q	-12.000	452.000	0.000	0.000
425	57500.000	25000.000	Q	-15.000	452.000	0.000	0.000
426	57500.000	27500.000	Q	-36.000	452.000	0.000	0.000
427	57500.000	30000.000	Q	-44.000	452.000	0.000	0.000
428	57500.000	32500.000	Q	-40.000	452.000	0.000	0.000
429	57500.000	35000.000	Q	-40.000	452.000	0.000	0.000
430	57500.000	37500.000	Q	-42.000	452.000	0.000	0.000
431	57500.000	40000.000	Q	-44.000	452.000	0.000	0.000
432	57500.000	42500.000	Q	-45.000	452.000	0.000	0.000

----- BADON 3 -----

Element	Nodes				k	If	Is
1	1	19	20	2	199.60000	0.00000	0.00000
2	2	20	21	3	199.60000	0.00000	0.00000
3	3	21	22	4	199.60000	0.00000	0.00000
4	4	22	23	5	199.60000	0.00000	0.00000
5	5	23	24	6	199.60000	0.00000	0.00000
6	6	24	25	7	199.60000	0.00000	0.00000
7	7	25	26	8	199.60000	0.00000	0.00000
8	8	26	27	9	199.80000	0.00000	0.00000
9	9	27	28	10	200.00000	-0.00080	0.00000
10	10	28	29	11	189.80000	-0.00128	0.00000
11	11	29	30	12	199.60000	0.00000	0.00000
12	12	30	31	13	199.60000	0.00000	0.00000
13	13	31	32	14	199.60000	0.00000	0.00000
14	14	32	33	15	199.60000	0.00000	0.00000
15	15	33	34	16	199.60000	0.00000	0.00000
16	16	34	35	17	199.40000	0.00000	0.00000
17	17	35	36	18	199.60000	0.00000	0.00000
18	19	37	38	20	199.60000	0.00000	0.00000
19	20	38	39	21	199.60000	0.00000	0.00000
20	21	39	40	22	199.60000	0.00000	0.00000

----- BADON 3 -----

Element	Nodes				k	If	Is
21	22	40	41	23	199.60000	0.00000	0.00000
22	23	41	42	24	199.60000	0.00000	0.00000
23	24	42	43	25	199.60000	0.00000	0.00000
24	25	43	44	26	199.60000	0.00000	0.00000
25	26	44	45	27	200.00000	0.00000	0.00000
26	27	45	46	28	200.00000	-0.00144	0.00000
27	28	46	47	29	200.00000	-0.00144	0.00000
28	29	47	48	30	200.00000	-0.00144	0.00000
29	30	48	49	31	200.00000	-0.00080	0.00000
30	31	49	50	32	200.00000	0.00000	0.00000
31	32	50	51	33	199.60000	-0.00064	0.00000
32	33	51	52	34	199.00000	0.00000	0.00000
33	34	52	53	35	198.60000	0.00000	0.00000
34	35	53	54	36	198.10000	0.00000	0.00000
35	37	55	56	38	199.60000	0.00000	0.00000
36	38	56	57	39	199.60000	0.00000	0.00000
37	39	57	58	40	199.60000	0.00000	0.00000
38	40	58	59	41	199.60000	0.00000	0.00000
39	41	59	60	42	199.60000	0.00000	0.00000
40	42	60	61	43	199.60000	0.00000	0.00000

===== BADON 3 =====

Element	Nodes				k	If	Is
41	43	61	62	44	199.60000	0.00000	0.00000
42	44	62	63	45	199.10000	0.00000	0.00000
43	45	63	64	46	198.70000	-0.00048	0.00000
44	46	64	65	47	198.70000	-0.00048	0.00000
45	47	65	66	48	199.00000	-0.00032	0.00000
46	48	66	67	49	199.80000	-0.00096	0.00000
47	49	67	68	50	200.00000	-0.00088	0.00000
48	50	68	69	51	199.20000	0.00000	0.00000
49	51	69	70	52	197.60000	0.00000	0.00000
50	52	70	71	53	196.70000	0.00000	0.00000
51	53	71	72	54	196.20000	0.00000	0.00000
52	55	73	74	56	199.60000	0.00000	0.00000
53	56	74	75	57	199.60000	0.00000	0.00000
54	57	75	76	58	199.60000	0.00000	0.00000
55	58	76	77	59	199.60000	0.00000	0.00000
56	59	77	78	60	199.60000	0.00000	0.00000
57	60	78	79	61	198.80000	0.00000	0.00000
58	61	79	80	62	197.70000	0.00000	0.00000
59	62	80	81	63	196.80000	0.00000	0.00000
60	63	81	82	64	195.90000	0.00000	0.00000

===== BADON 3 =====

Element	Nodes				k	If	Is
61	64	82	83	65	195.70000	0.00000	0.00000
62	65	83	84	66	195.80000	0.00000	0.00000
63	66	84	85	67	0.01000	0.00000	0.00000
64	67	85	86	68	0.01000	0.00000	0.00000
65	68	86	87	69	0.01000	0.00000	0.00000
66	69	87	88	70	97.80000	0.00000	0.00000
67	70	88	89	71	97.30000	0.00000	0.00000
68	71	89	90	72	97.10000	0.00000	0.00000
69	73	91	92	74	198.80000	0.00000	0.00000
70	74	92	93	75	197.90000	0.00000	0.00000
71	75	93	94	76	197.50000	0.00000	0.00000
72	76	94	95	77	197.30000	0.00000	0.00000
73	77	95	96	78	197.20000	0.00000	0.00000
74	78	96	97	79	196.10000	0.00000	0.00000
75	79	97	98	80	194.70000	0.00000	0.00000
76	80	98	99	81	194.10000	0.00000	0.00000
77	81	99	100	82	193.70000	0.00000	0.00000
78	82	100	101	83	193.40000	0.00000	0.00000
79	83	101	102	84	144.90000	0.00000	0.00000
80	84	102	103	85	96.40000	0.00000	0.00000

===== BADON 3 =====

Element	Nodes				k	If	Is
81	85	103	104	86	1.00000	0.00000	0.00000
82	86	104	105	87	1.00000	0.00000	0.00000
83	87	105	106	88	1.00000	0.00000	0.00000
84	88	106	107	89	96.10000	0.00000	0.00000
85	89	107	108	90	95.90000	0.00000	0.00000
86	91	109	110	92	196.30000	0.00000	0.00000
87	92	110	111	93	195.00000	0.00000	0.00000
88	93	111	112	94	194.50000	0.00000	0.00000
89	94	112	113	95	194.20000	0.00000	0.00000
90	95	113	114	96	193.80000	0.00000	0.00000
91	96	114	115	97	193.40000	0.00000	0.00000
92	97	115	116	98	192.90000	0.00000	0.00000
93	98	116	117	99	192.50000	0.00000	0.00000
94	99	117	118	100	192.10000	0.00000	0.00000
95	100	118	119	101	191.90000	0.00000	0.00000
96	101	119	120	102	191.70000	0.00000	0.00000
97	102	120	121	103	95.80000	0.00000	0.00000
98	103	121	122	104	1.00000	0.00000	0.00000
99	104	122	123	105	1.00000	0.00000	0.00000
100	105	123	124	106	1.00000	0.00000	0.00000

===== BADON 3 =====

Element	Nodes				k	If	Is
101	106	124	125	107	94.90000	0.00000	0.00000
102	107	125	126	108	94.90000	0.00000	0.00000
103	109	127	128	110	193.40000	0.00000	0.00000
104	110	128	129	111	193.00000	0.00000	0.00000
105	111	129	130	112	192.70000	0.00000	0.00000
106	112	130	131	113	192.30000	0.00000	0.00000
107	113	131	132	114	192.00000	0.00000	0.00000
108	114	132	133	115	191.70000	0.00000	0.00000
109	115	133	134	116	191.40000	0.00000	0.00000
110	116	134	135	117	191.10000	0.00000	0.00000
111	117	135	136	118	190.80000	0.00000	0.00000
112	118	136	137	119	190.50000	0.00000	0.00000
113	119	137	138	120	190.30000	0.00000	0.00000
114	120	138	139	121	95.10000	0.00000	0.00000
115	121	139	140	122	0.20000	0.00000	0.00000
116	122	140	141	123	0.20000	0.00000	0.00000
117	123	141	142	124	0.20000	0.00000	0.00000
118	124	142	143	125	93.90000	0.00000	0.00000
119	125	143	144	126	94.00000	0.00000	0.00000
120	127	145	146	128	191.40000	0.00000	0.00000

===== BADON 3 =====

Element	¦------ Nodes			-------¦	k	If	Is
121	128	146	147	129	191.20000	0.00000	0.00000
122	129	147	148	130	190.90000	0.00000	0.00000
123	130	148	149	131	190.60000	0.00000	0.00000
124	131	149	150	132	190.40000	0.00000	0.00000
125	132	150	151	133	190.10000	0.00000	0.00000
126	133	151	152	134	189.90000	0.00000	0.00000
127	134	152	153	135	189.60000	0.00000	0.00000
128	135	153	154	136	141.90000	0.00000	0.00000
129	136	154	155	137	141.50000	0.00000	0.00000
130	137	155	156	138	94.10000	0.00000	0.00000
131	138	156	157	139	9.40000	0.00000	0.00000
132	139	157	158	140	9.30000	0.00000	0.00000
133	140	158	159	141	9.20000	0.00000	0.00000
134	141	159	160	142	46.10000	0.00000	0.00000
135	142	160	161	143	46.30000	0.00000	0.00000
136	143	161	162	144	46.40000	0.00000	0.00000
137	145	163	164	146	189.60000	0.00000	0.00000
138	146	164	165	147	189.40000	0.00000	0.00000
139	147	165	166	148	189.20000	0.00000	0.00000
140	148	166	167	149	188.90000	0.00000	0.00000

===== BADON 3 =====

Element	¦------ Nodes			-------¦	k	If	Is
141	149	167	168	150	188.70000	0.00000	0.00000
142	150	168	169	151	188.50000	0.00000	0.00000
143	151	169	170	152	141.20000	0.00000	0.00000
144	152	170	171	153	141.00000	0.00000	0.00000
145	153	171	172	154	140.60000	0.00000	0.00000
146	154	172	173	155	140.10000	0.00000	0.00000
147	155	173	174	156	139.30000	0.00000	0.00000
148	156	174	175	157	92.10000	0.00000	0.00000
149	157	175	176	158	73.00000	0.00000	0.00000
150	158	176	177	159	54.60000	0.00000	0.00000
151	159	177	178	160	36.40000	0.00000	0.00000
152	160	178	179	161	36.50000	0.00000	0.00000
153	161	179	180	162	36.60000	0.00000	0.00000
154	163	181	182	164	150.20000	0.00000	0.00000
155	164	182	183	165	150.10000	0.00000	0.00000
156	165	183	184	166	149.90000	0.00000	0.00000
157	166	184	185	167	149.60000	0.00000	0.00000
158	167	185	186	168	149.40000	0.00000	0.00000
159	168	186	187	169	111.80000	0.00000	0.00000
160	169	187	188	170	74.40000	0.00000	0.00000

===== BADON 3 =====

Element	Nodes				k	If	Is
161	170	188	189	171	55.60000	0.00000	0.00000
162	171	189	190	172	46.10000	0.00000	0.00000
163	172	190	191	173	45.90000	0.00000	0.00000
164	173	191	192	174	45.70000	0.00000	0.00000
165	174	192	193	175	45.40000	0.00000	0.00000
166	175	193	194	176	45.10000	0.00000	0.00000
167	176	194	195	177	35.90000	0.00000	0.00000
168	177	195	196	178	17.90000	0.00000	0.00000
169	178	196	197	179	17.80000	0.00000	0.00000
170	179	197	198	180	17.80000	0.00000	0.00000
171	181	199	200	182	111.40000	0.00000	0.00000
172	182	200	201	183	111.20000	0.00000	0.00000
173	183	201	202	184	111.00000	0.00000	0.00000
174	184	202	203	185	110.80000	0.00000	0.00000
175	185	203	204	186	110.40000	0.00000	0.00000
176	186	204	205	187	73.30000	0.00000	0.00000
177	187	205	206	188	54.70000	0.00000	0.00000
178	188	206	207	189	45.40000	0.00000	0.00000
179	189	207	208	190	45.10000	0.00000	0.00000
180	190	208	209	191	44.80000	0.00000	0.00000

===== BADON 3 =====

Element	Nodes				k	If	Is
181	191	209	210	192	35.60000	0.00000	0.00000
182	192	210	211	193	26.50000	0.00000	0.00000
183	193	211	212	194	17.60000	0.00000	0.00000
184	194	212	213	195	17.50000	0.00000	0.00000
185	195	213	214	196	17.40000	0.00000	0.00000
186	196	214	215	197	17.30000	0.00000	0.00000
187	197	215	216	198	17.30000	0.00000	0.00000
188	199	217	218	200	73.10000	0.00000	0.00000
189	200	218	219	201	73.00000	0.00000	0.00000
190	201	219	220	202	72.80000	0.00000	0.00000
191	202	220	221	203	72.60000	0.00000	0.00000
192	203	221	222	204	72.20000	0.00000	0.00000
193	204	222	223	205	71.80000	0.00000	0.00000
194	205	223	224	206	35.60000	0.00000	0.00000
195	206	224	225	207	35.30000	0.00000	0.00000
196	207	225	226	208	35.10000	0.00000	0.00000
197	208	226	227	209	30.50000	0.00000	0.00000
198	209	227	228	210	30.30000	0.00000	0.00000
199	210	228	229	211	30.00000	0.00000	0.00000
200	211	229	230	212	25.50000	0.00000	0.00000

===== BADON 3 =====

Element	¦------ Nodes			-------¦	k	If	Is
201	212	230	231	213	25.40000	0.00000	0.00000
202	213	231	232	214	25.30000	0.00000	0.00000
203	214	232	233	215	16.80000	0.00000	0.00000
204	215	233	234	216	16.70000	0.00000	0.00000
205	217	235	236	218	62.90000	0.00000	0.00000
206	218	236	237	219	62.70000	0.00000	0.00000
207	219	237	238	220	62.50000	0.00000	0.00000
208	220	238	239	221	62.20000	0.00000	0.00000
209	221	239	240	222	61.80000	0.00000	0.00000
210	222	240	241	223	61.30000	0.00000	0.00000
211	223	241	242	224	52.10000	0.00000	0.00000
212	224	242	243	225	51.60000	0.00000	0.00000
213	225	243	244	226	29.80000	0.00000	0.00000
214	226	244	245	227	29.60000	0.00000	0.00000
215	227	245	246	228	29.30000	0.00000	0.00000
216	228	246	247	229	29.20000	0.00000	0.00000
217	229	247	248	230	24.80000	0.00000	0.00000
218	230	248	249	231	20.60000	0.00000	0.00000
219	231	249	250	232	16.40000	0.00000	0.00000
220	232	250	251	233	16.30000	0.00000	0.00000

===== BADON 3 =====

Element	¦------ Nodes			-------¦	k	If	Is
221	233	251	252	234	24.40000	0.00000	0.00000
222	235	253	254	236	53.00000	0.00000	0.00000
223	236	254	255	237	61.60000	0.00000	0.00000
224	237	255	256	238	61.30000	0.00000	0.00000
225	238	256	257	239	60.90000	0.00000	0.00000
226	239	257	258	240	60.40000	0.00000	0.00000
227	240	258	259	241	59.90000	0.00000	0.00000
228	241	259	260	242	42.30000	0.00000	0.00000
229	242	260	261	243	41.90000	0.00000	0.00000
230	243	261	262	244	29.00000	0.00000	0.00000
231	244	262	263	245	28.70000	0.00000	0.00000
232	245	263	264	246	28.40000	0.00000	0.00000
233	246	264	265	247	16.10000	0.00000	0.00000
234	247	265	266	248	24.00000	0.00000	0.00000
235	248	266	267	249	19.90000	0.00000	0.00000
236	249	267	268	250	19.90000	0.00000	0.00000
237	250	268	269	251	19.90000	0.00000	0.00000
238	251	269	270	252	23.80000	0.00000	0.00000
239	253	271	272	254	43.40000	0.00000	0.00000
240	254	272	273	255	51.90000	0.00000	0.00000

===== BADON 3 =====

Element	Nodes				k	If	Is
241	255	273	274	256	51.60000	0.00000	0.00000
242	256	274	275	257	51.20000	0.00000	0.00000
243	257	275	276	258	50.60000	0.00000	0.00000
244	258	276	277	259	50.10000	0.00000	0.00000
245	259	277	278	260	41.20000	0.00000	0.00000
246	260	278	279	261	40.60000	0.00000	0.00000
247	261	279	280	262	24.00000	0.00000	0.00000
248	262	280	281	263	23.70000	0.00000	0.00000
249	263	281	282	264	15.60000	0.00000	0.00000
250	264	282	283	265	15.40000	0.00000	0.00000
251	265	283	284	266	15.20000	0.00000	0.00000
252	266	284	285	267	15.30000	0.00000	0.00000
253	267	285	286	268	15.40000	0.00000	0.00000
254	268	286	287	269	15.40000	0.00000	0.00000
255	269	287	288	270	23.20000	0.00000	0.00000
256	271	289	290	272	25.60000	0.00000	0.00000
257	272	290	291	273	34.00000	0.00000	0.00000
258	273	291	292	274	33.70000	0.00000	0.00000
259	274	292	293	275	33.30000	0.00000	0.00000
260	275	293	294	276	32.80000	0.00000	0.00000

===== BADON 3 =====

Element	Nodes				k	If	Is
261	276	294	295	277	32.40000	0.00000	0.00000
262	277	295	296	278	31.90000	0.00000	0.00000
263	278	296	297	279	23.50000	0.00000	0.00000
264	279	297	298	280	22.90000	0.00000	0.00000
265	280	298	299	281	19.60000	0.00000	0.00000
266	281	299	300	282	17.30000	0.00000	0.00000
267	282	300	301	283	10.80000	0.00080	0.00000
268	283	301	302	284	16.20000	0.00032	0.00000
269	284	302	303	285	17.10000	0.00000	0.00000
270	285	303	304	286	18.20000	0.00000	0.00000
271	286	304	305	287	19.20000	0.00000	0.00000
272	287	305	306	288	19.90000	0.00000	0.00000
273	289	307	308	290	25.20000	0.00000	0.00000
274	290	308	309	291	25.00000	0.00000	0.00000
275	291	309	310	292	28.80000	0.00000	0.00000
276	292	310	311	293	28.30000	0.00000	0.00000
277	293	311	312	294	27.80000	0.00000	0.00000
278	294	312	313	295	27.30000	0.00000	0.00000
279	295	313	314	296	25.60000	0.00000	0.00000
280	296	314	315	297	18.40000	0.00000	0.00000

===== BADON 3 =====

Element	Nodes				k	If	Is
281	297	315	316	298	15.90000	0.00000	0.00000
282	298	316	317	299	14.30000	0.00000	0.00000
283	299	317	318	300	13.10000	0.00000	0.00000
284	300	318	319	301	8.30000	0.00064	0.00000
285	301	319	320	302	8.40000	0.00064	0.00000
286	302	320	321	303	9.20000	0.00000	0.00000
287	303	321	322	304	10.00000	0.00000	0.00000
288	304	322	323	305	10.70000	0.00000	0.00000
289	305	323	324	306	11.20000	0.00000	0.00000
290	307	325	326	308	4.10000	0.00000	0.00000
291	308	326	327	309	5.70000	0.00000	0.00000
292	309	327	328	310	15.90000	0.00000	0.00000
293	310	328	329	311	19.60000	0.00000	0.00000
294	311	329	330	312	18.10000	0.00000	0.00000
295	312	330	331	313	14.70000	0.00000	0.00000
296	313	331	332	314	12.40000	0.00000	0.00000
297	314	332	333	315	10.90000	0.00000	0.00000
298	315	333	334	316	9.70000	0.00000	0.00000
299	316	334	335	317	9.00000	0.00000	0.00000
300	317	335	336	318	8.60000	0.00000	0.00000

===== BADON 3 =====

Element	Nodes				k	If	Is
301	318	336	337	319	8.50000	0.00048	0.00000
302	319	337	338	320	8.90000	0.00048	0.00000
303	320	338	339	321	9.70000	0.00000	0.00000
304	321	339	340	322	10.70000	0.00000	0.00000
305	322	340	341	323	11.50000	0.00000	0.00000
306	323	341	342	324	7.30000	0.00000	0.00000
307	325	343	344	326	3.20000	0.00000	0.00000
308	326	344	345	327	4.70000	0.00000	0.00000
309	327	345	346	328	15.50000	0.00000	0.00000
310	328	346	347	329	20.10000	0.00000	0.00000
311	329	347	348	330	16.00000	0.00000	0.00000
312	330	348	349	331	13.10000	0.00000	0.00000
313	331	349	350	332	15.20000	0.00000	0.00000
314	332	350	351	333	13.60000	0.00000	0.00000
315	333	351	352	334	12.60000	0.00000	0.00000
316	334	352	353	335	11.90000	0.00072	0.00000
317	335	353	354	336	14.50000	0.00056	0.00000
318	336	354	355	337	10.40000	0.00048	0.00000
319	337	355	356	338	11.20000	0.00016	0.00000
320	338	356	357	339	12.40000	0.00000	0.00000

===== BADON 3 =====

Element	Nodes				k	If	Is
321	339	357	358	340	11.70000	0.00000	0.00000
322	340	358	359	341	6.40000	0.00000	0.00000
323	341	359	360	342	6.70000	0.00000	0.00000
324	343	361	362	344	1.50000	0.00000	0.00000
325	344	362	363	345	1.50000	0.00000	0.00000
326	345	363	364	346	1.90000	0.00000	0.00000
327	346	364	365	347	2.60000	0.00000	0.00000
328	347	365	366	348	8.60000	0.00000	0.00000
329	348	366	367	349	14.50000	0.00000	0.00000
330	349	367	368	350	16.00000	0.00000	0.00000
331	350	368	369	351	14.70000	0.00000	0.00000
332	351	369	370	352	13.80000	0.00000	0.00000
333	352	370	371	353	18.60000	0.00056	0.00000
334	353	371	372	354	18.50000	0.00080	0.00000
335	354	372	373	355	9.50000	0.00064	0.00000
336	355	373	374	356	7.30000	0.00000	0.00000
337	356	374	375	357	3.30000	0.00000	0.00000
338	357	375	376	358	2.90000	0.00000	0.00000
339	358	376	377	359	2.40000	0.00000	0.00000
340	359	377	378	360	1.60000	0.00000	0.00000

===== BADON 3 =====

Element	Nodes				k	If	Is
341	361	379	380	362	1.30000	0.00000	0.00000
342	362	380	381	363	1.20000	0.00000	0.00000
343	363	381	382	364	1.50000	0.00000	0.00000
344	364	382	383	365	1.70000	0.00000	0.00000
345	365	383	384	366	1.70000	0.00000	0.00000
346	366	384	385	367	6.20000	0.00000	0.00000
347	367	385	386	368	11.20000	0.00000	0.00000
348	368	386	387	369	12.90000	0.00000	0.00000
349	369	387	388	370	12.30000	0.00000	0.00000
350	370	388	389	371	12.00000	0.00000	0.00000
351	371	389	390	372	12.20000	0.00072	0.00000
352	372	390	391	373	10.10000	0.00032	0.00000
353	373	391	392	374	2.70000	0.00000	0.00000
354	374	392	393	375	0.20000	0.00000	0.00000
355	375	393	394	376	0.20000	0.00000	0.00000
356	376	394	395	377	0.20000	0.00000	0.00000
357	377	395	396	378	0.30000	0.00000	0.00000
358	379	397	398	380	0.20000	0.00000	0.00000
359	380	398	399	381	0.20000	0.00000	0.00000
360	381	399	400	382	0.20000	0.00000	0.00000

===== BADON 3 =====

Element	Nodes				k	If	Is
361	382	400	401	383	0.10000	0.00000	0.00000
362	383	401	402	384	2.40000	0.00000	0.00000
363	384	402	403	385	5.50000	0.00000	0.00000
364	385	403	404	386	8.50000	0.00000	0.00000
365	386	404	405	387	7.70000	0.00000	0.00000
366	387	405	406	388	7.40000	0.00000	0.00000
367	388	406	407	389	7.40000	0.00000	0.00000
368	389	407	408	390	7.70000	0.00048	0.00000
369	390	408	409	391	2.40000	0.00005	0.00000
370	391	409	410	392	0.04000	0.00005	0.00000
371	392	410	411	393	0.04000	0.00005	0.00000
372	393	411	412	394	0.04000	0.00005	0.00000
373	394	412	413	395	0.04000	0.00005	0.00000
374	395	413	414	396	0.04000	0.00005	0.00000
375	397	415	416	398	0.04000	0.00004	0.00000
376	398	416	417	399	0.04000	0.00004	0.00000
377	399	417	418	400	0.04000	0.00004	0.00000
378	400	418	419	401	0.04000	0.00004	0.00000
379	401	419	420	402	0.04000	0.00004	0.00000
380	402	420	421	403	0.04000	0.00004	0.00000

===== BADON 3 =====

Element	Nodes				k	If	Is
381	403	421	422	404	0.00001	0.00000	0.00000
382	404	422	423	405	6.57000	0.00384	0.00000
383	405	423	424	406	6.34000	0.00547	0.00000
384	406	424	425	407	6.42000	0.00384	0.00000
385	407	425	426	408	0.00001	0.00000	0.00000
386	408	426	427	409	0.00001	0.00000	0.00000
387	409	427	428	410	0.00001	0.00000	0.00000
388	410	428	429	411	0.00001	0.00000	0.00000
389	411	429	430	412	0.00001	0.00000	0.00000
390	412	430	431	413	0.00001	0.00000	0.00000
391	413	431	432	414	0.00001	0.00000	0.00000

===== BADON 3 =====

Time steps

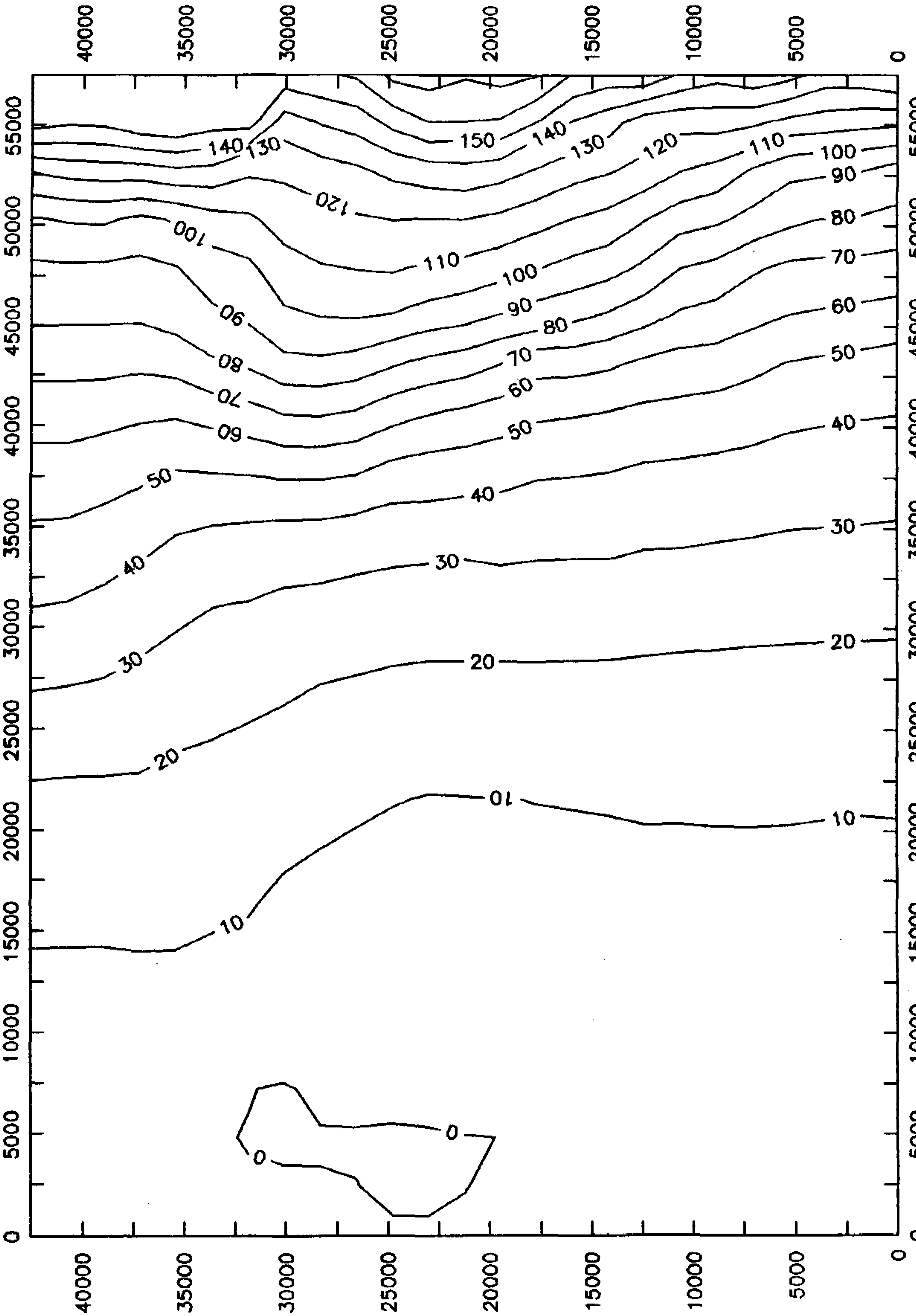
Time	Multiplication factor
50.000	1.000
100.000	1.000
150.000	1.000
200.000	1.000
300.000	1.000
400.000	1.000
500.000	1.000
700.000	1.000
900.000	1.000
1200.000	1.000
1500.000	1.000
1800.000	1.000
2200.000	1.000
2700.000	1.000
3300.000	1.000
4000.000	1.000
5000.000	1.000
6000.000	1.000
7000.000	1.000
8500.000	1.000
10000.000	1.000
12000.000	1.000
15000.000	1.000
18250.000	1.000
22000.000	1.000
26000.000	1.000
31000.000	1.000
36500.000	1.000
41000.000	1.000
45500.000	1.000
50000.000	1.000
54750.000	1.000
59000.000	1.000
63000.000	1.000
68000.000	1.000
73000.000	1.000

Annex A1: Abstractions (m^3/day) for scenario 1, abstractions in east (current situation).

x-coordinate	0	2500	5000	7500	10000	12500	15000	17500	20000	22500	25000	27500
y-coordinate												
42500	0	0	0	0	0	0	0	0	0	0	0	0
40000	0	0	0	0	0	0	0	0	0	0	0	0
37500	0	0	0	0	0	0	0	0	0	0	250	1906
35000	0	0	0	0	0	250	0	500	0	0	0	500
32500	0	0	0	0	0	0	250	0	0	250	0	250
30000	0	0	0	0	0	0	0	0	0	0	250	751
27500	0	0	0	0	0	500	250	0	0	0	0	1430
25000	0	0	0	250	0	0	250	3122	3110	2395	500	1716
22500	0	0	0	0	0	965	1442	3574	2860	0	500	1001
20000	0	0	0	0	965	250	0	965	500	715	250	1442
17500	0	0	0	0	0	0	0	0	0	0	500	1191
15000	0	0	0	0	0	0	0	0	0	0	500	0
12500	0	0	0	0	0	0	0	0	0	0	0	0
10000	0	0	0	0	0	0	0	0	0	0	0	0
7500	0	0	0	0	0	0	0	0	0	0	0	0
5000	0	0	0	0	0	0	0	0	0	0	0	0
2500	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0

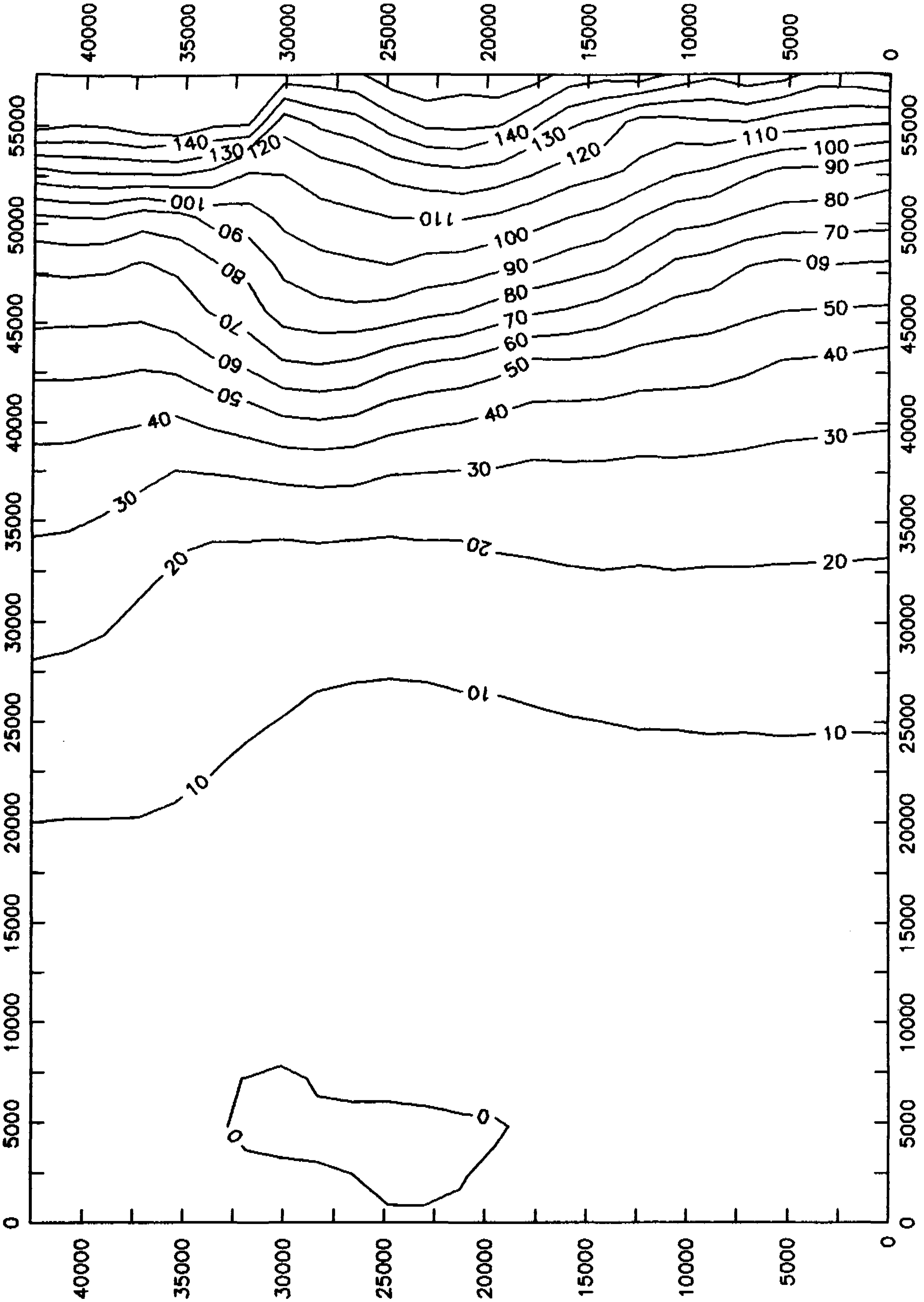
x-coordinate	30000	32500	35000	37500	40000	42500	45000	47500	50000	52500	55000	57500
y-coordinate												
42500	0	0	0	0	0	0	0	0	0	0	0	0
40000	0	0	0	0	0	0	0	0	0	0	0	0
37500	500	1442	250	965	1430	2383	250	1430	0	0	0	0
35000	1680	4301	2872	5016	2407	3360	965	3098	0	0	0	0
32500	1442	1716	4766	3360	2645	1942	965	3860	500	250	0	0
30000	500	1215	2633	1215	250	965	250	1466	500	715	0	0
27500	1430	4099	1466	2395	500	250	715	4540	1692	8841	250	0
25000	250	715	1680	4063	1215	2169	3574	1680	2157	965	250	0
22500	500	4301	3860	1716	751	965	1001	7387	3837	1716	0	0
20000	0	1215	2169	0	965	1906	2860	4790	250	1466	0	0
17500	250	0	0	2169	500	4790	2407	1454	1430	500	0	0
15000	0	0	1430	0	2157	3860	965	500	715	0	0	0
12500	250	0	250	0	250	1430	0	250	0	0	0	0
10000	0	0	0	0	0	0	0	0	0	0	0	0
7500	0	0	0	0	0	0	0	0	0	0	0	0
5000	0	0	0	0	0	0	0	0	0	0	0	0
2500	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0

Annex A1: Abstractions (m3/day) for scenario 1, abstractions in east (current situation).



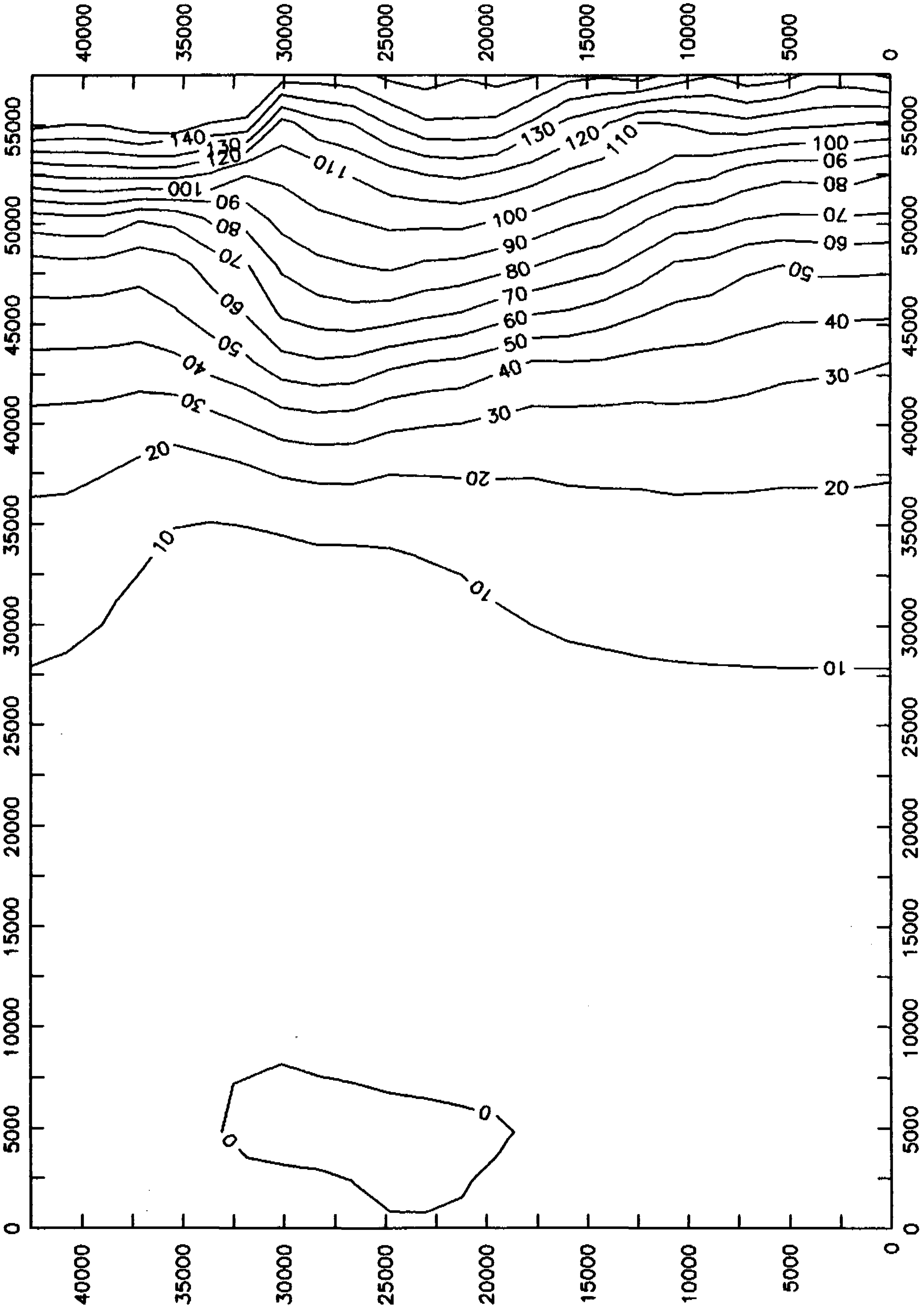
Annex A2: Phreatic head (m) after 50 years abstractions in the east (current situation).

elderh.1



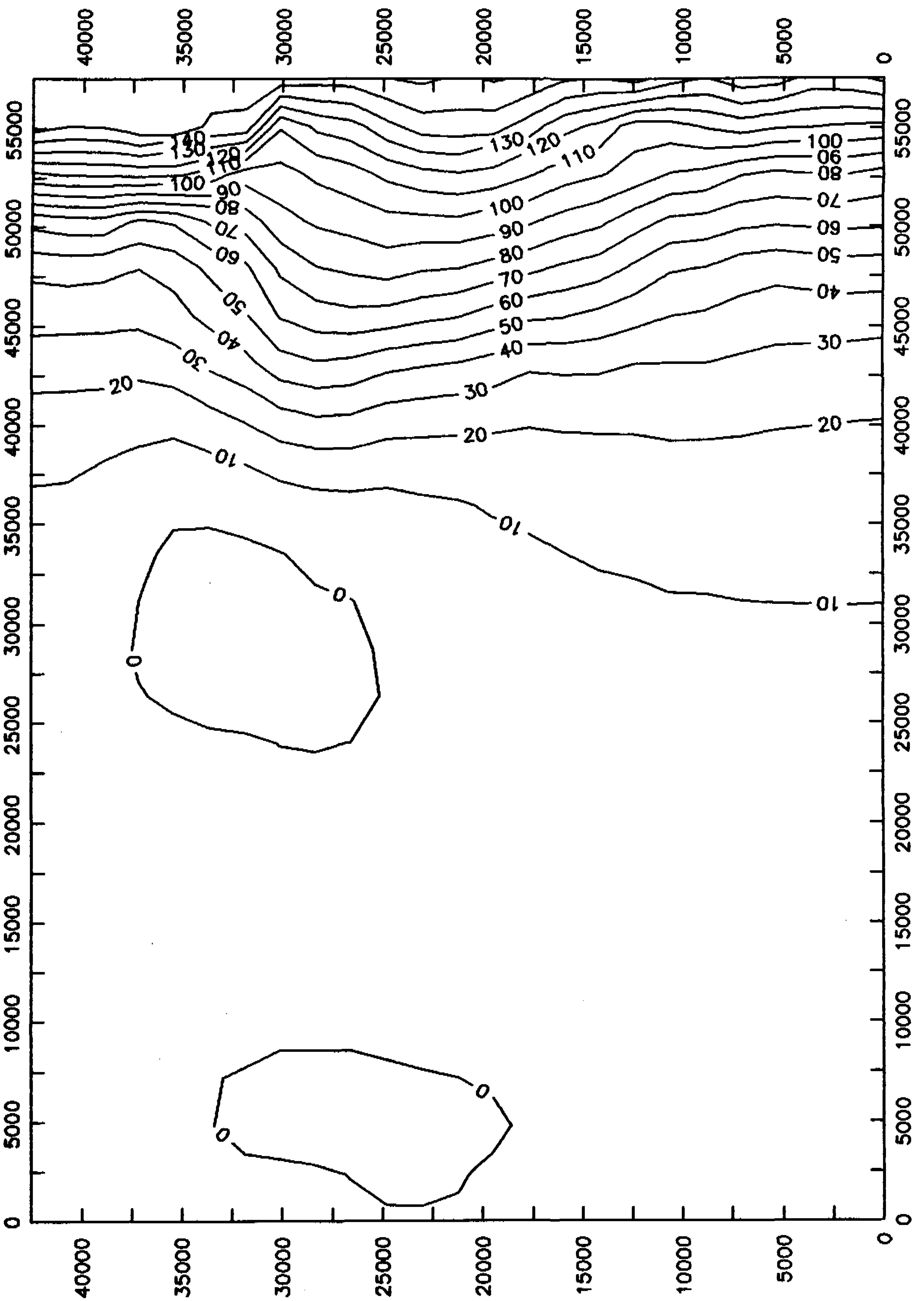
Annex A3: Phreatic head (m) after 100 years abstractions in the east (current situation).

elderh.2



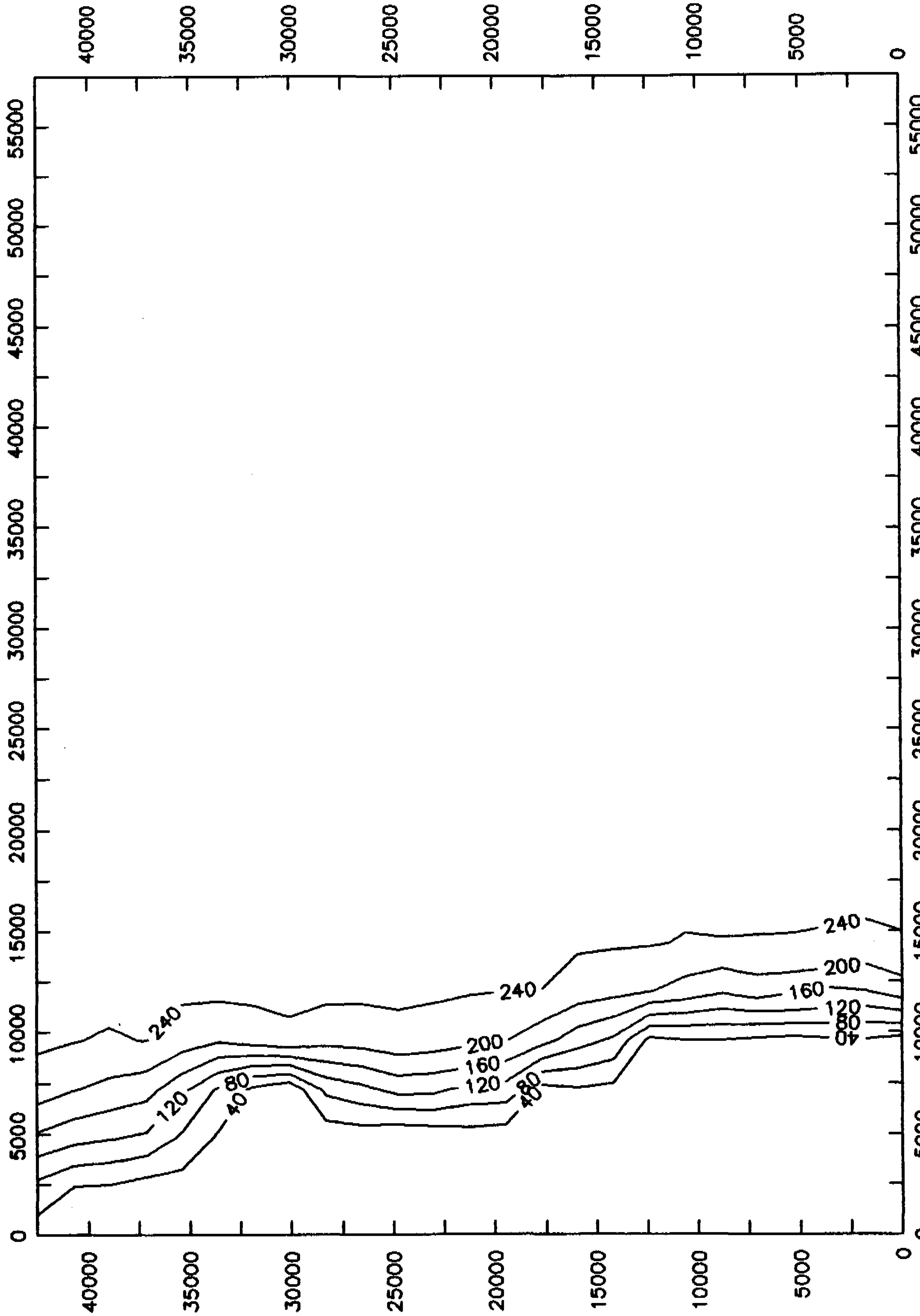
Annex A4: Phreatic head (m) after 150 years abstractions in the east (current situation).

elderh.3



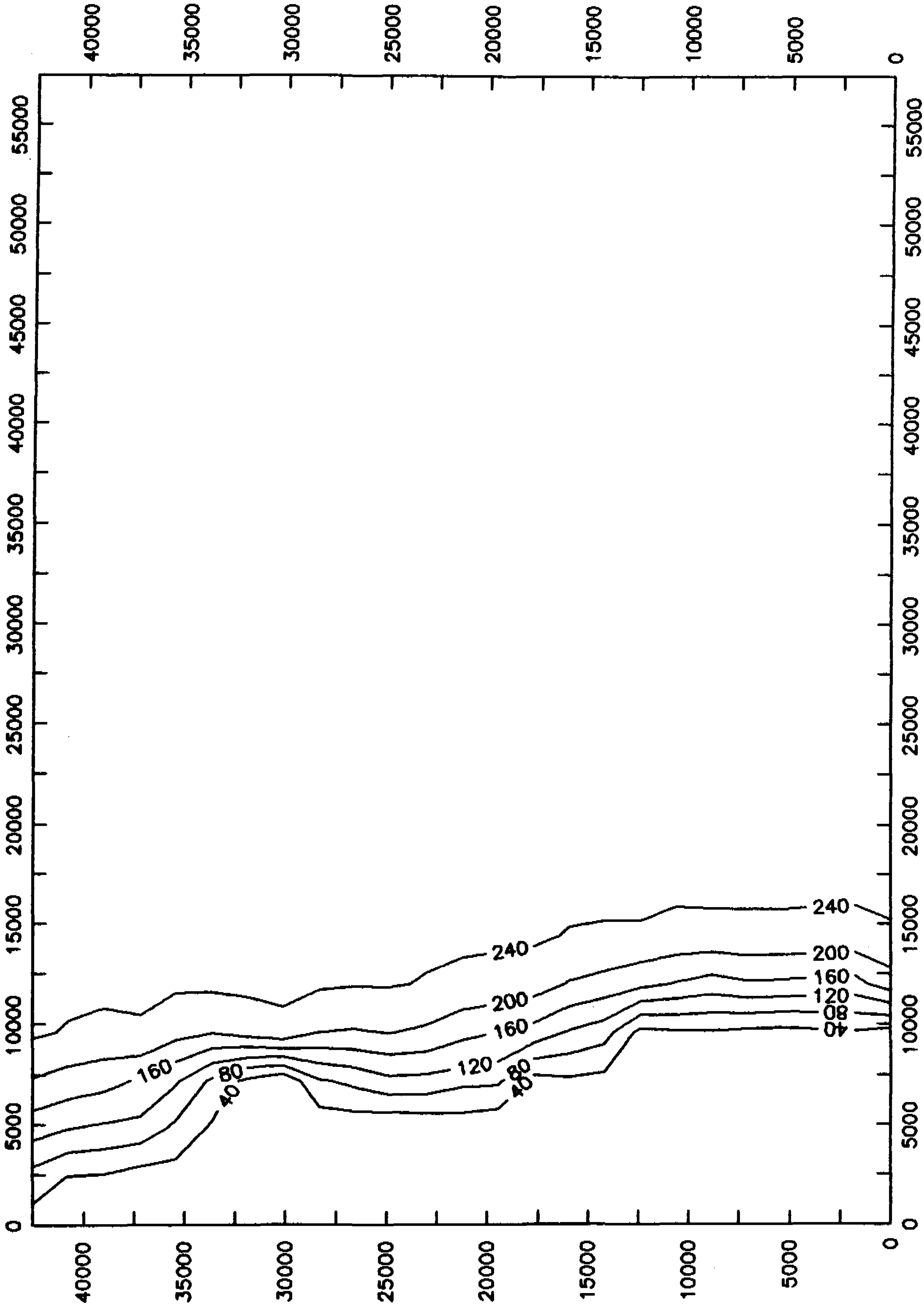
Annex A5: Phreatic head (m) after 200 years abstractions in the east (current situation).

elderh.4



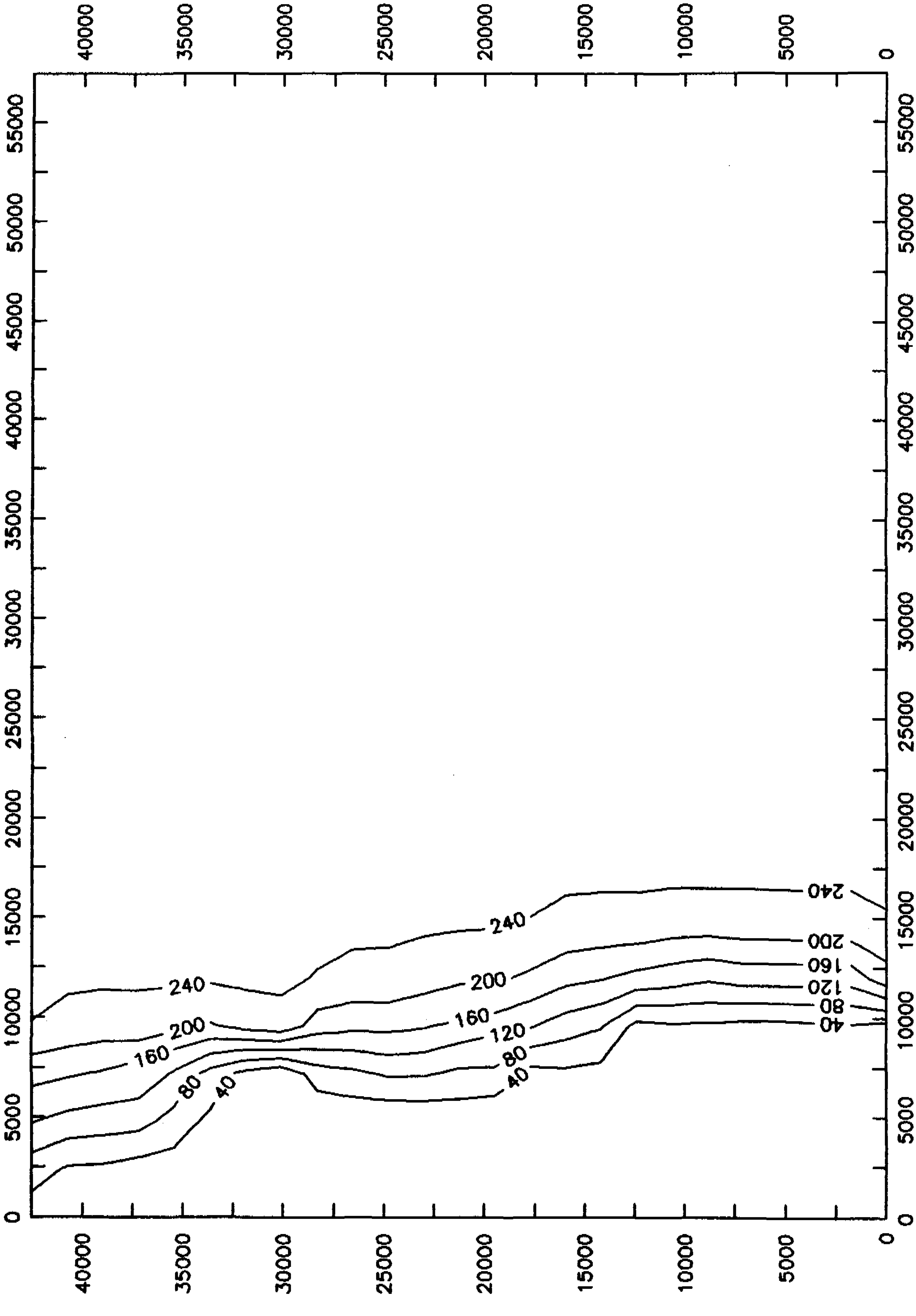
Annex A6: Depth of the fresh / salt interface (m) after 50 years abstraction in the east (current situation).

elderh.5



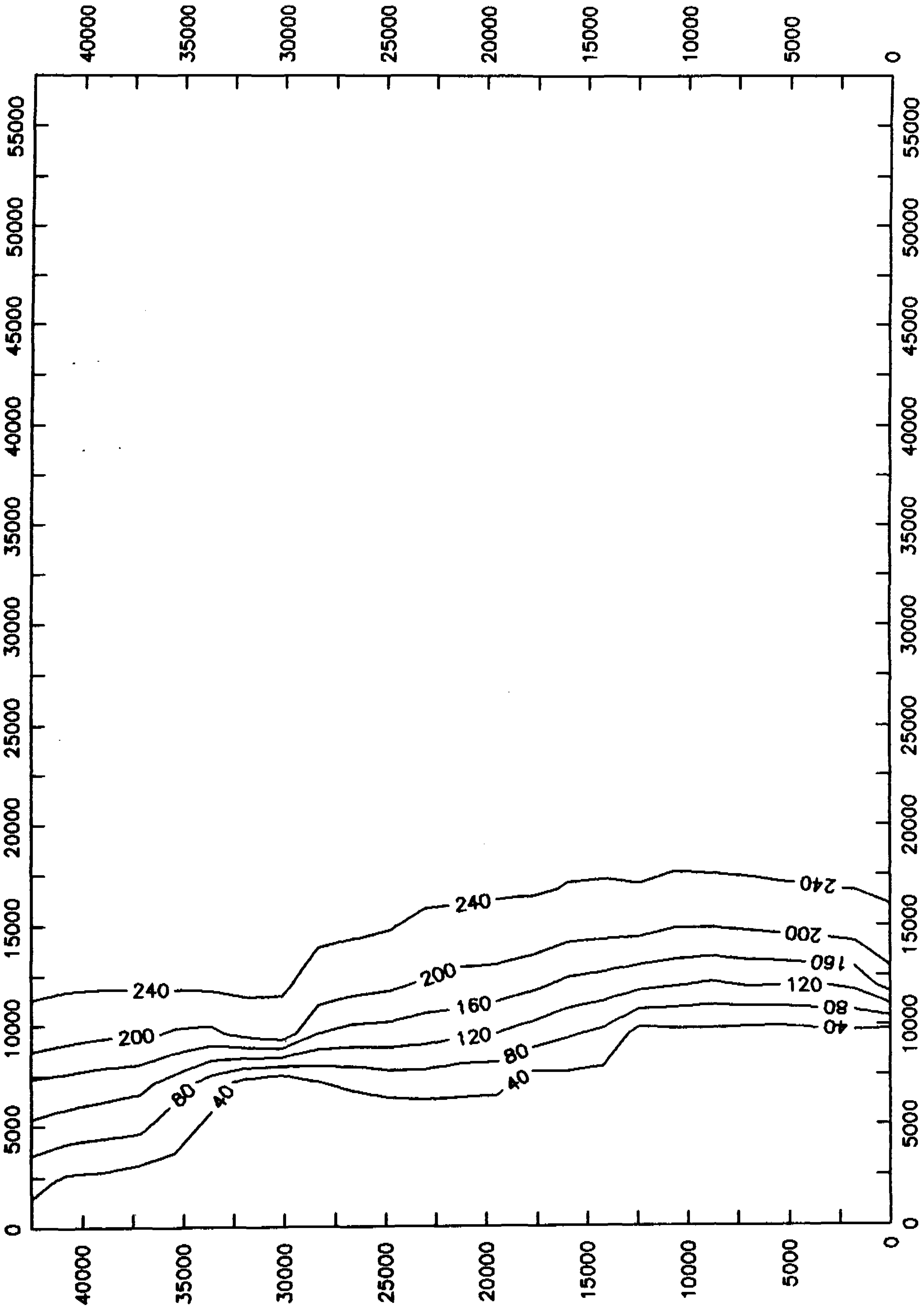
Annex A7: Depth of the fresh / salt interface (m) after 100 years abstraction in the east (current situation).

elderh.6

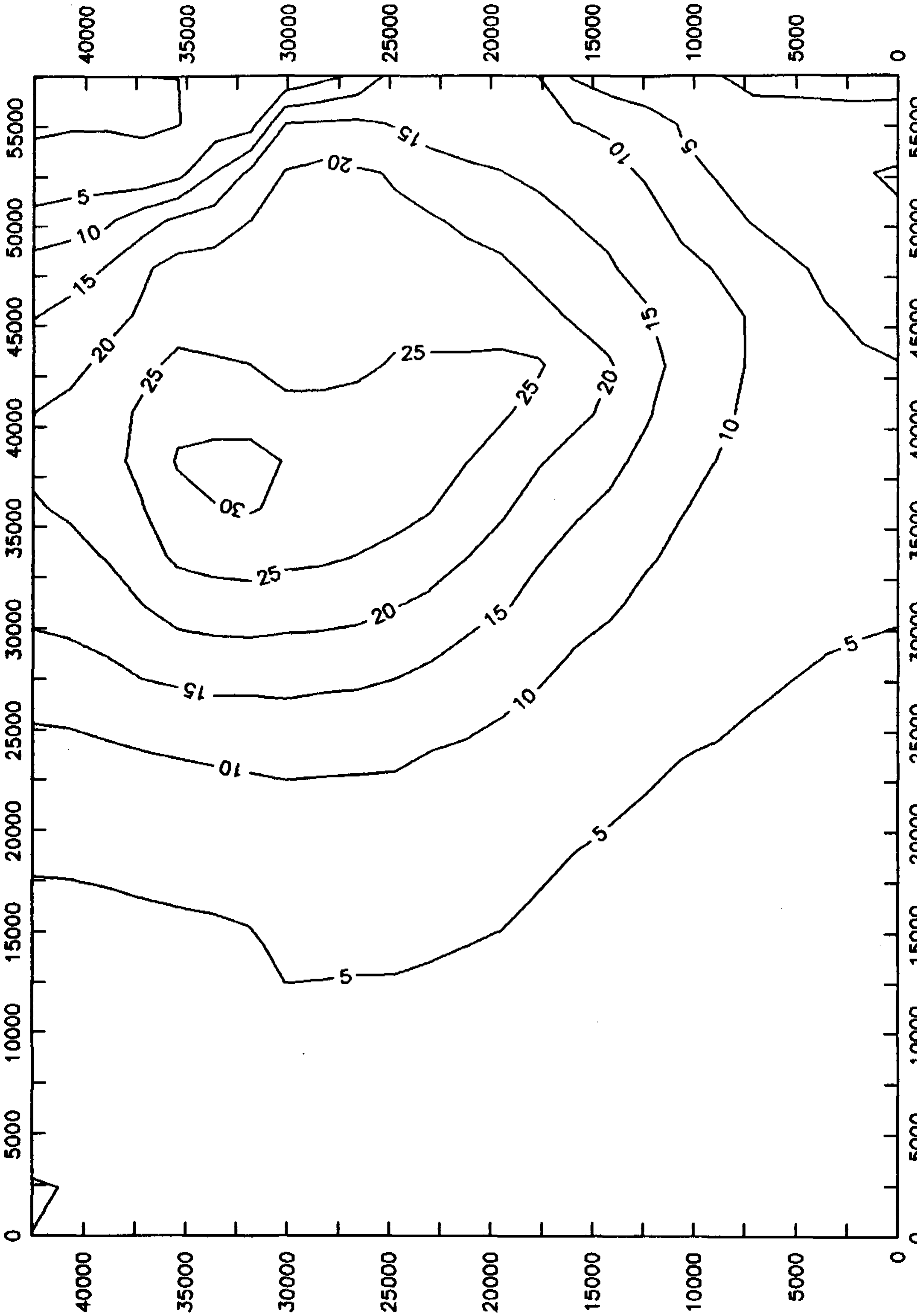


Annex A8: Depth of the fresh / salt interface (m) after 150 years abstraction in the east (current situation).

elderh.7

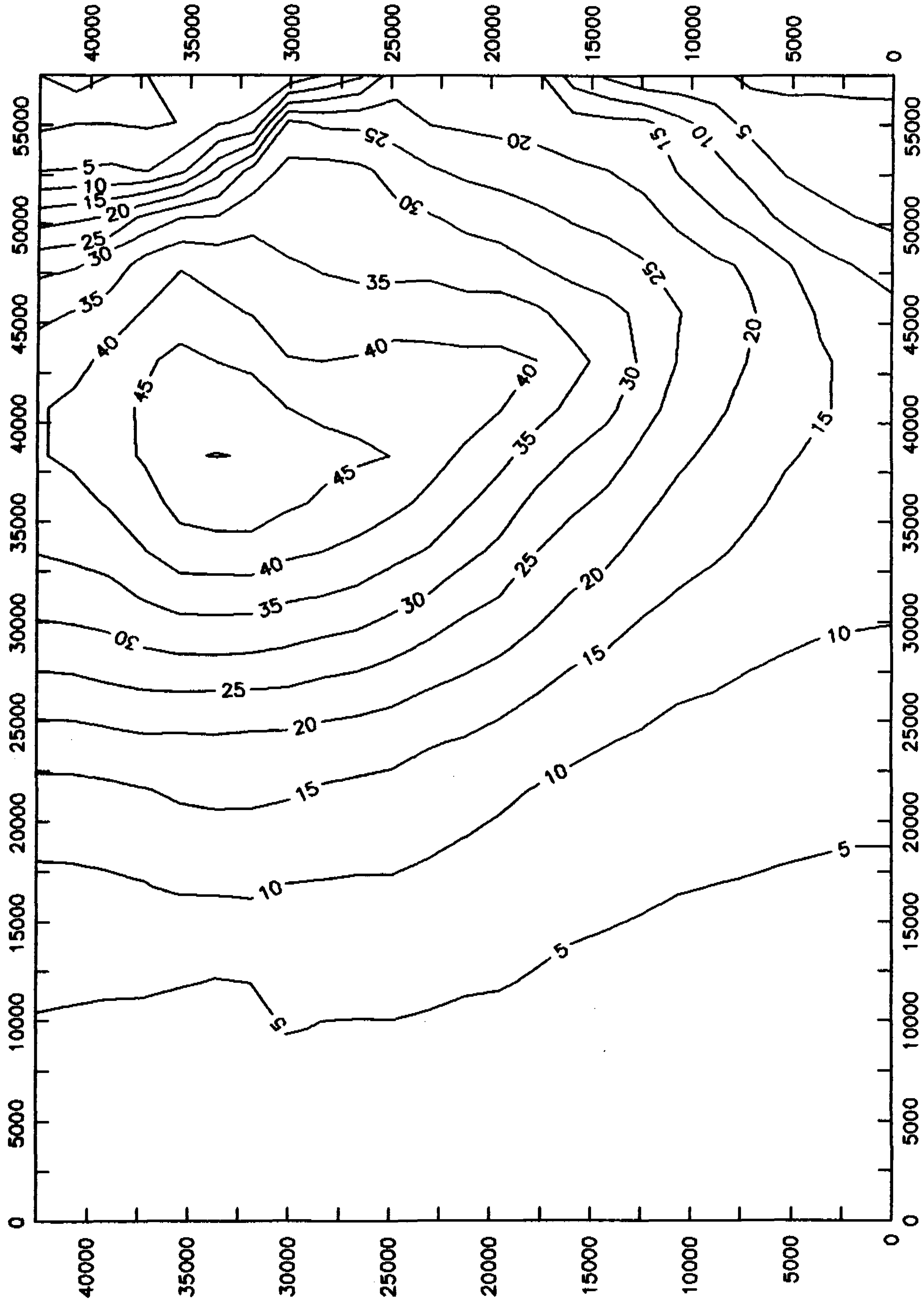


Annex A9: Depth of the fresh / salt interface (m) after 200 years abstraction in the east (current situation).



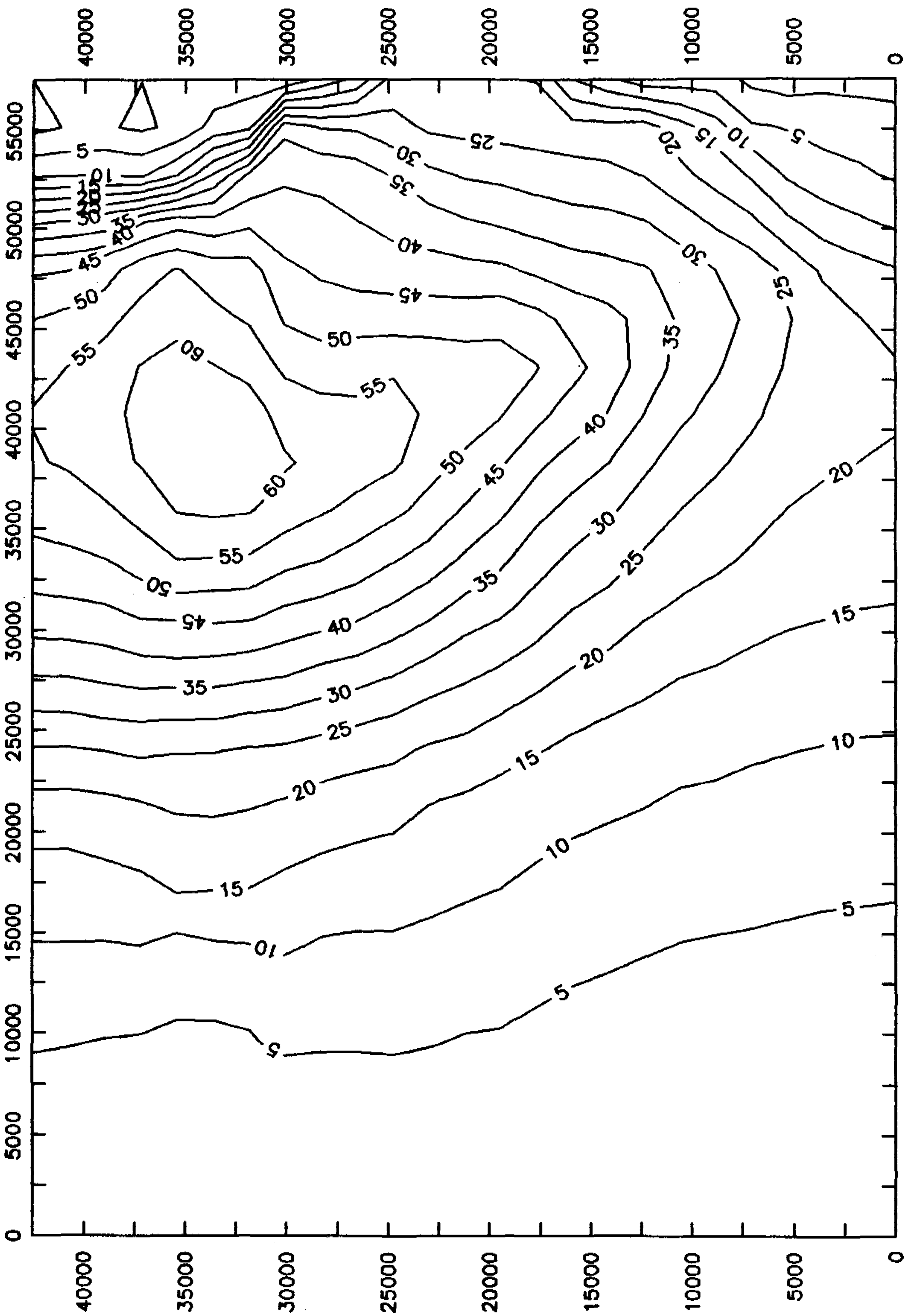
Annex A10: Drawdown of the phreatic head (m) after 50 years abstraction in the east (current situation).

elderh.9



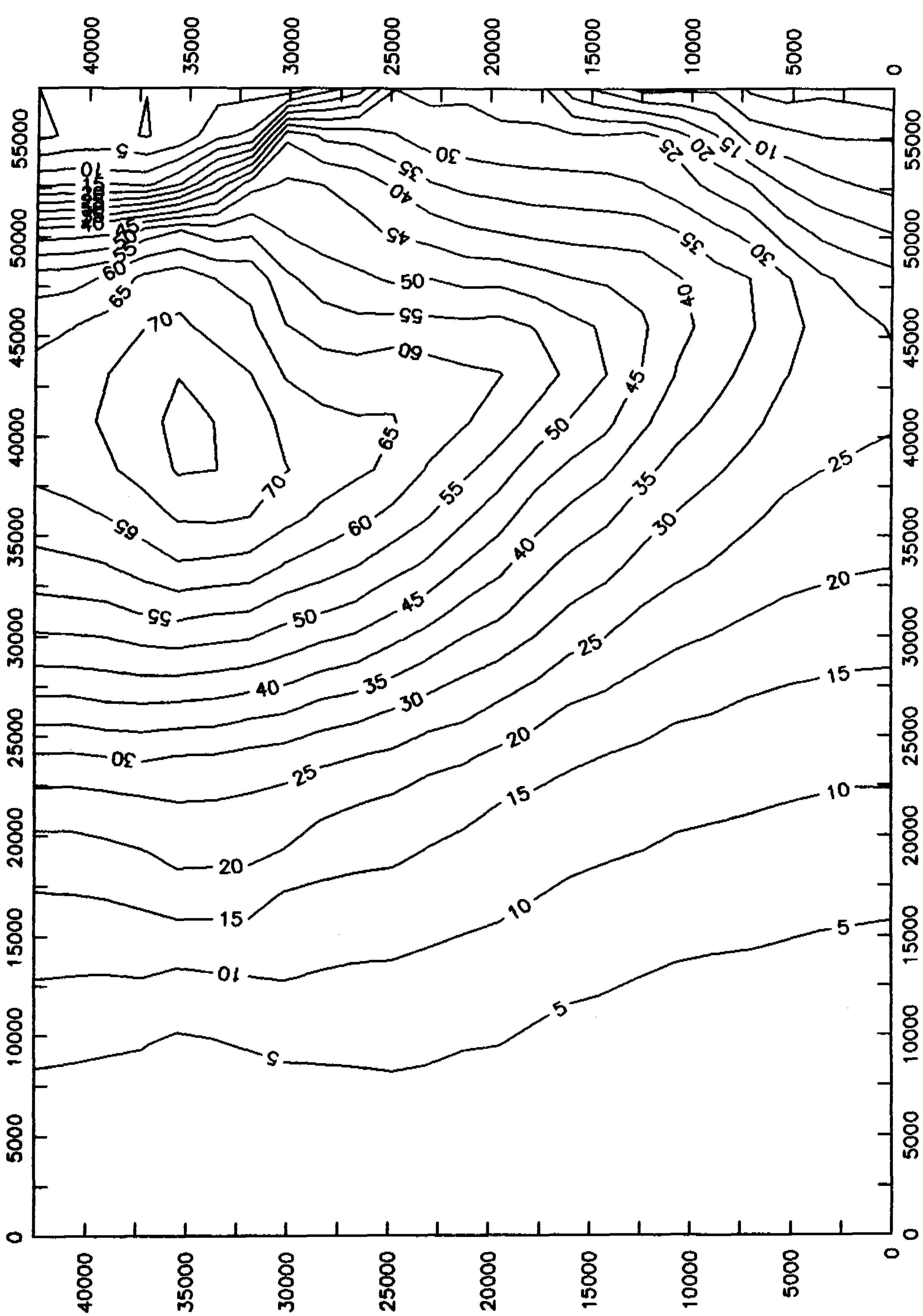
Annex A11: Drawdown of the phreatic head (m) after 100 years abstraction in the east (current situation).

elderh.10

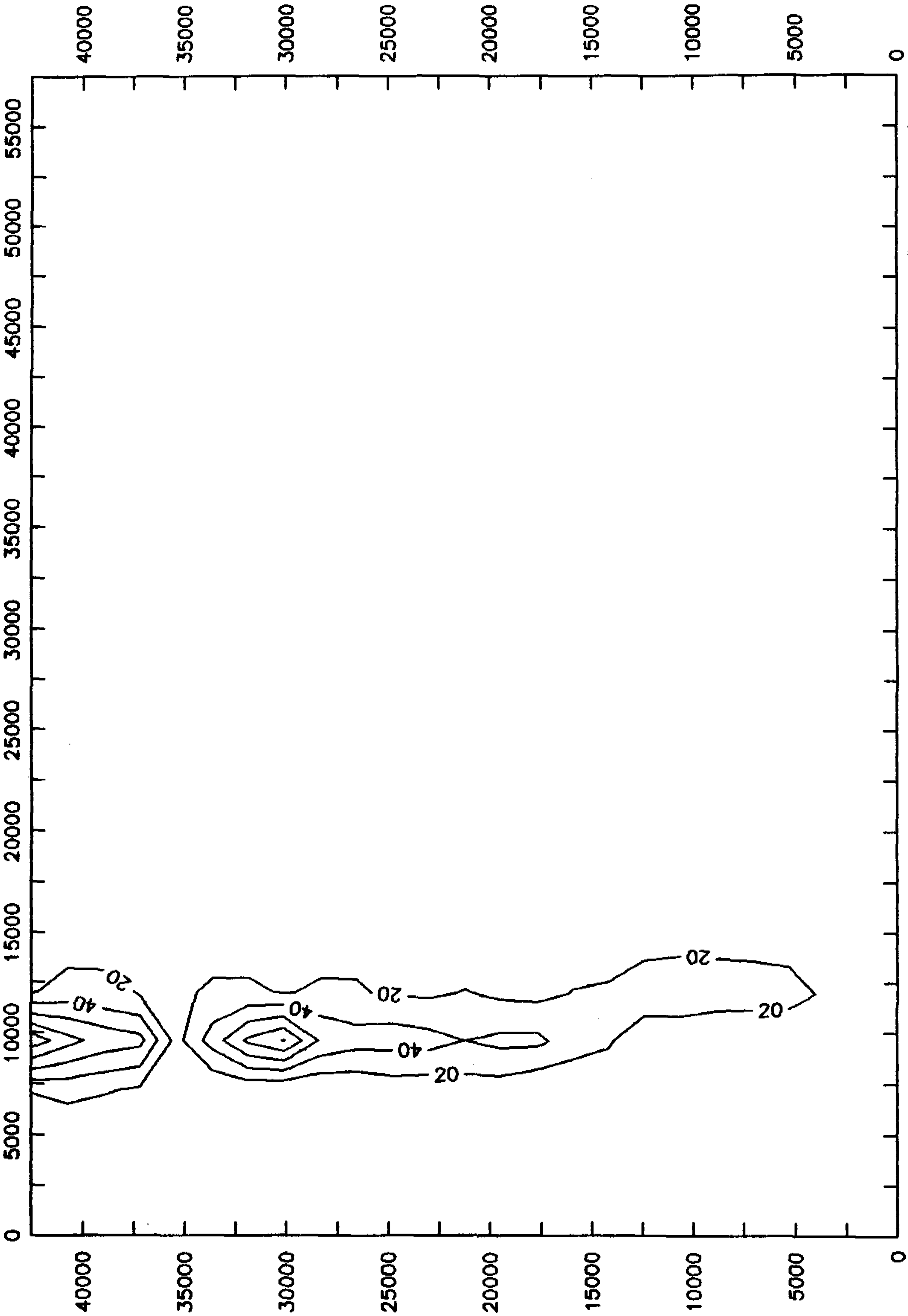


Annex A12: Drawdown of the phreatic head (m) after 150 years abstraction in the east (current situation).

elderh.11

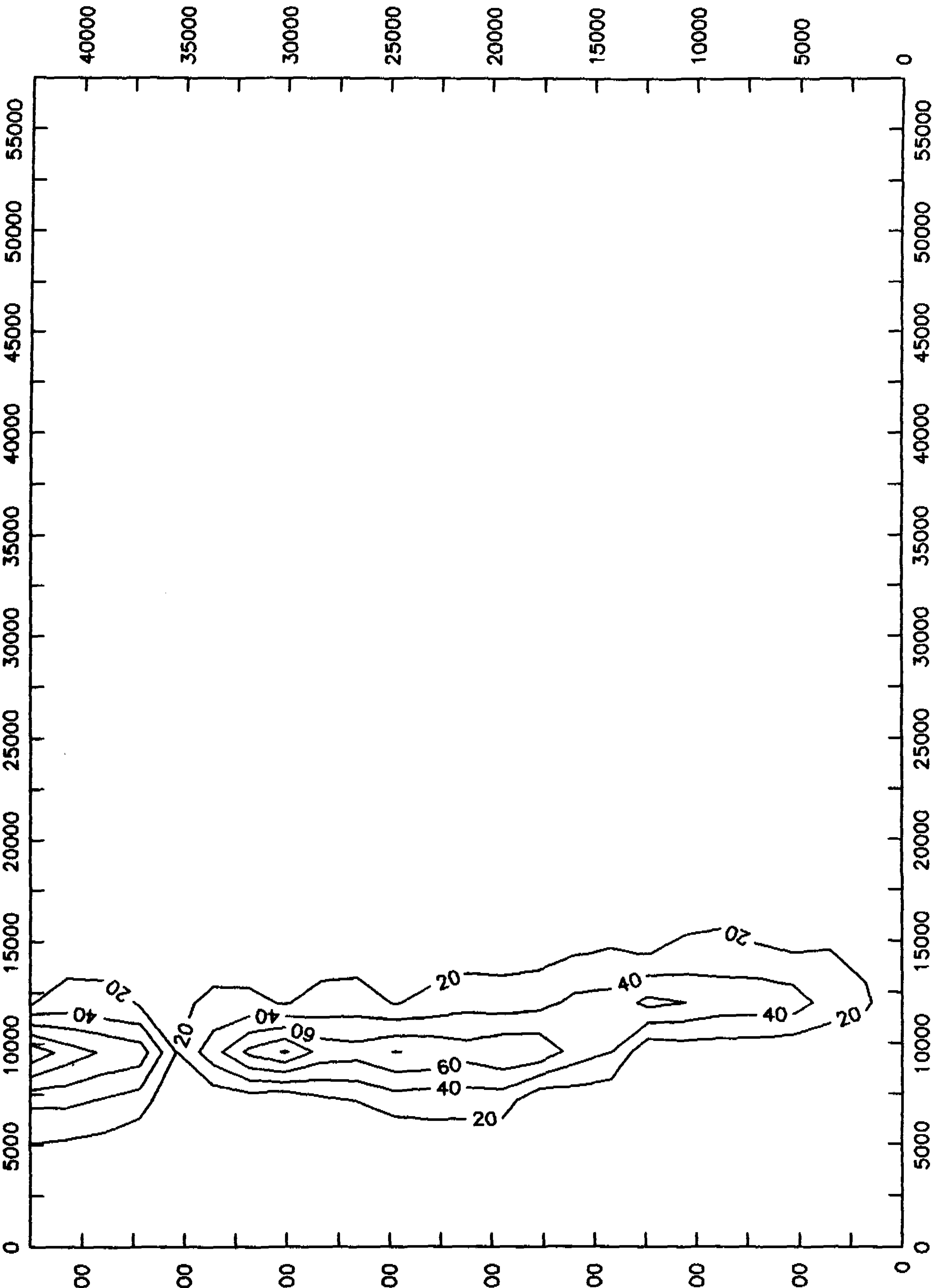


Annex A13: Drawdown of the phreatic head (m) after 200 years abstraction in the east (current situation).



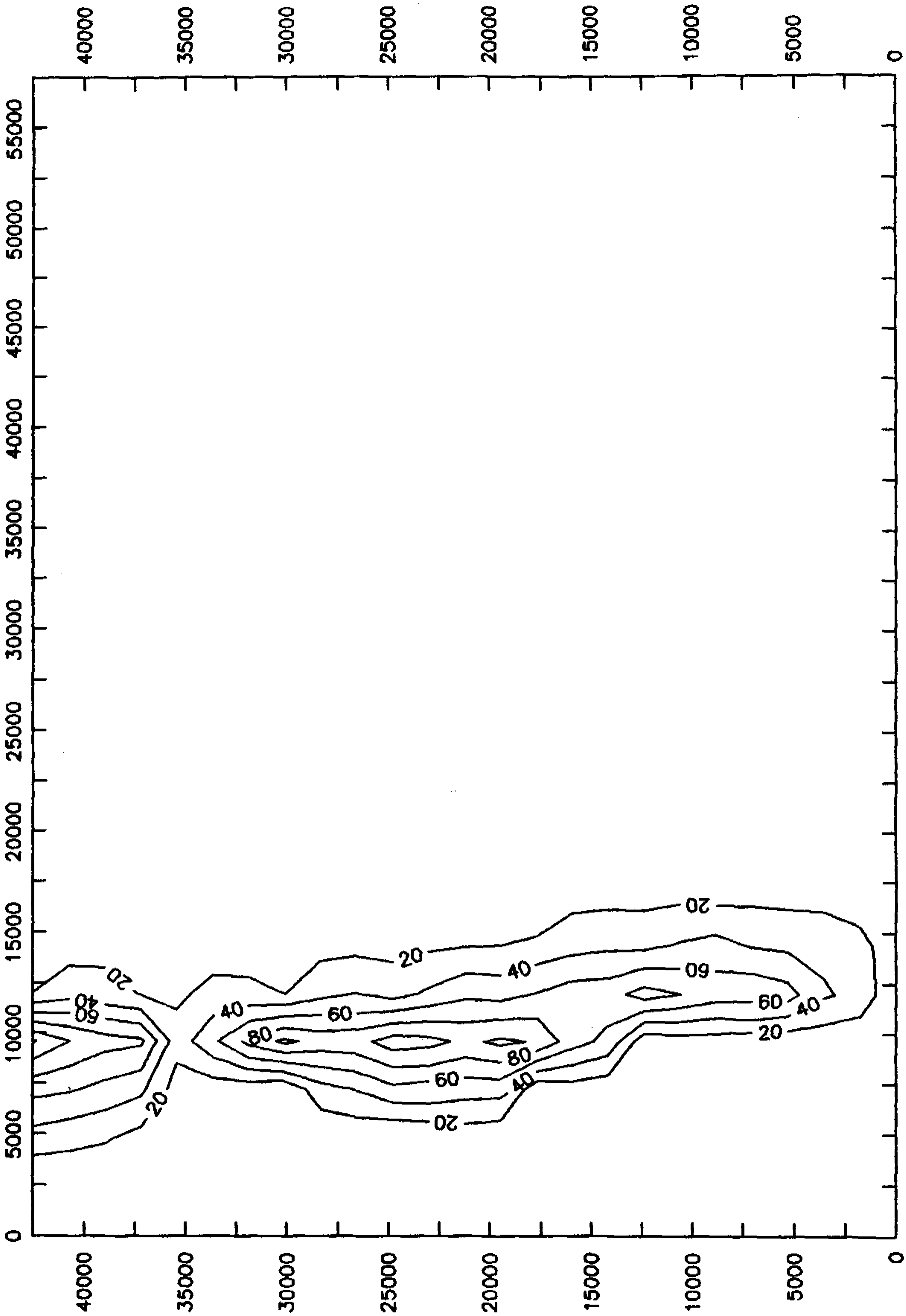
Annex A14: Upcoming of the fresh / salt interface (m) after 50 years abstraction in the east (current situation).

elderh.13

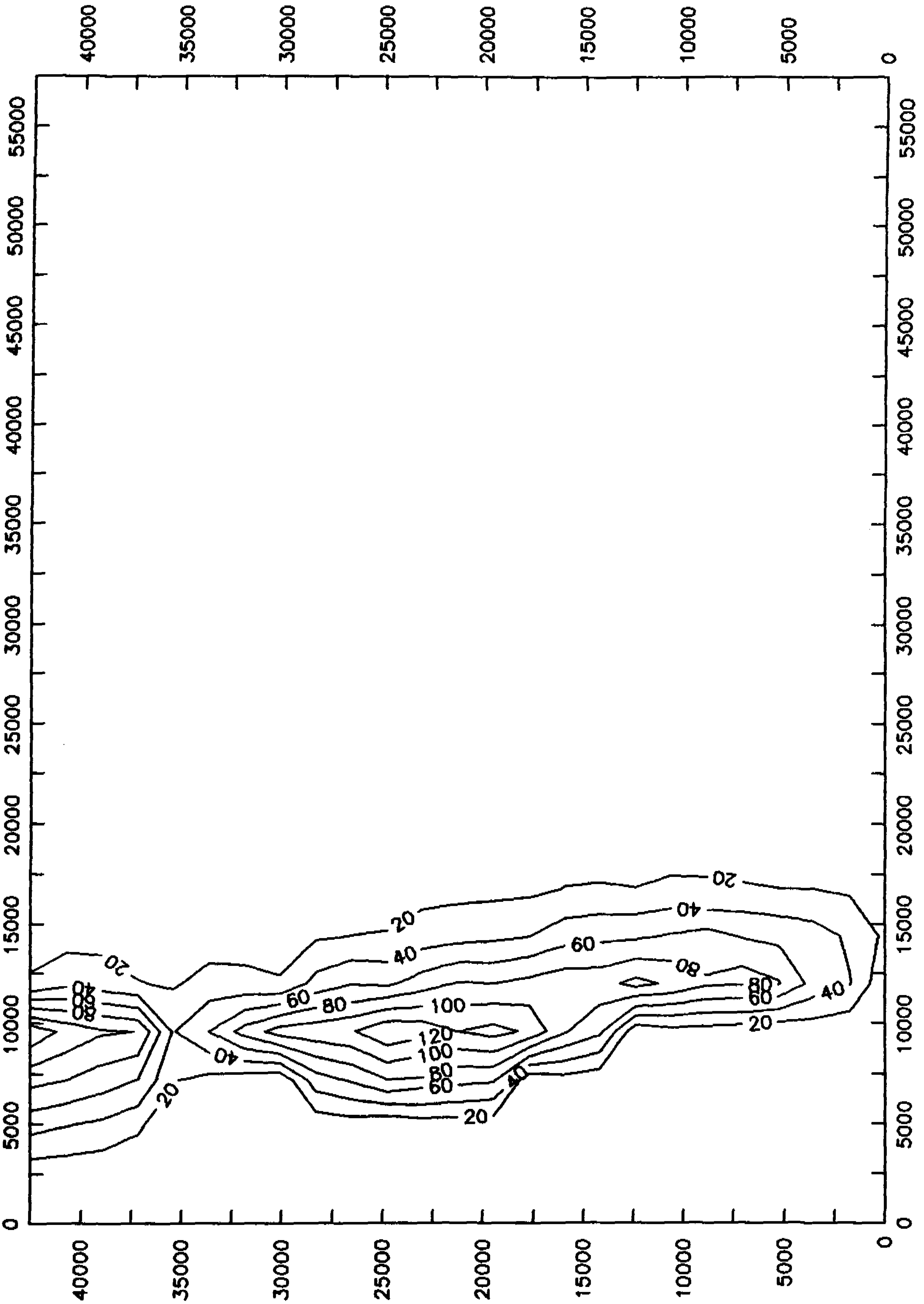


Annex A15: Upcoming of the fresh / salt interface (m) after 100 years abstraction in the east (current situation).

elderh.14



Annex A16: Upcoming of the fresh / salt interface (m) after 150 years abstraction in the east (current situation).



Annex A17: Upcoming of the fresh / salt interface (m) after 200 years abstraction in the east (current situation).

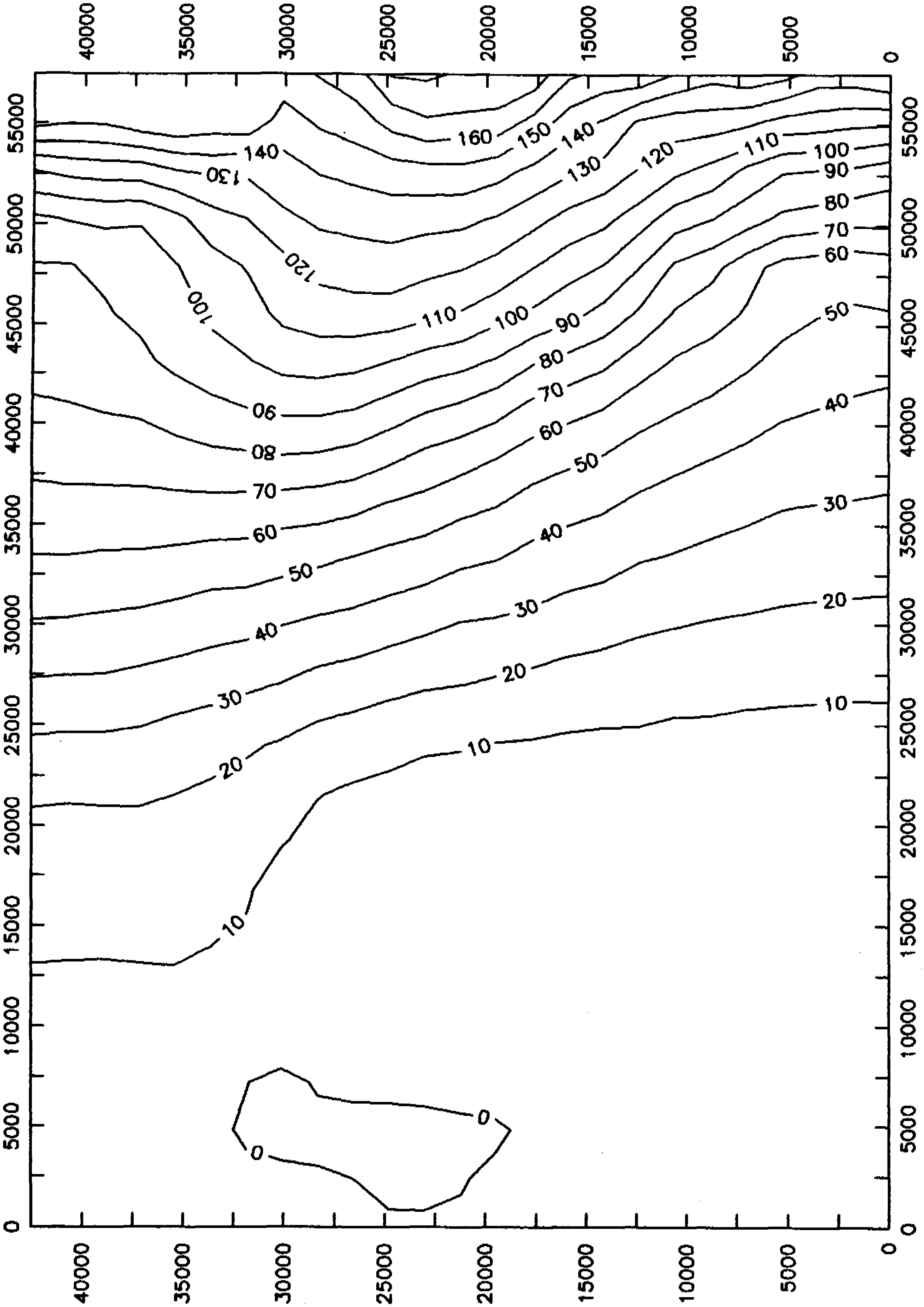
elderh.16

Annex B1: Groundwater abstractions (m^3/day) for scenario 2, (abstractions in west) (75% of abstractions in west and 25% in east).

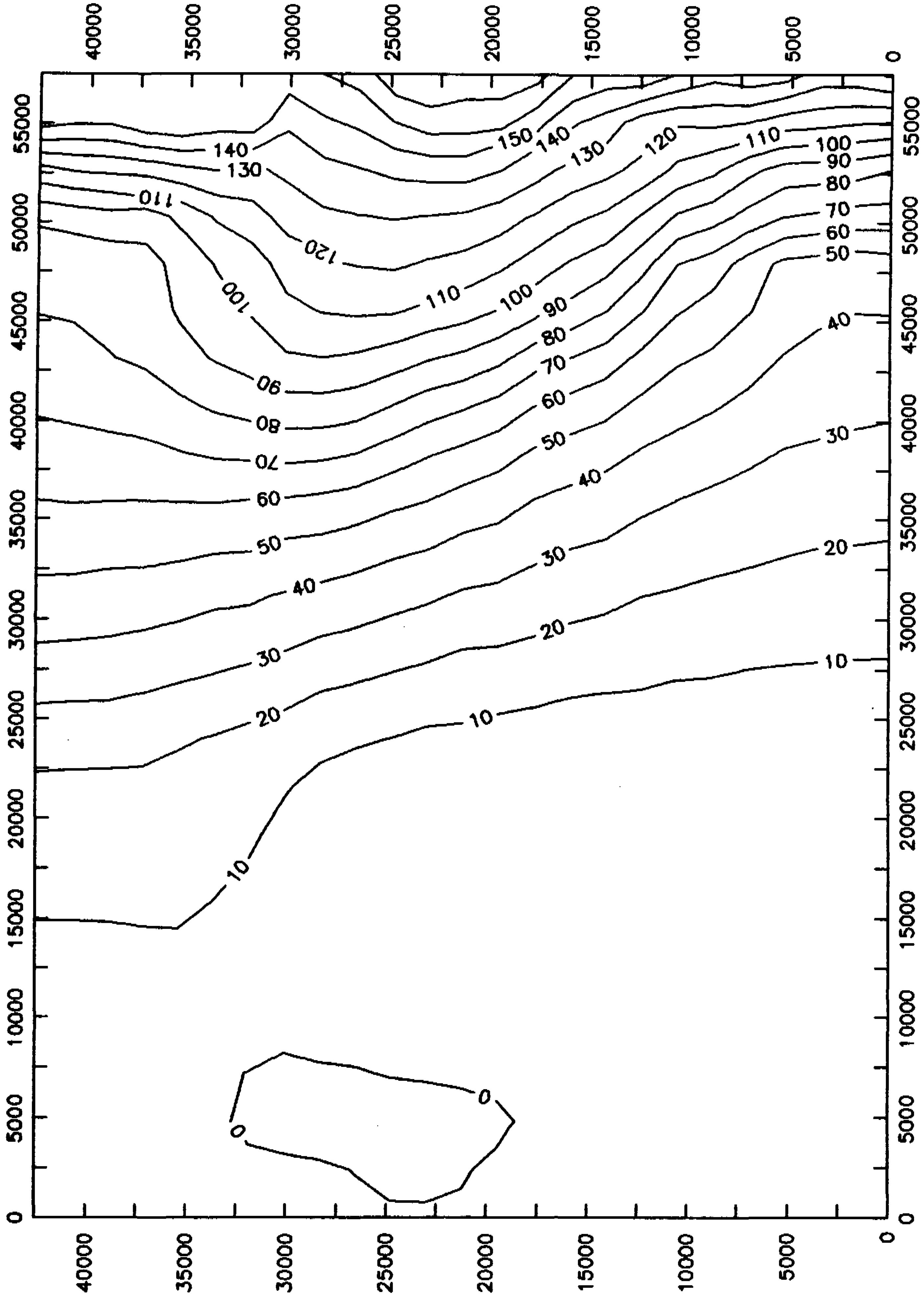
* Colums that are not represented in this table contain only elements without abstraction.

x-coordinate	17500	20000	22500	47500
y-coordinate				
42500	0	0	0	0
40000	0	0	0	-3311
37500	0	0	0	-3311
35000	0	0	0	-3311
32500	0	0	0	-3311
30000	0	0	0	-3311
27500	-4816	-4816	-4816	-3311
25000	-4816	-4816	-4816	-3311
22500	-4816	-4816	-4816	-3311
20000	-4816	-4816	-4816	-3311
17500	-4816	-4816	-4816	-3311
15000	-4816	-4816	-4816	-3311
12500	-4816	-4816	-4816	-3311
10000	-4816	-4816	-4816	-3311
7500	-4816	-4816	-4816	-3311
5000	-4816	-4816	-4816	-3311
2500	-4816	-4816	-4816	-3311
0	0	0	0	0

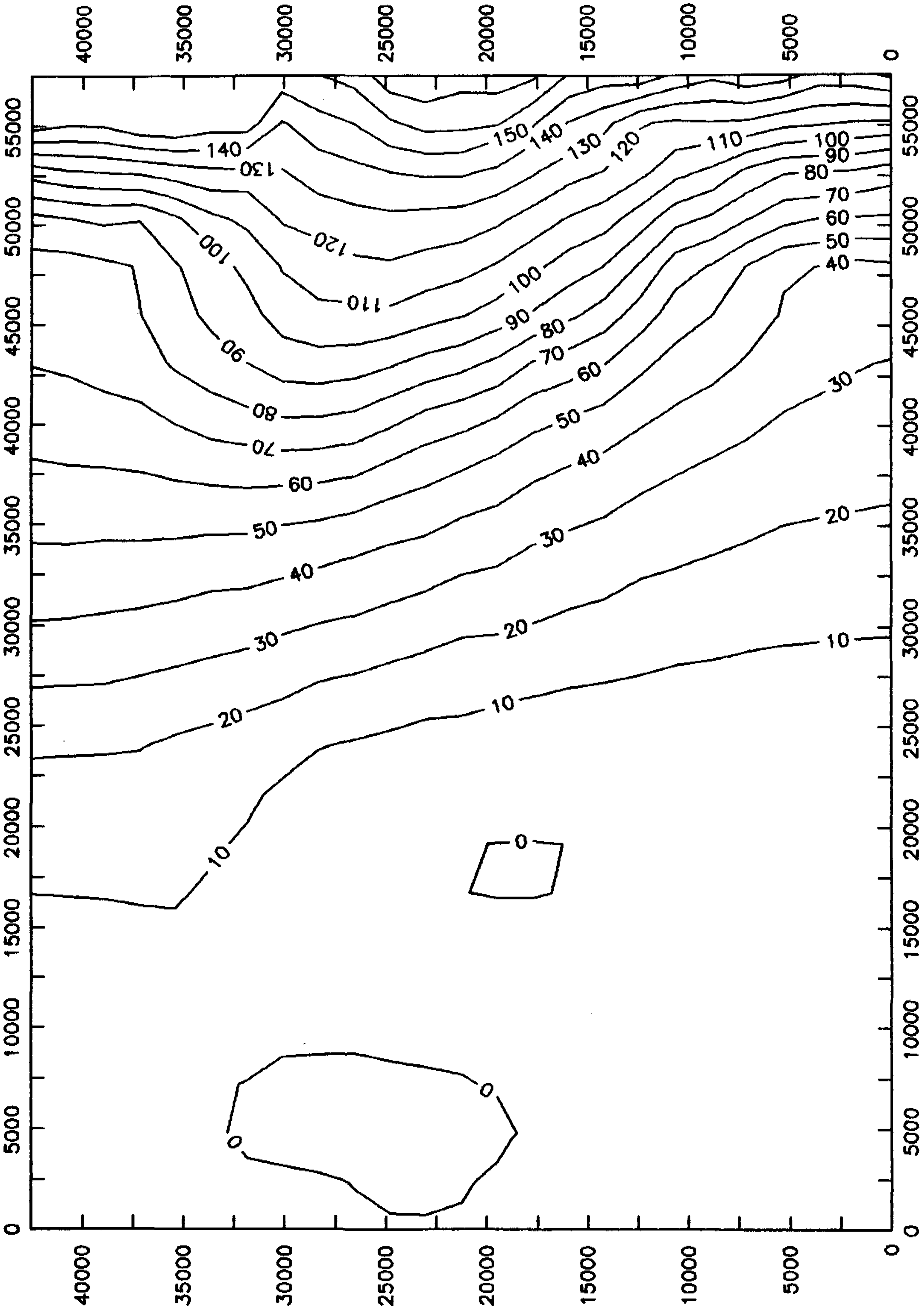
Annex B1: Groundwater abstractions (m3/day) for scenario 2 (abstractions in west). (75% of abstractions in west and 25% in east).



Annex B2: Phreatic head (m) after 50 years abstraction in the west.

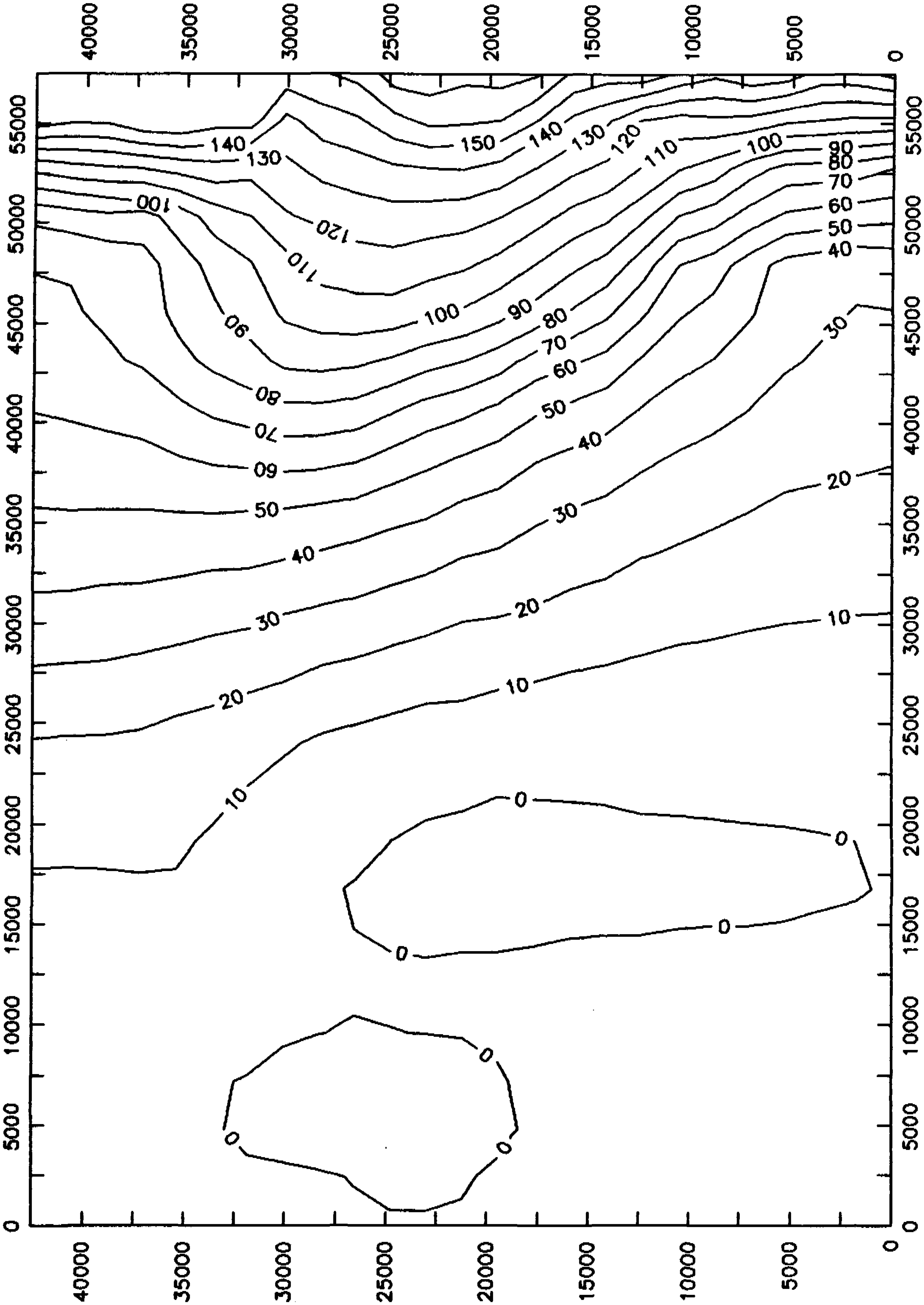


Annex B3: Phreatic head (m) after 100 years abstraction in the west.



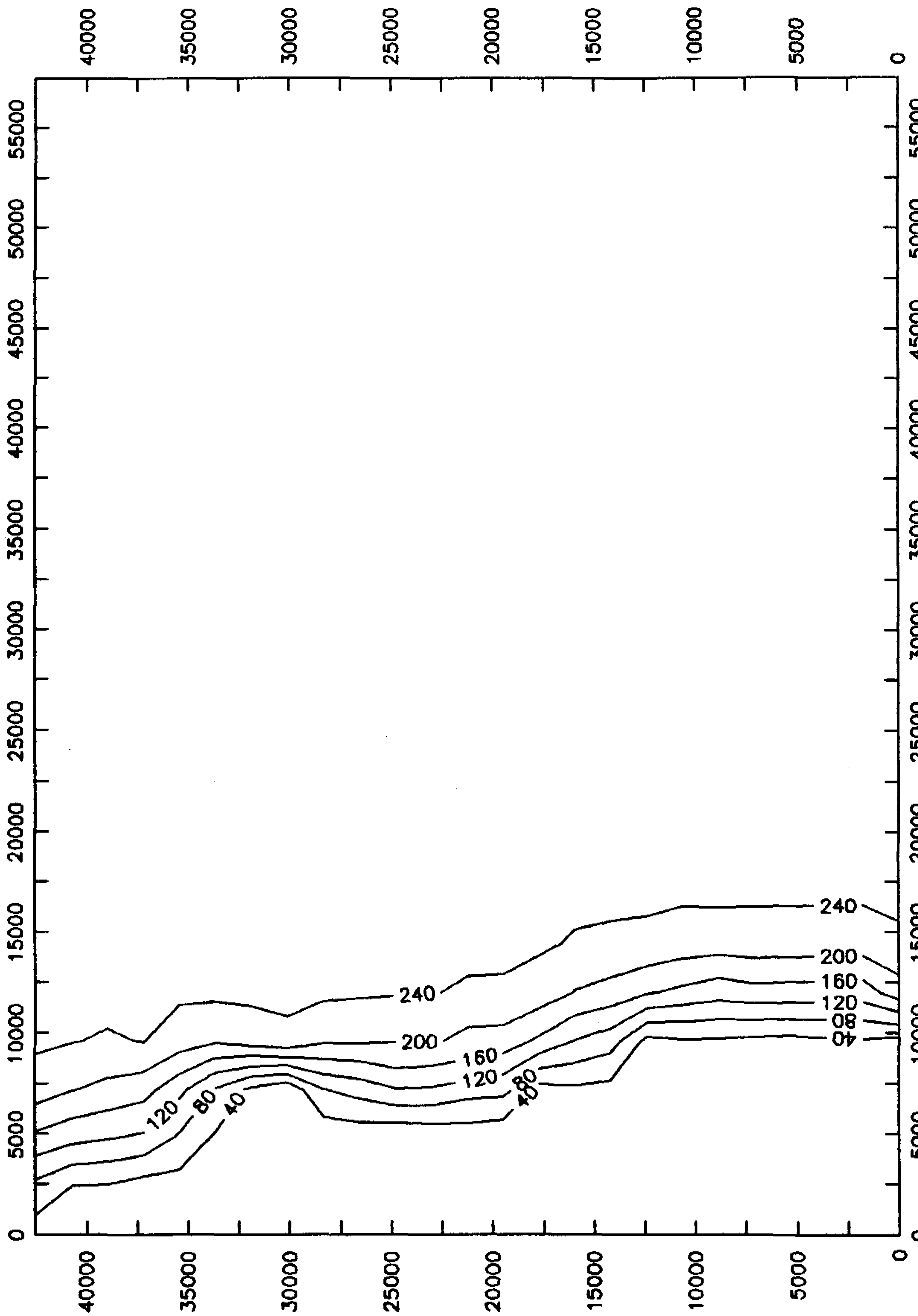
Annex B4: Phreatic head (m) after 150 years abstraction in the west.

elderh.19



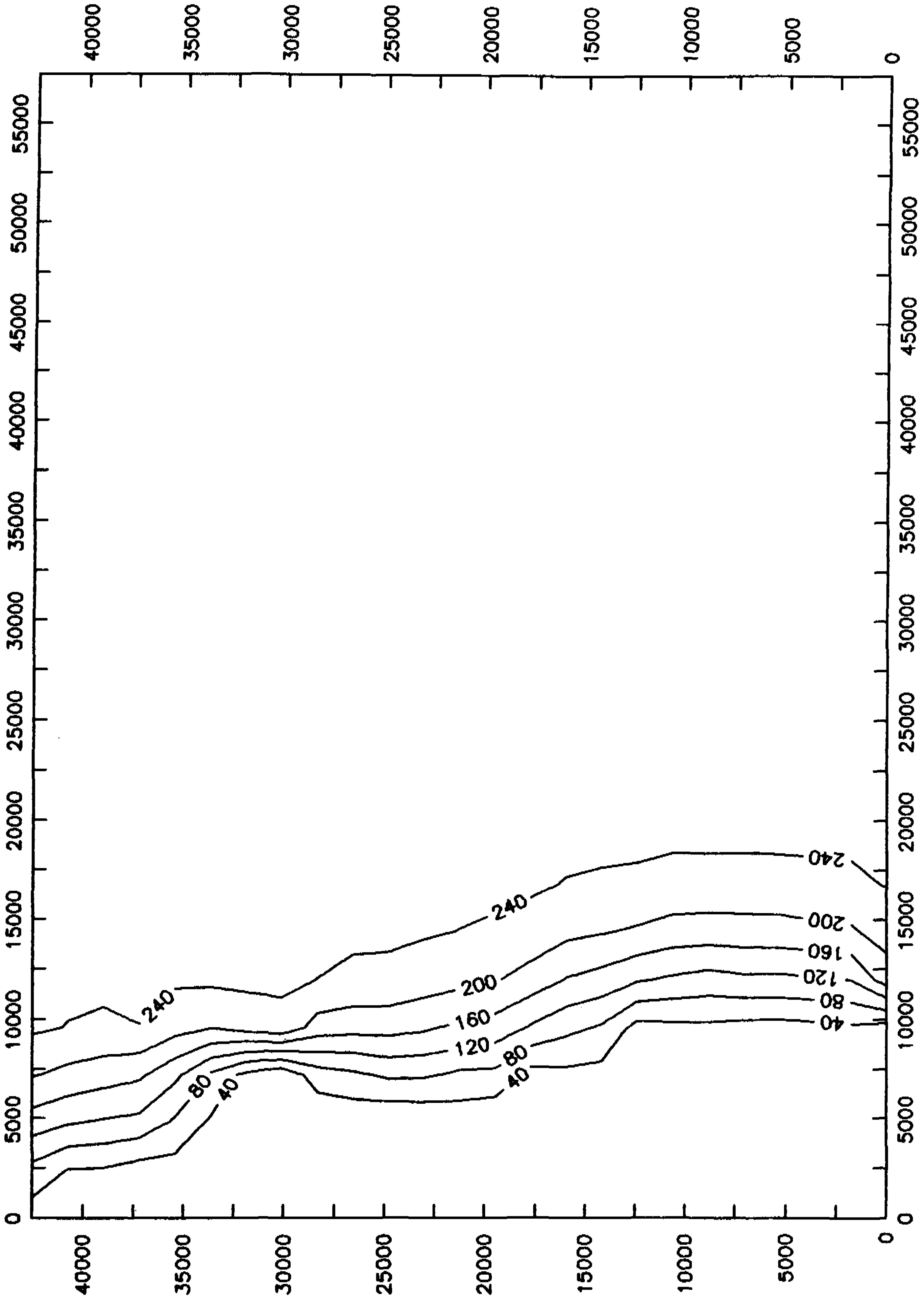
Annex B5: Phreatic head (m) after 200 years abstraction in the west.

elderh.20



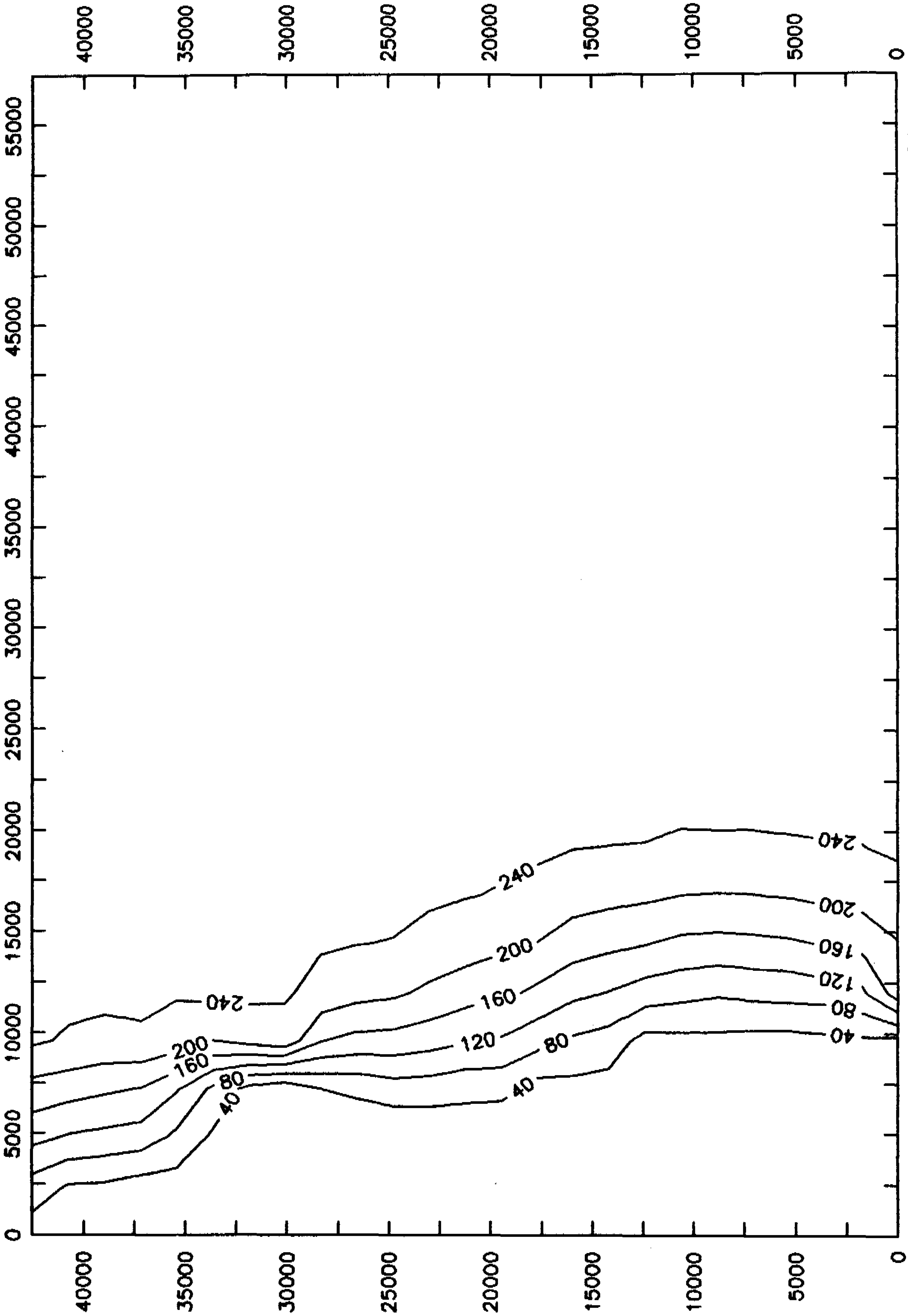
Annex B6: Depth fresh / salt interface (m) after 50 years abstraction in the west.

elderh.21



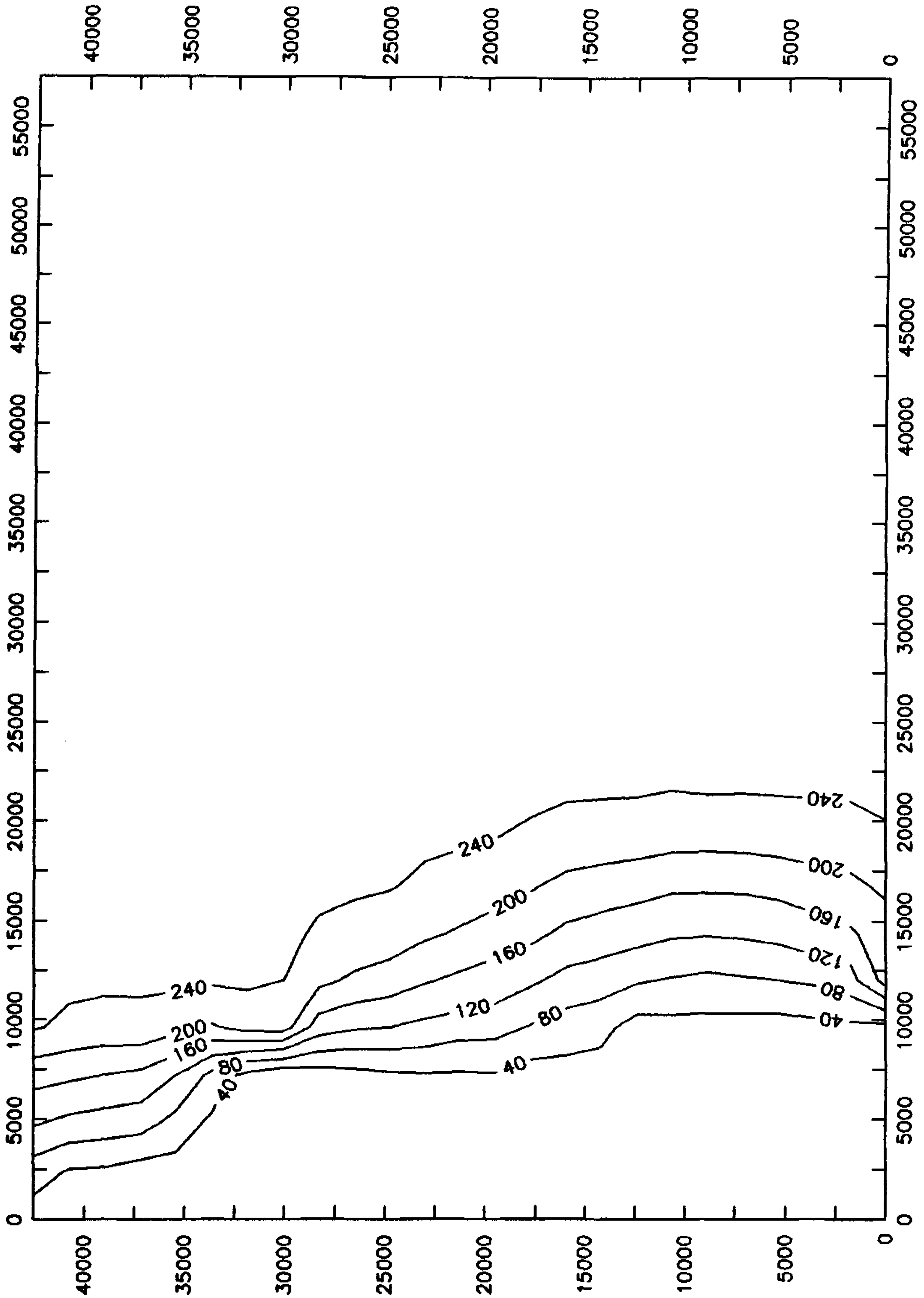
Annex B7: Depth fresh / salt interface (m) after 100 years abstractic
in the west.

elderh.22

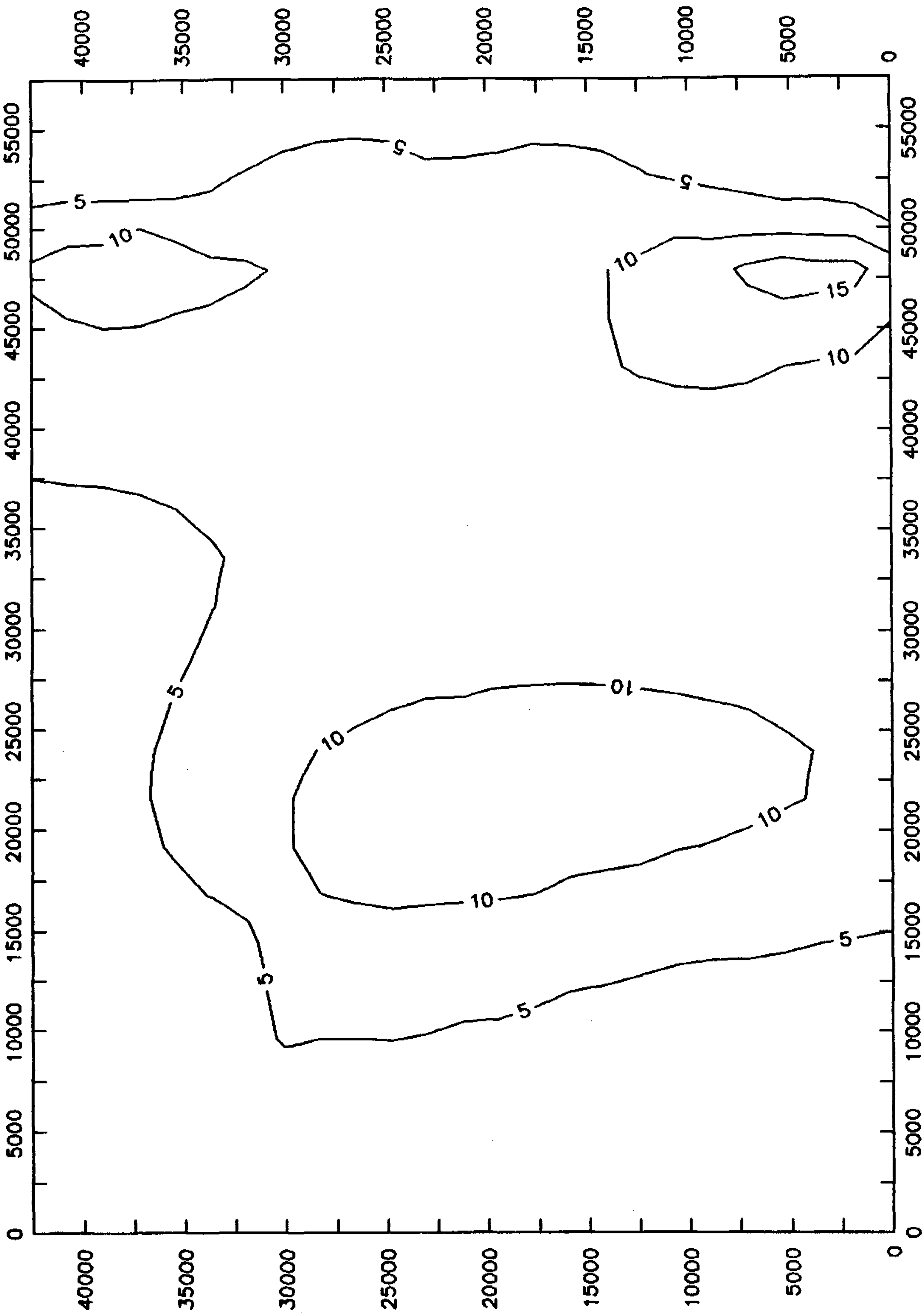


Annex B8: Depth fresh / salt interface (m) after 150 years abstractio[n]
in the west.

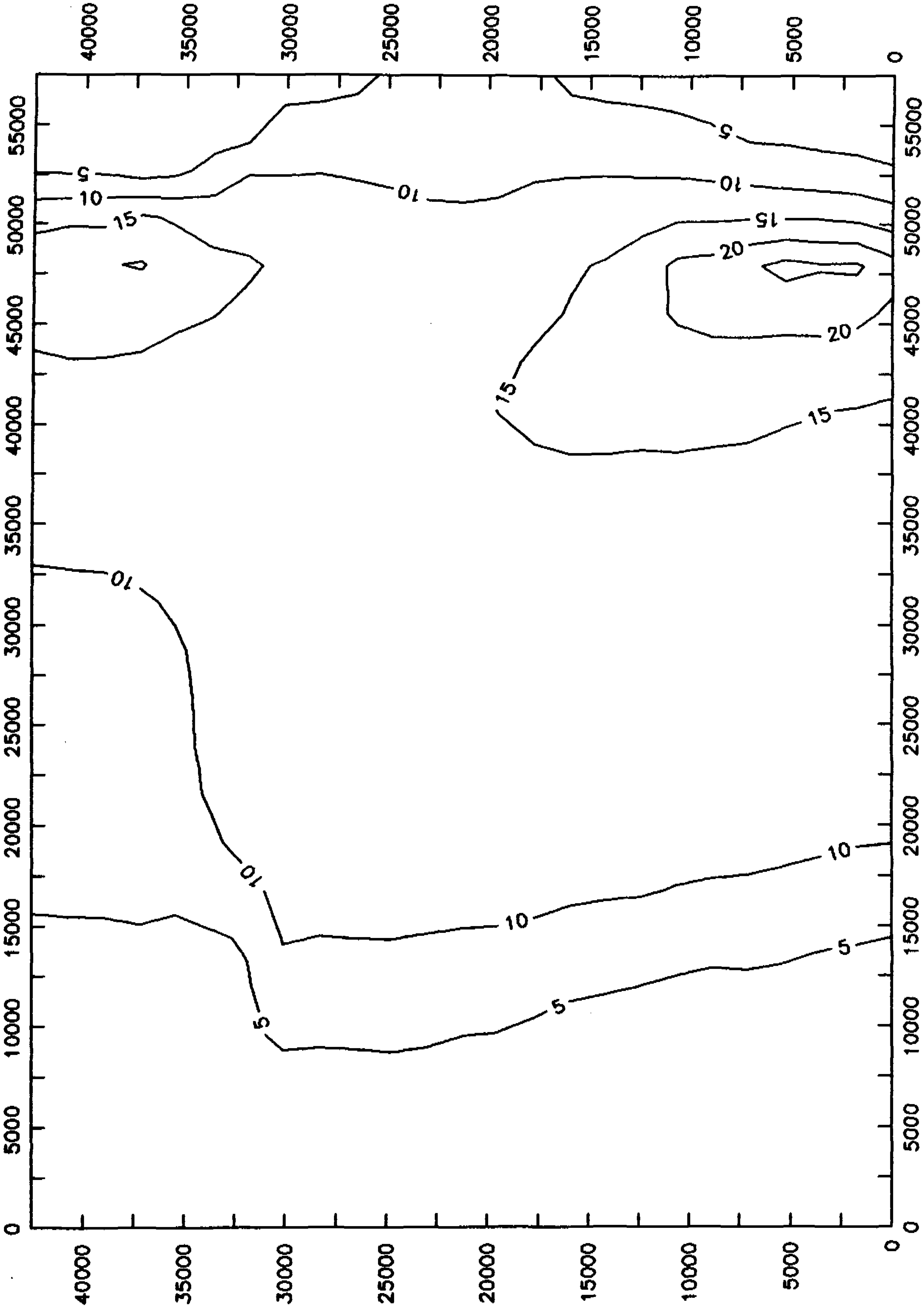
elderh.23



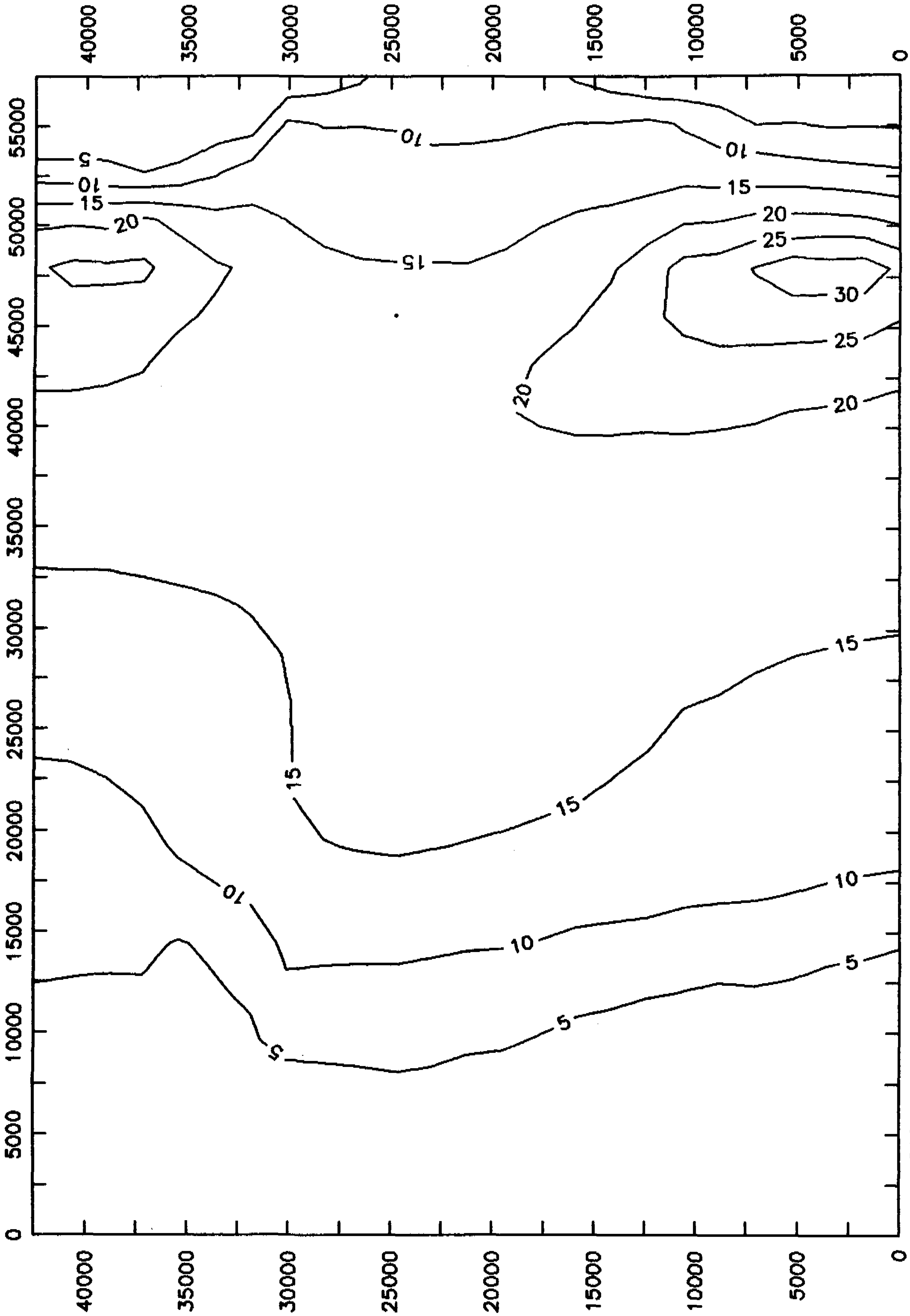
Annex B9: Depth fresh / salt interface (m) after 200 years abstractic in the west.



Annex B10: Drawdown of phreatic head (m) after 50 years abstraction in the west.

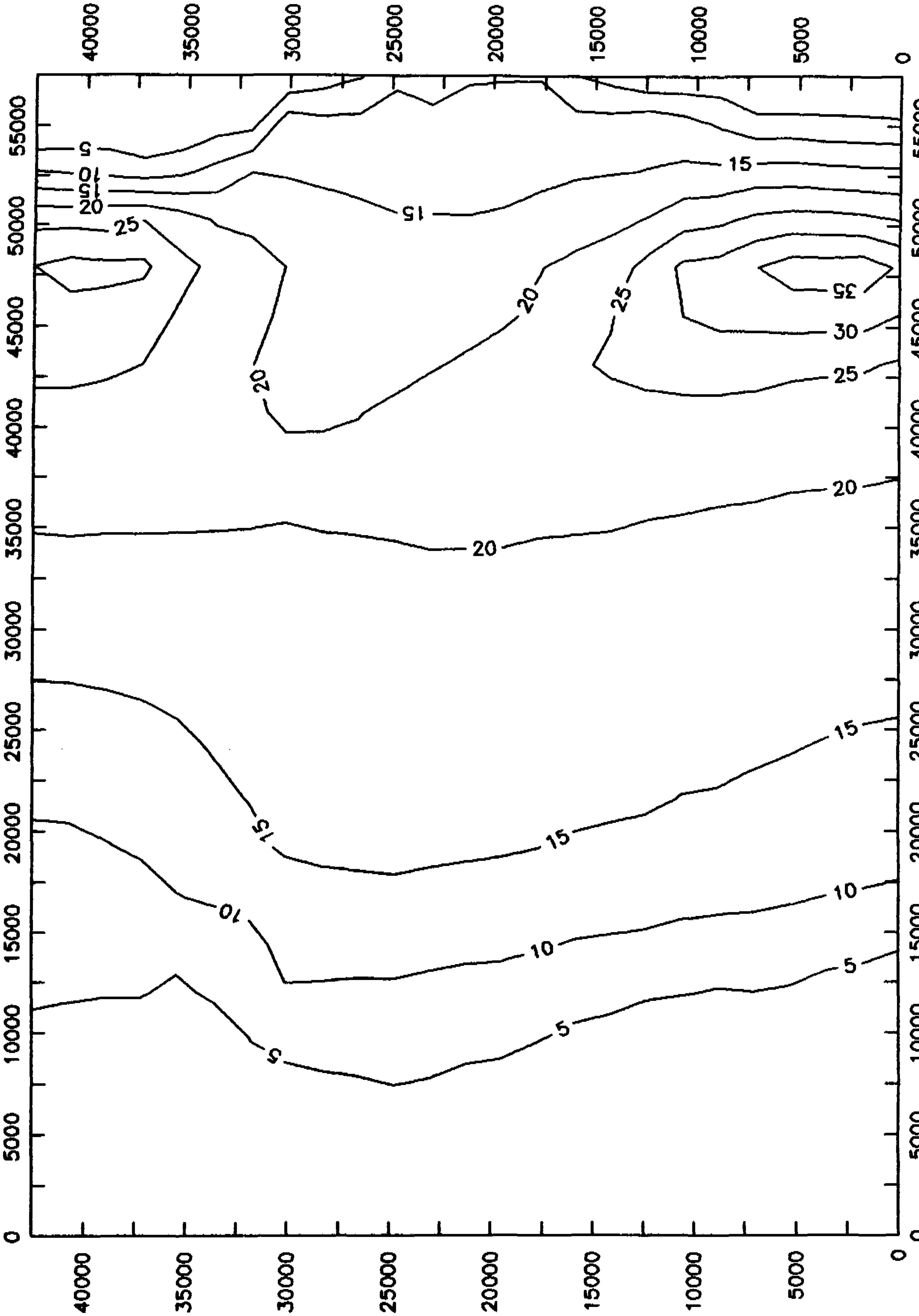


Annex B11: Drawdown of phreatic head (m) after 100 years abstraction in the west.



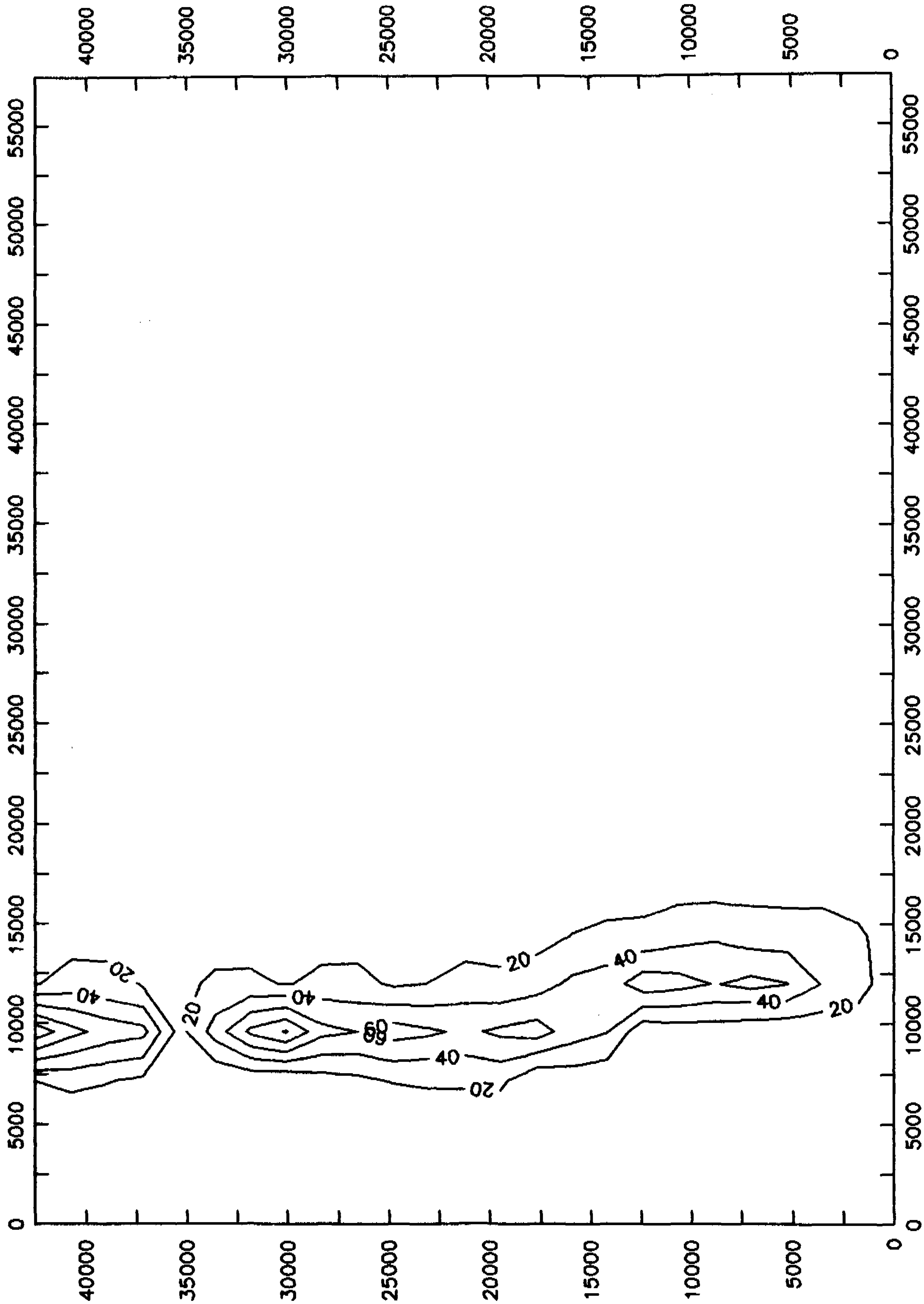
Annex B12: Drawdown of phreatic head (m) after 150 years abstraction in the west.

elderh.27

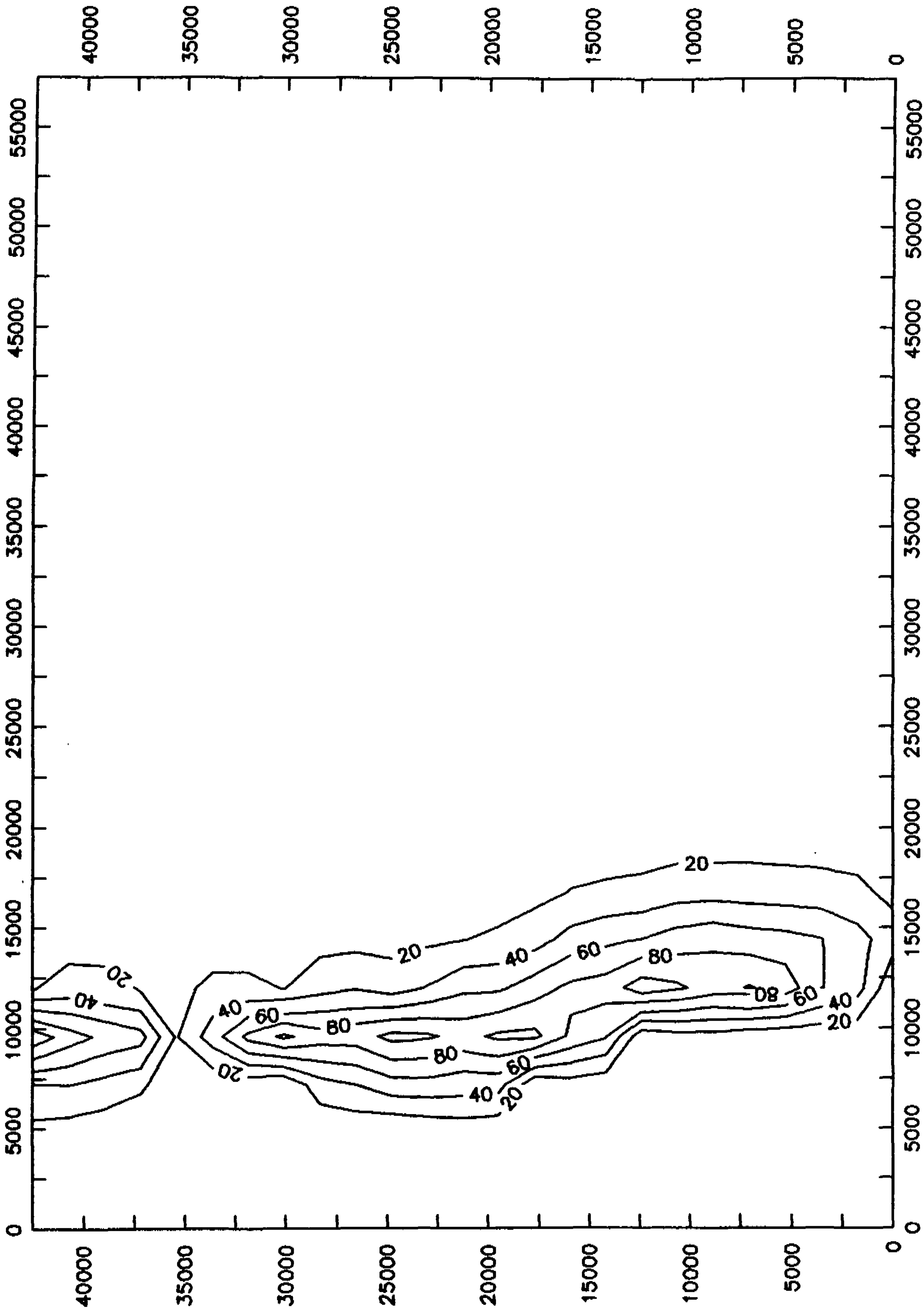


Annex B13: Drawdown of phreatic head (m) after 200 years abstraction in the west.

elderh.28

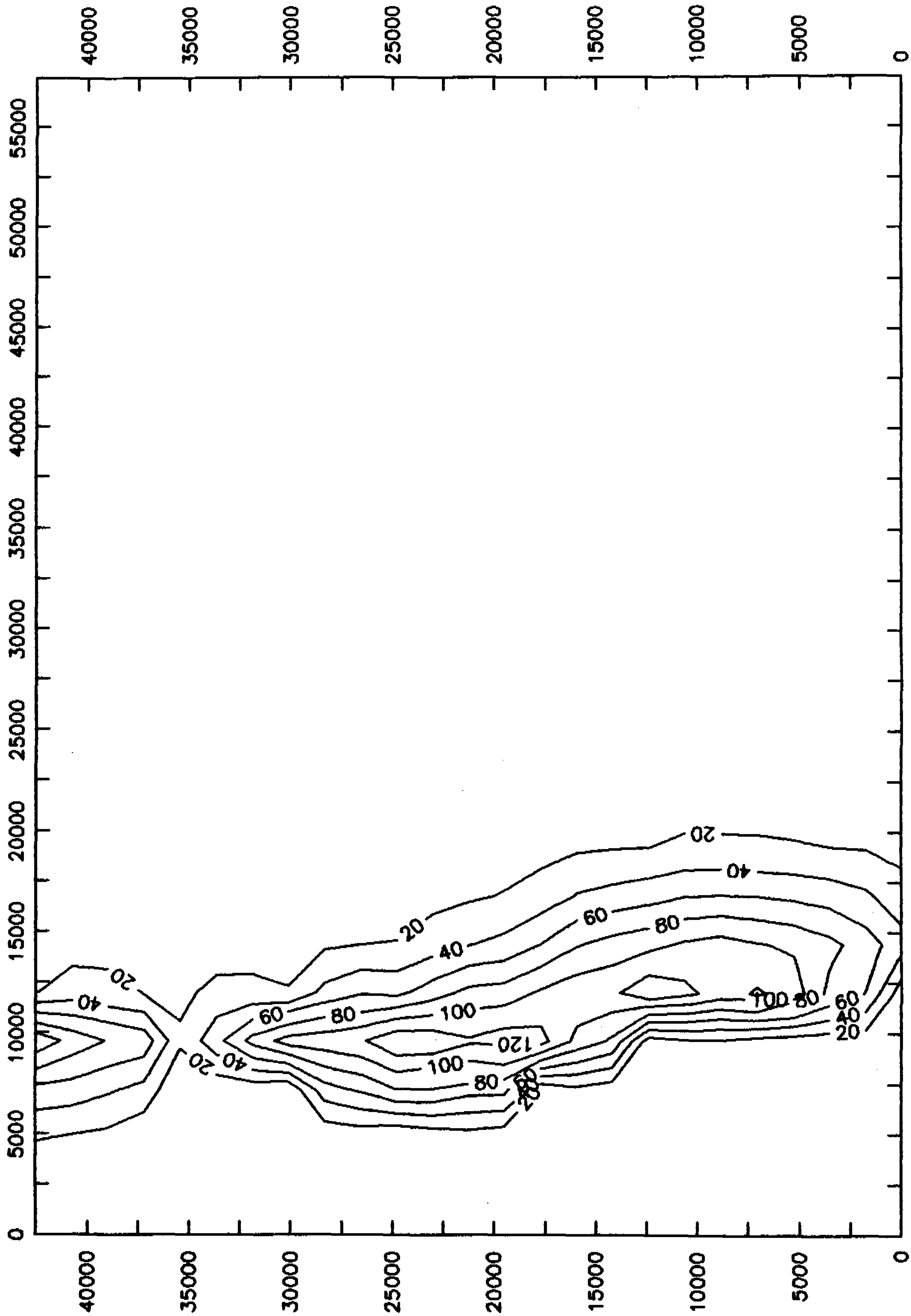


Annex B14: Upcoming of fresh / salt interface (m) after 50 years abstraction in the west.

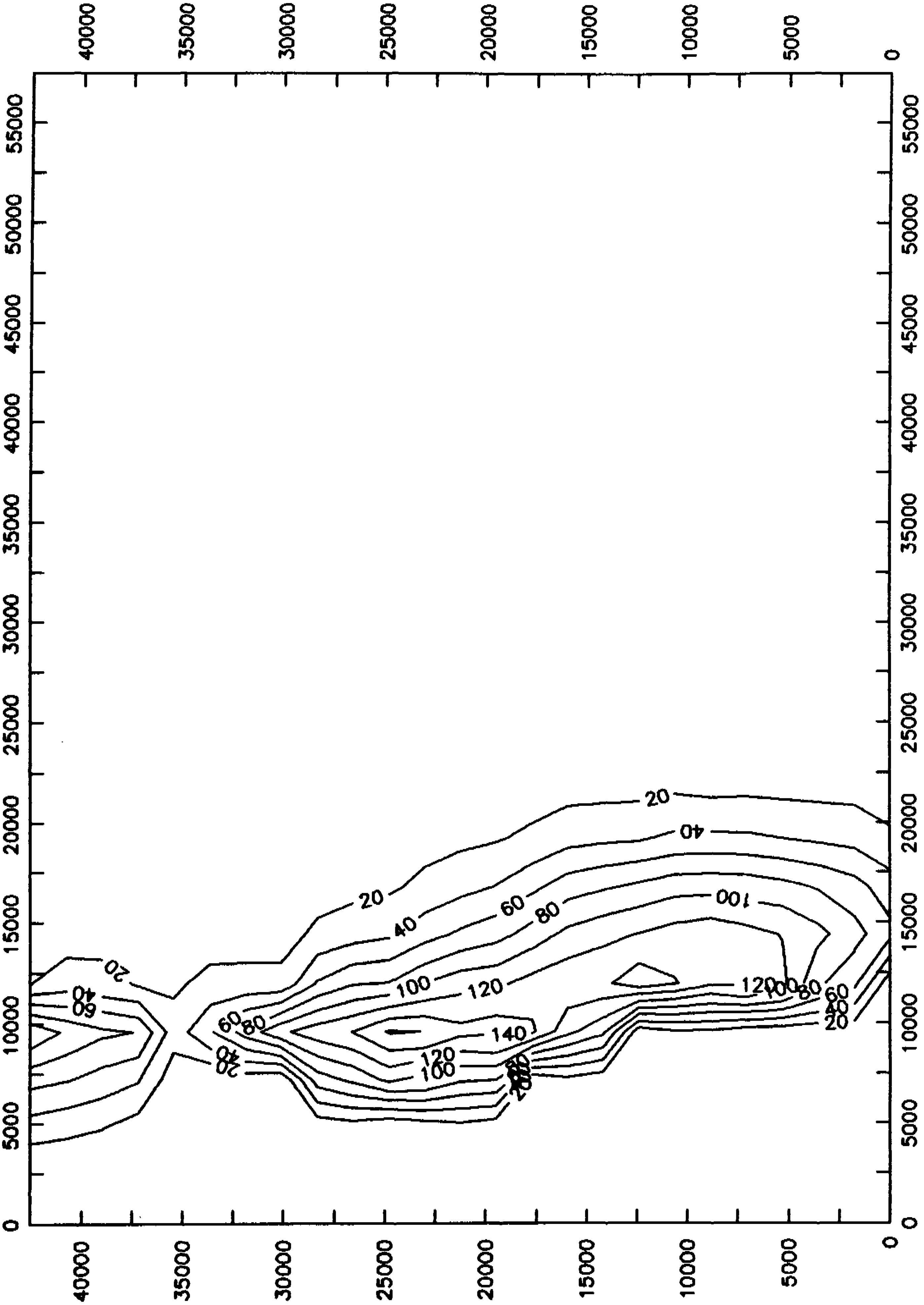


Annex B15: Upcoming of fresh / salt interface (m) after 100 years abstraction in the west.

elderh.30



Annex B16: Upcoming of fresh / salt interface (m) after 150 years abstraction in the west.



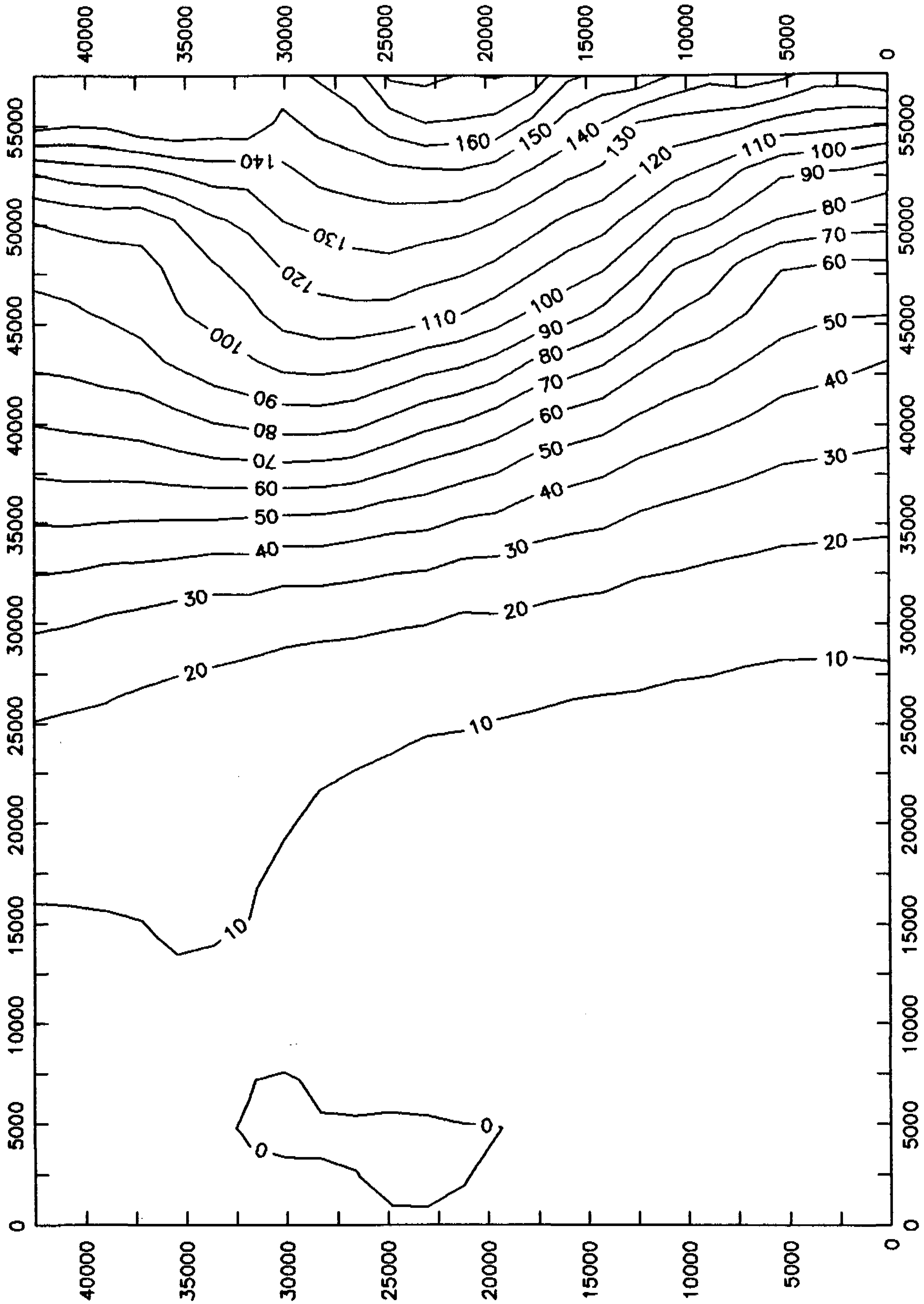
Annex B17: Upcoming of fresh / salt interface (m) after 200 years abstraction in the west.

Annex C1: Groundwater abstractions (m^3/day) for scenario 3, (central abstractions) (10% west, 75% central and 15% east).

* Colums that are not represented in this table contain only elements without abstraction.

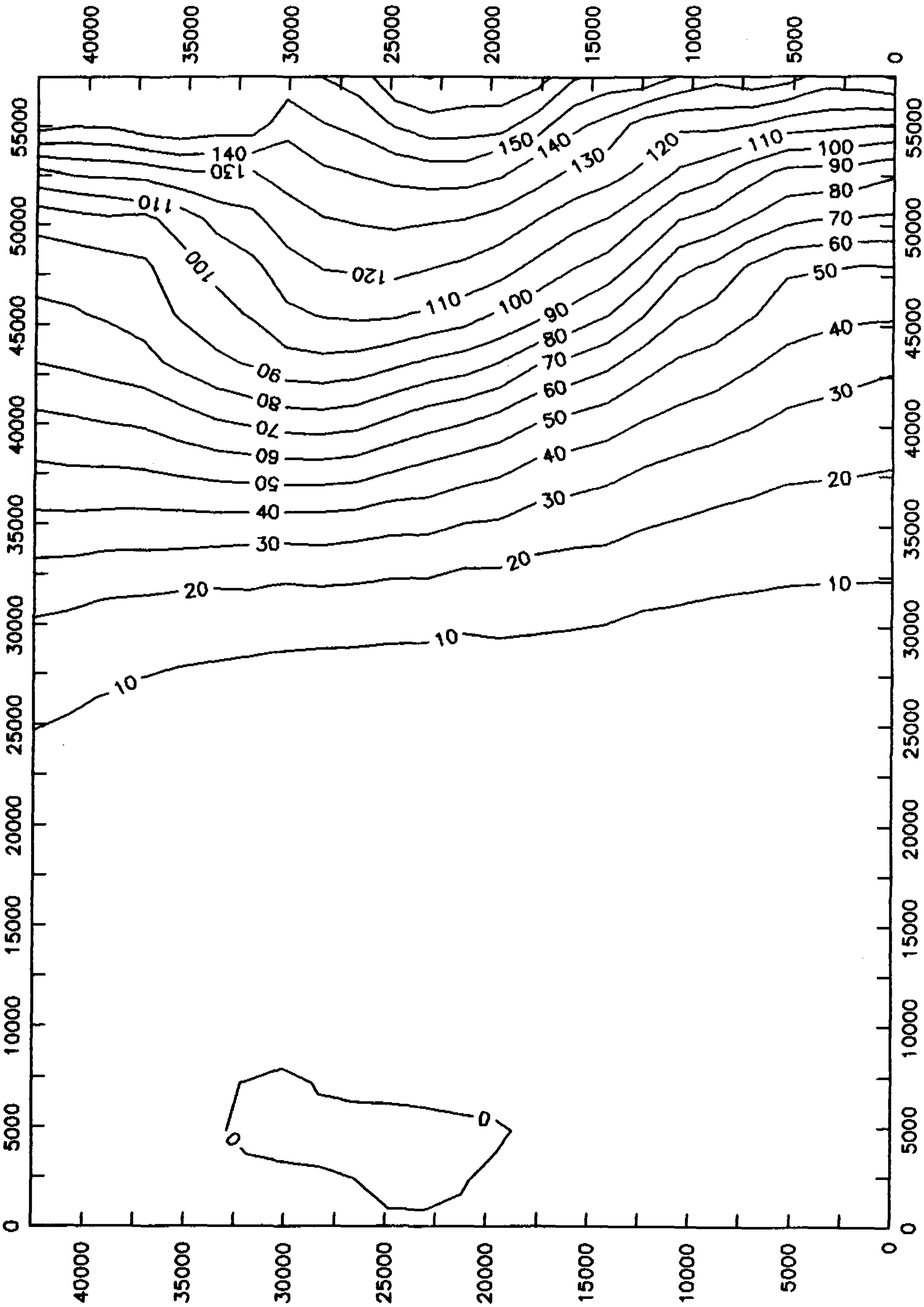
x-coordinate / y-coordinate	20000	27500	30000	32500	47500
42500	0	0	0	0	0
40000	0	-3311	-3311	-3311	-1987
37500	0	-3311	-3311	-3311	-1987
35000	0	-3311	-3311	-3311	-1987
32500	0	-3311	-3311	-3311	-1987
30000	0	-3311	-3311	-3311	-1987
27500	-1927	-3311	-3311	-3311	-1987
25000	-1927	-3311	-3311	-3311	-1987
22500	-1927	-3311	-3311	-3311	-1987
20000	-1927	-3311	-3311	-3311	-1987
17500	-1927	-3311	-3311	-3311	-1987
15000	-1927	-3311	-3311	-3311	-1987
12500	-1927	-3311	-3311	-3311	-1987
10000	-1927	-3311	-3311	-3311	-1987
7500	-1927	-3311	-3311	-3311	-1987
5000	-1927	-3311	-3311	-3311	-1987
2500	-1927	-3311	-3311	-3311	-1987
0	0	0	0	0	0

Annex C1: Groundwater abstractions (m3/day) for scenario 3 (central abstractions). (10% west, 75% central and 15% east).



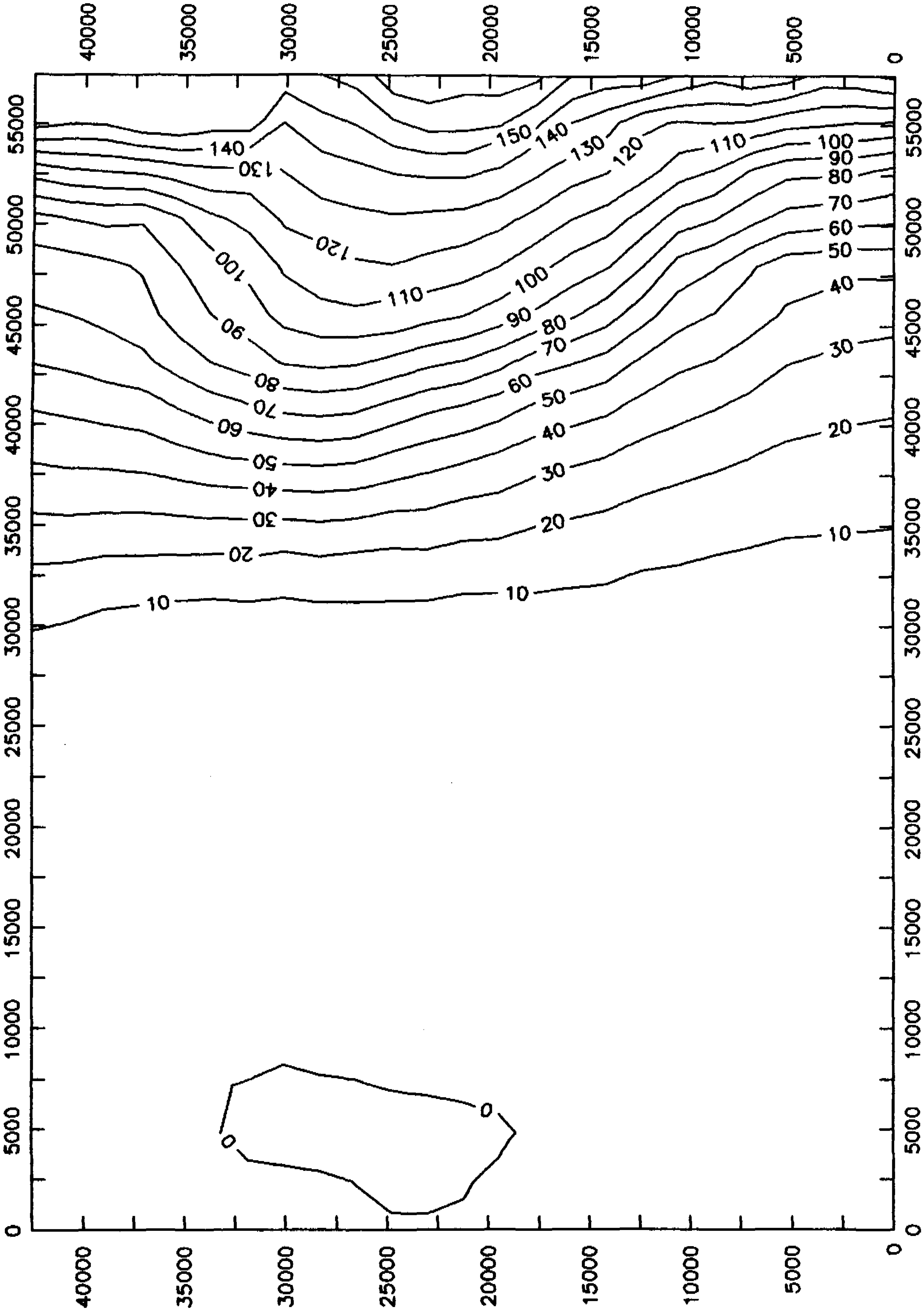
Annex C2: Phreatic head (m) after 50 years abstraction in central part.

elderh.33

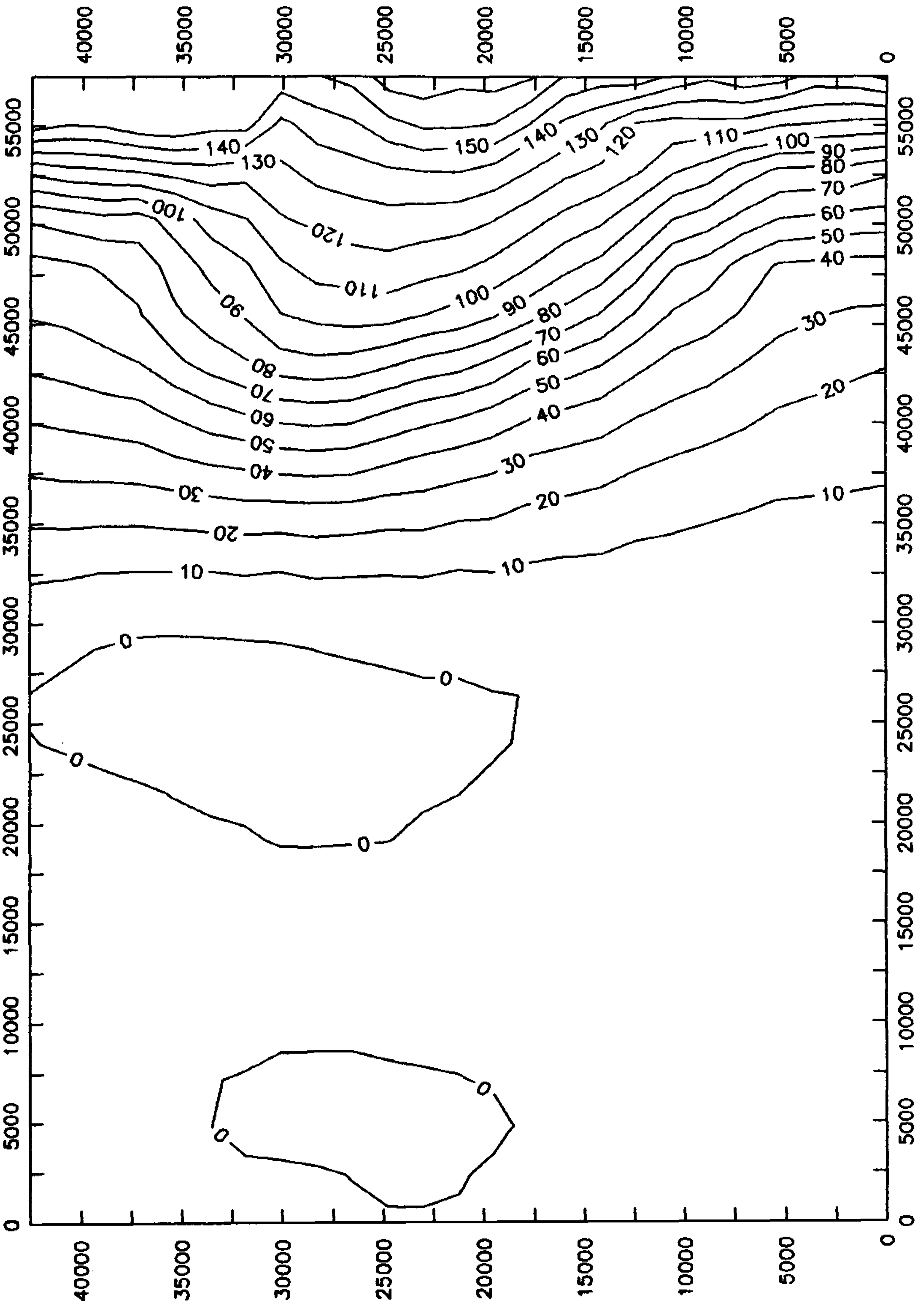


Annex C3: Phreatic head (m) after 100 years abstraction in central part.

elderh.34

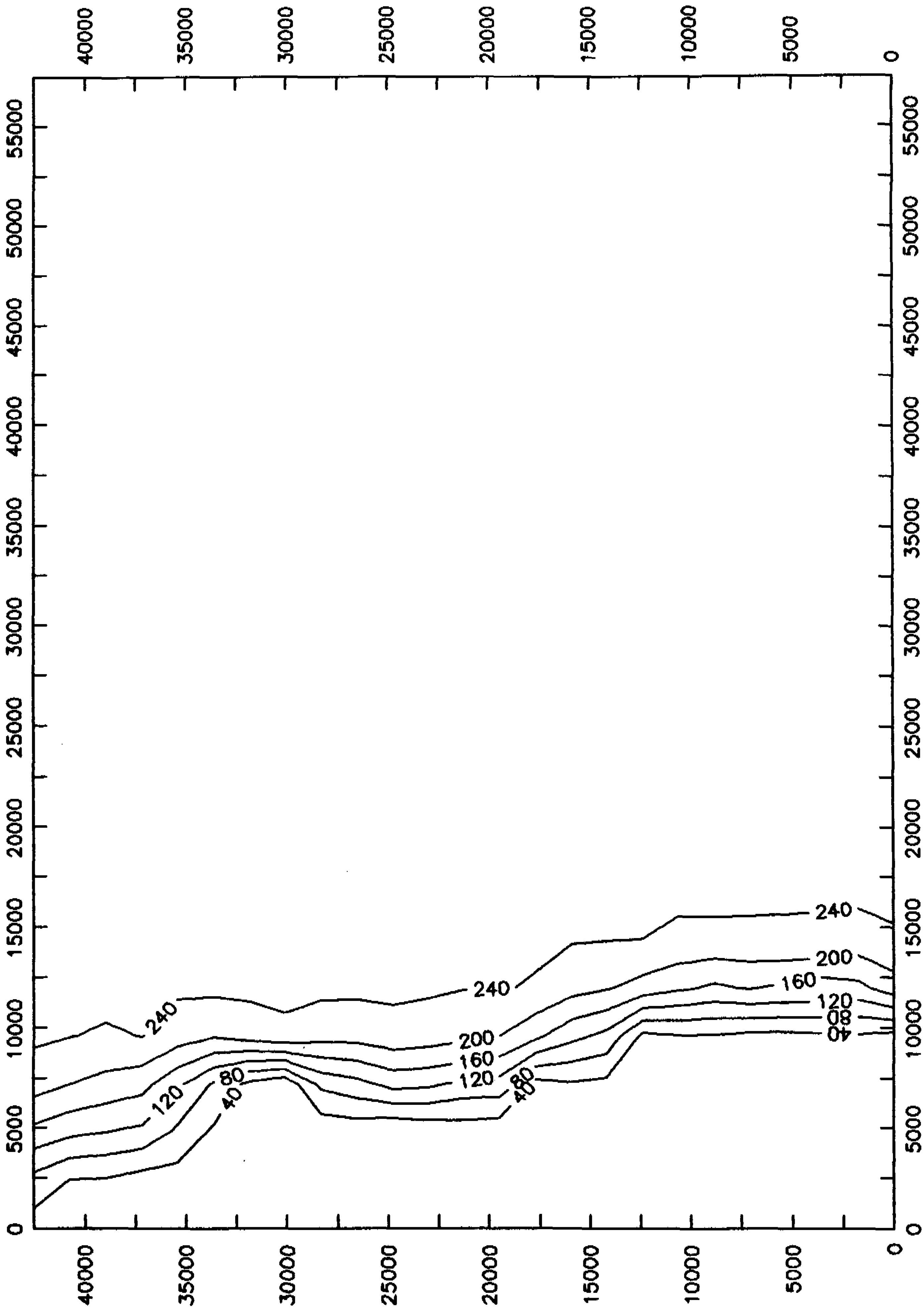


Annex C4: Phreatic head (m) after 150 years abstraction in central part.



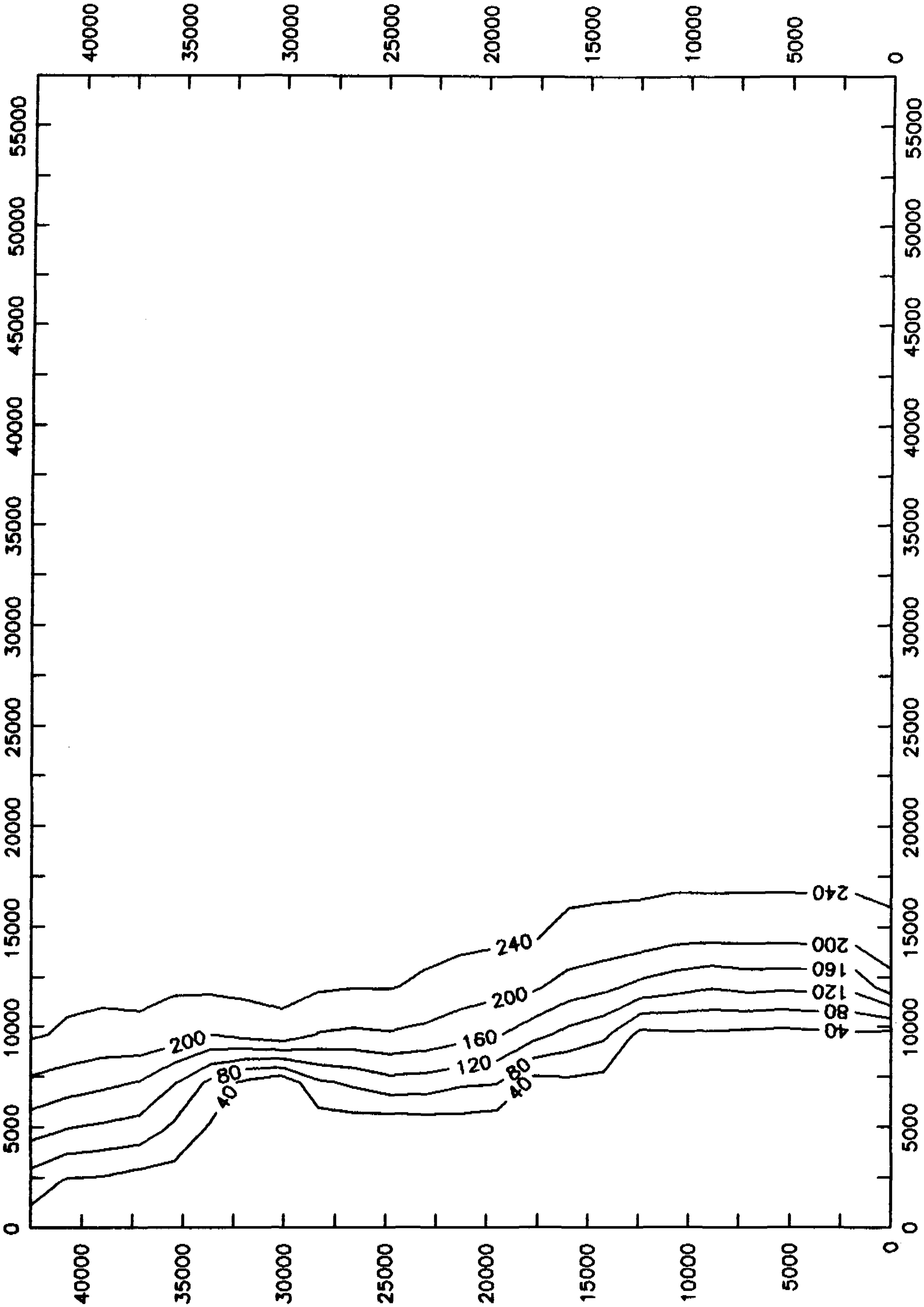
Annex C5: Phreatic head (m) after 200 years abstraction in central part.

elderh.36



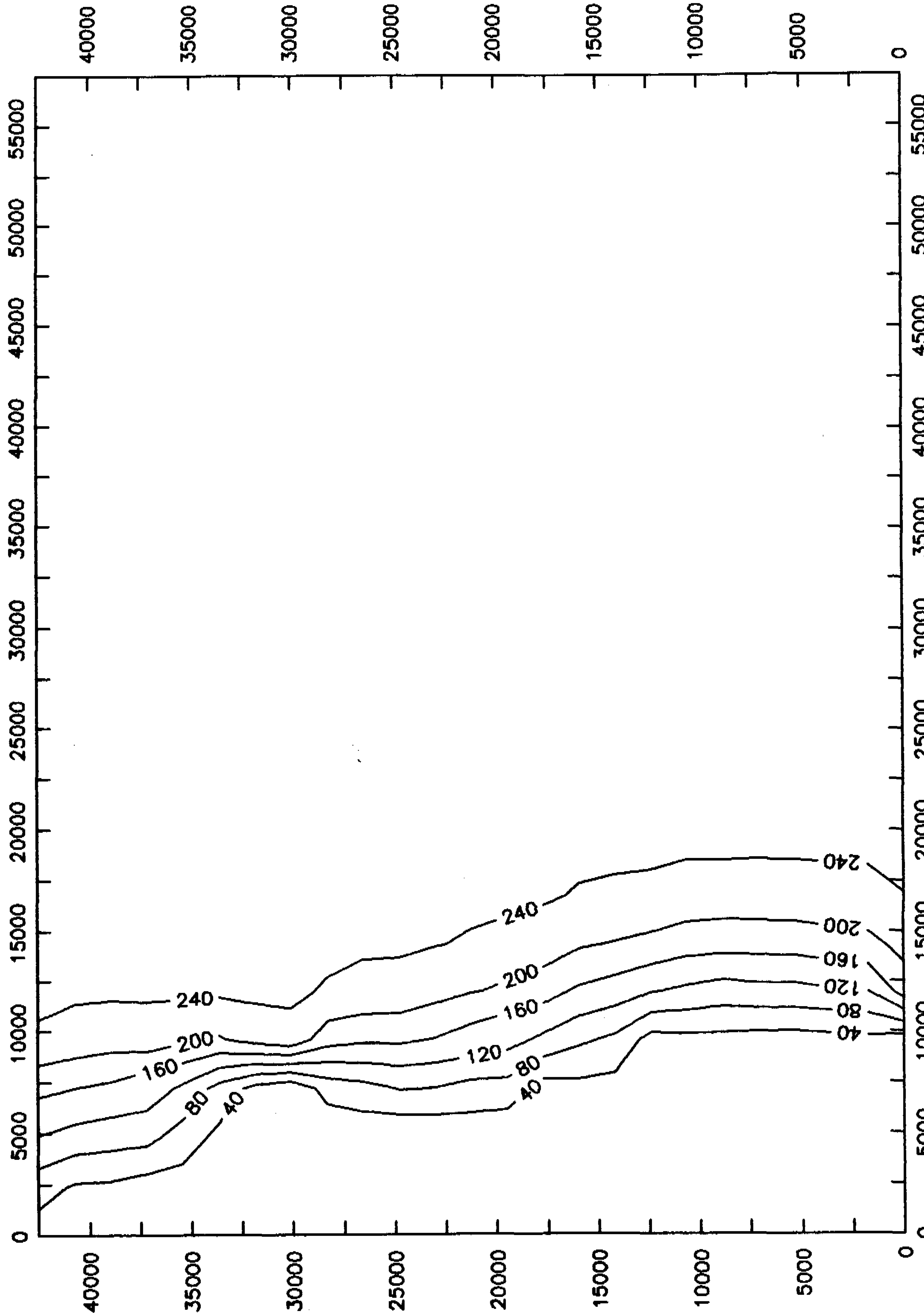
Annex C6: Depth interface (m) after 50 years abstraction in central part.

elderh.37



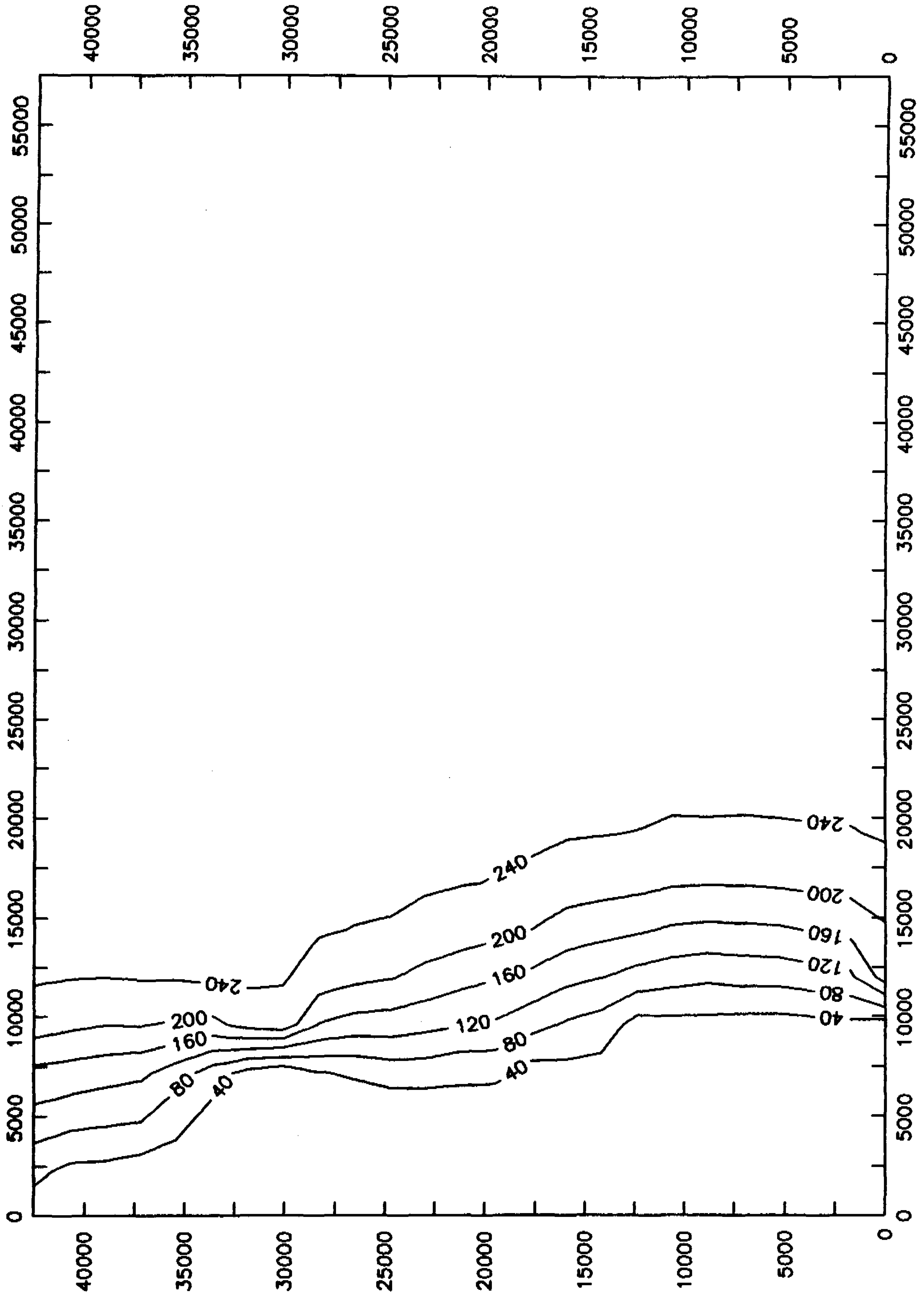
Annex C7: Depth interface (m) after 100 years abstraction in central part.

elderh.38



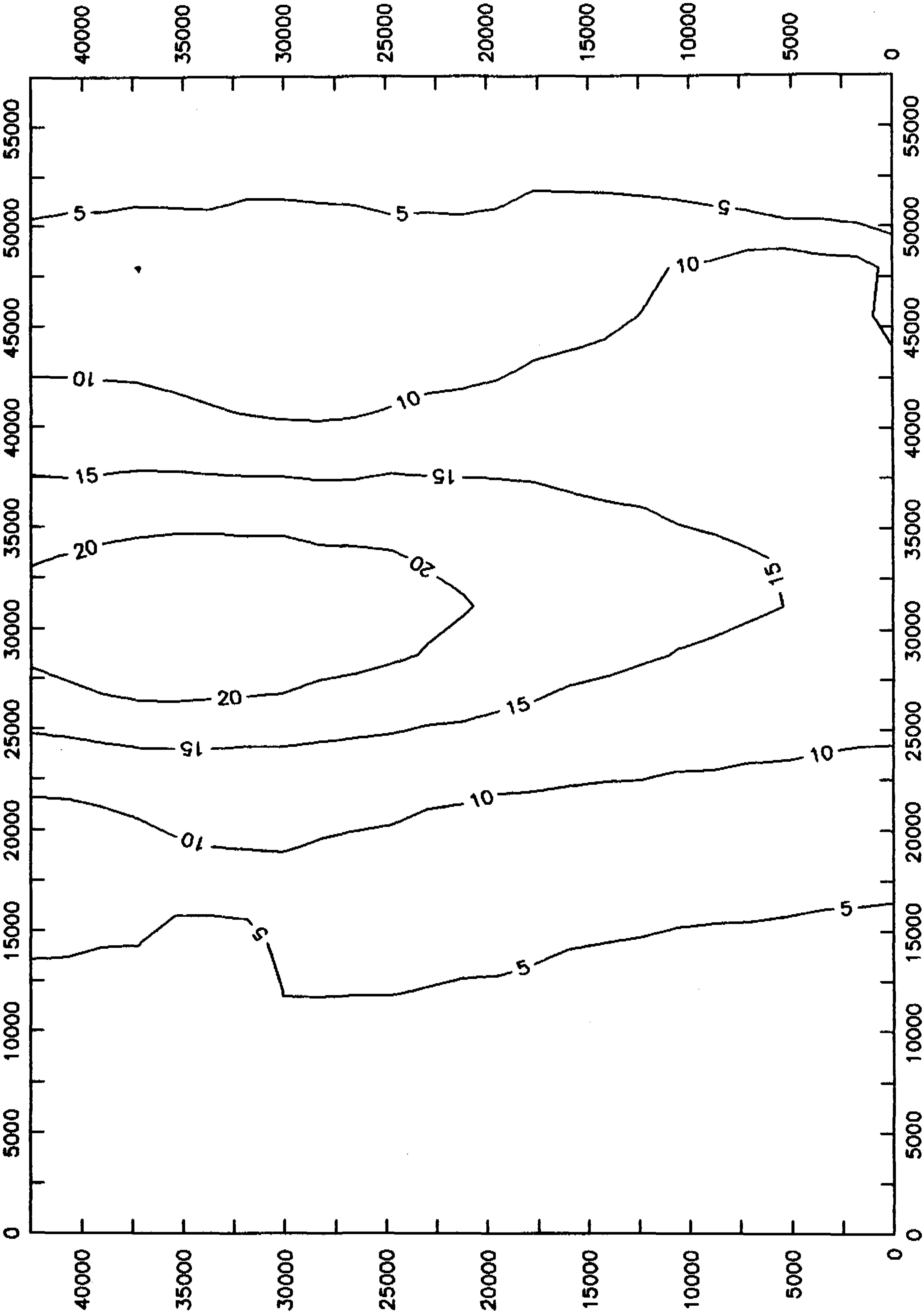
Annex C8: Depth interface (m) after 150 years abstraction in central part.

elderh.39

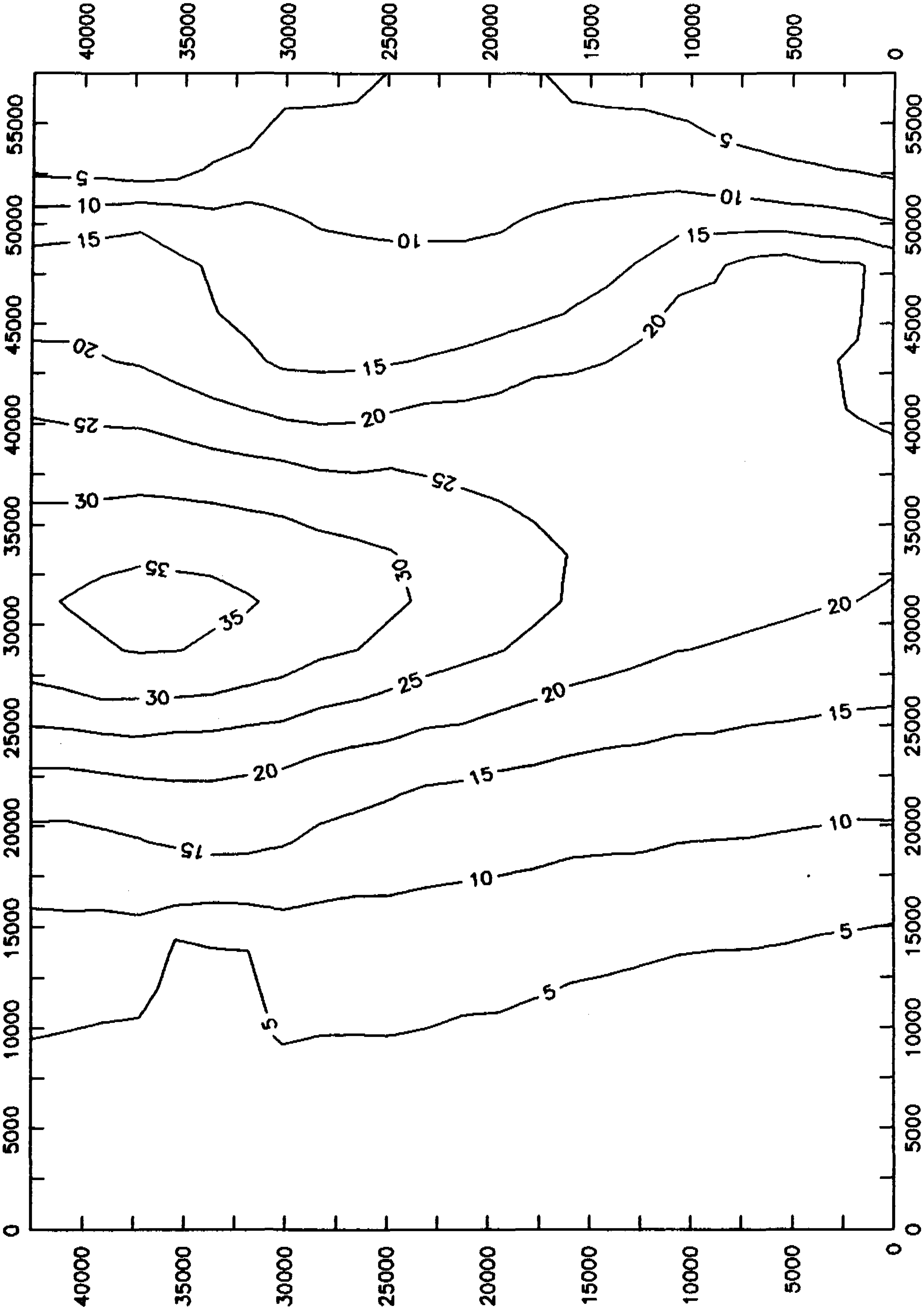


Annex C9: Depth interface (m) after 200 years abstraction in central part.

elderh.40

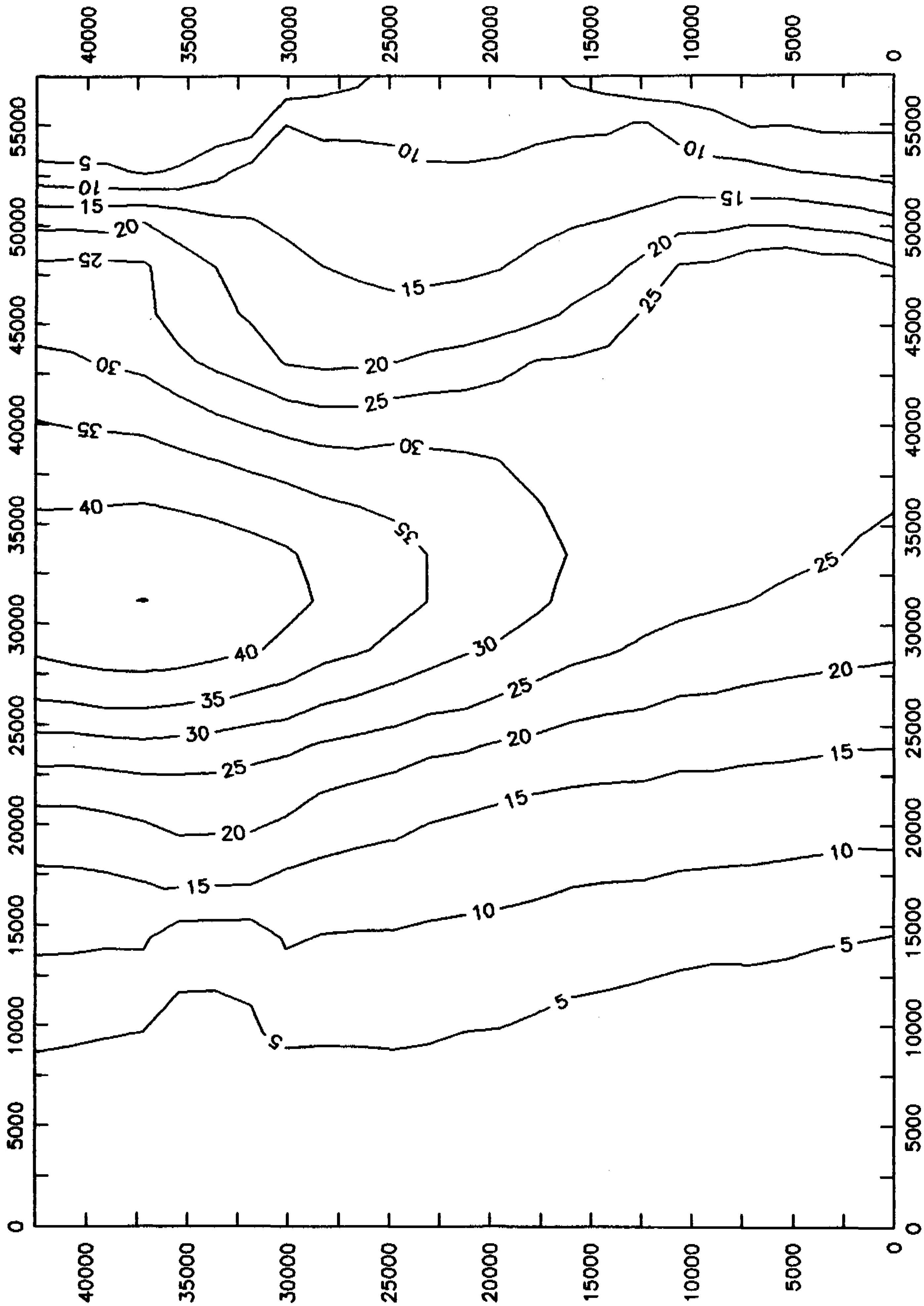


Annex C10: Drawdown of phreatic head (m) after 50 years abstraction in central part.

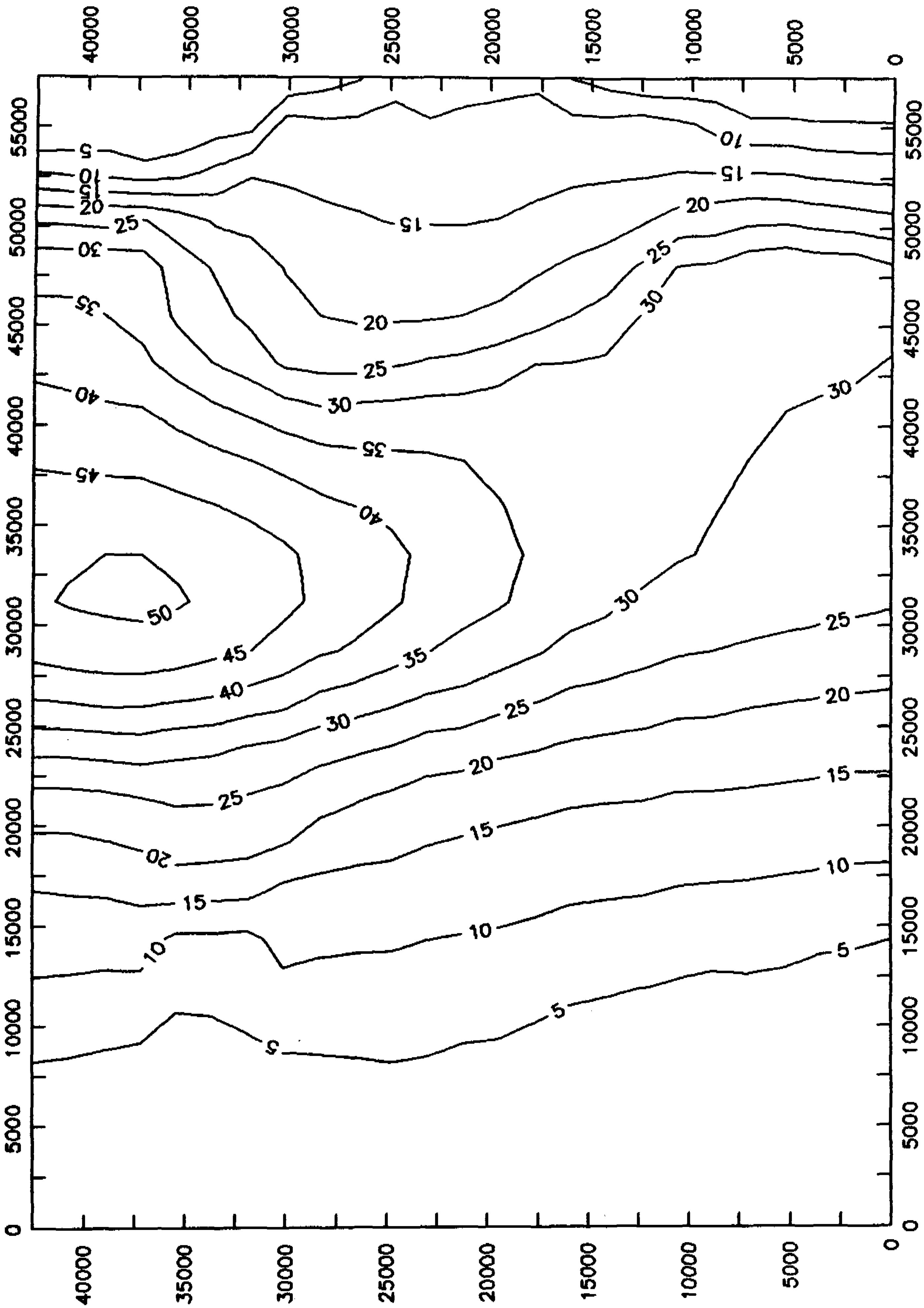


Annex C11: Drawdown of phreatic head (m) after 100 years abstraction in central part.

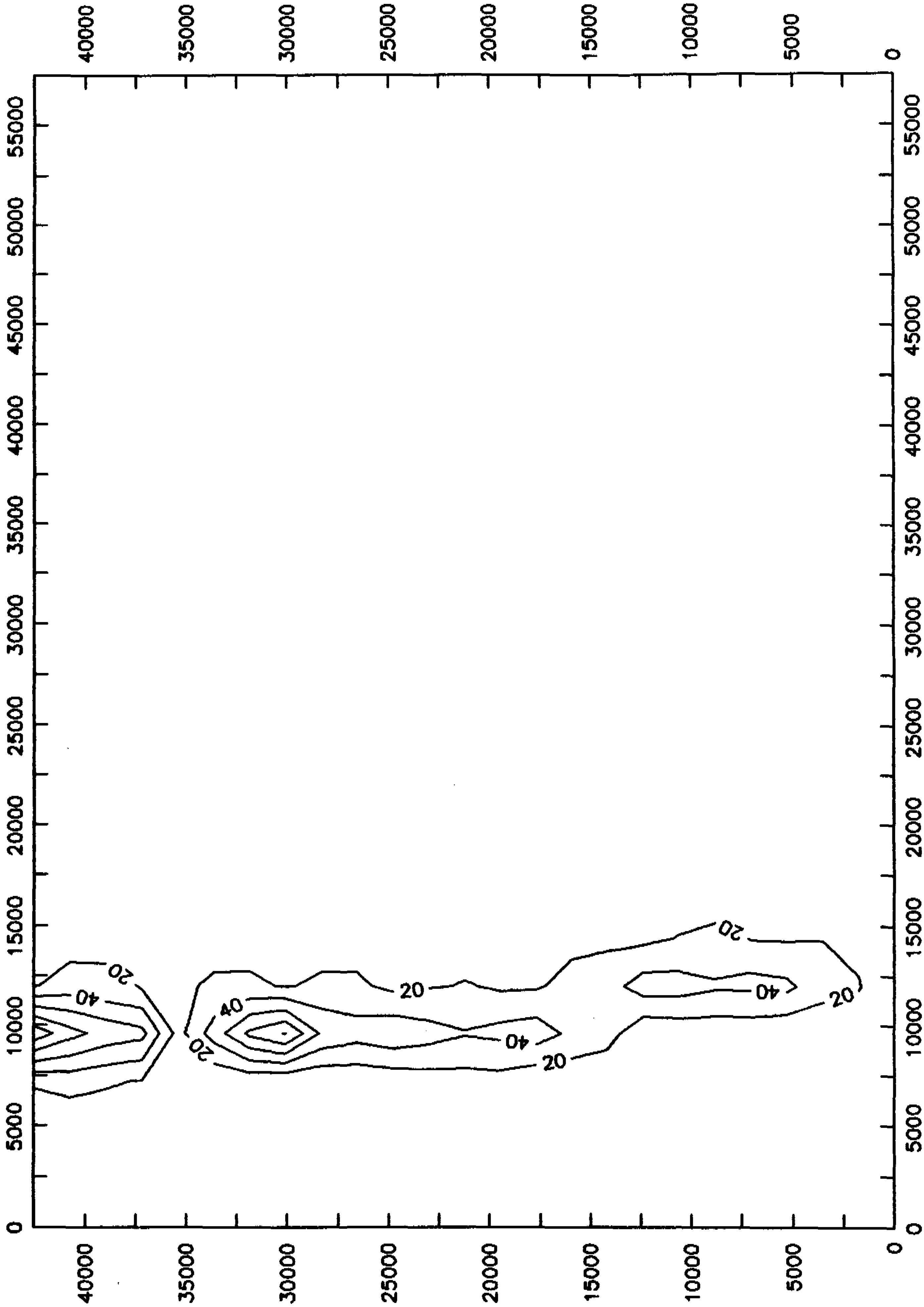
elderh.42



Annex C12: Drawdown of phreatic head (m) after 150 years abstraction in central part.

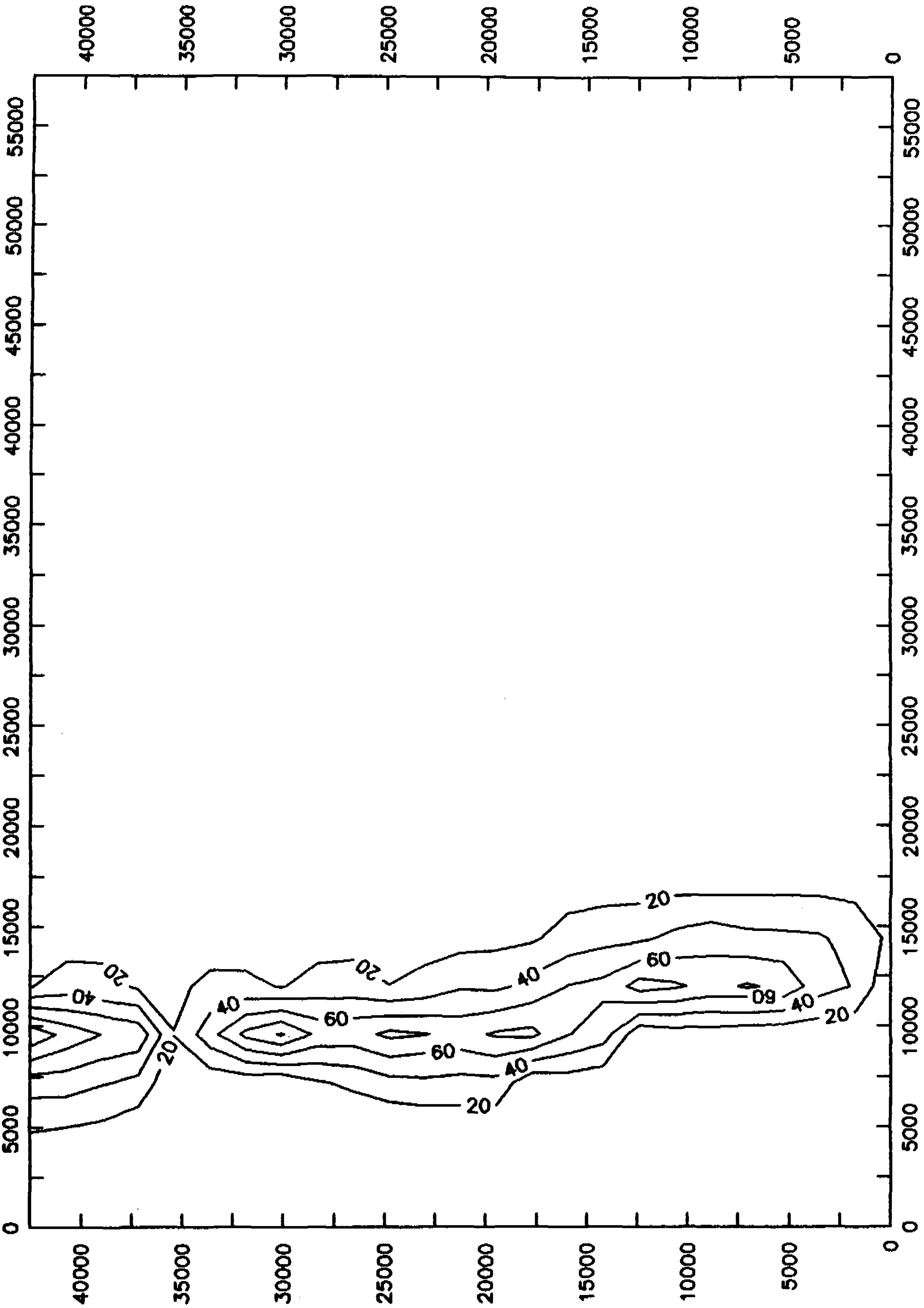


Annex C13: Drawdown of phreatic head (m) after 200 years abstraction in central part.



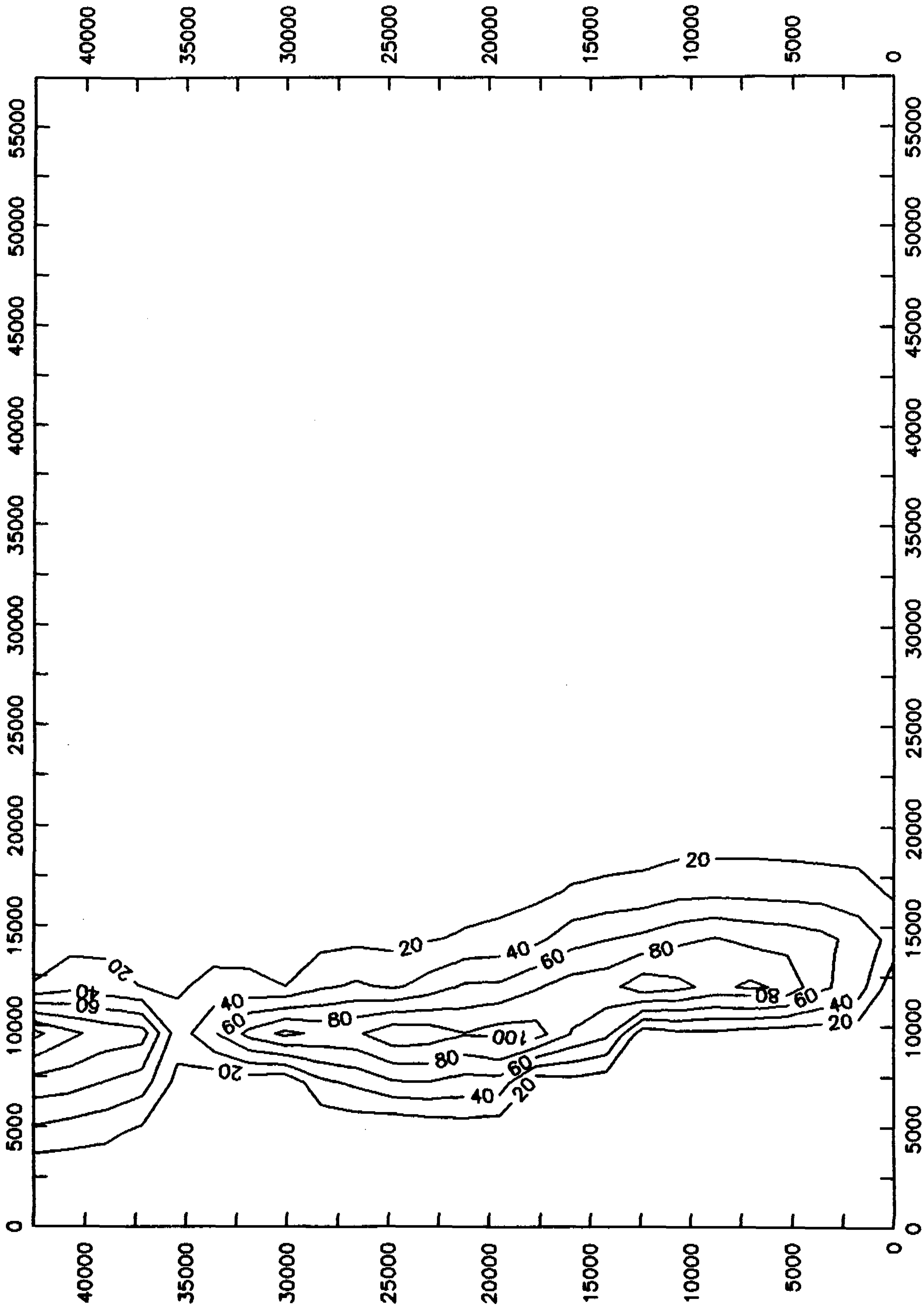
Annex C14: Upcoming of fresh / salt interface (m) after 50 years abstraction in central part.

elderh.45



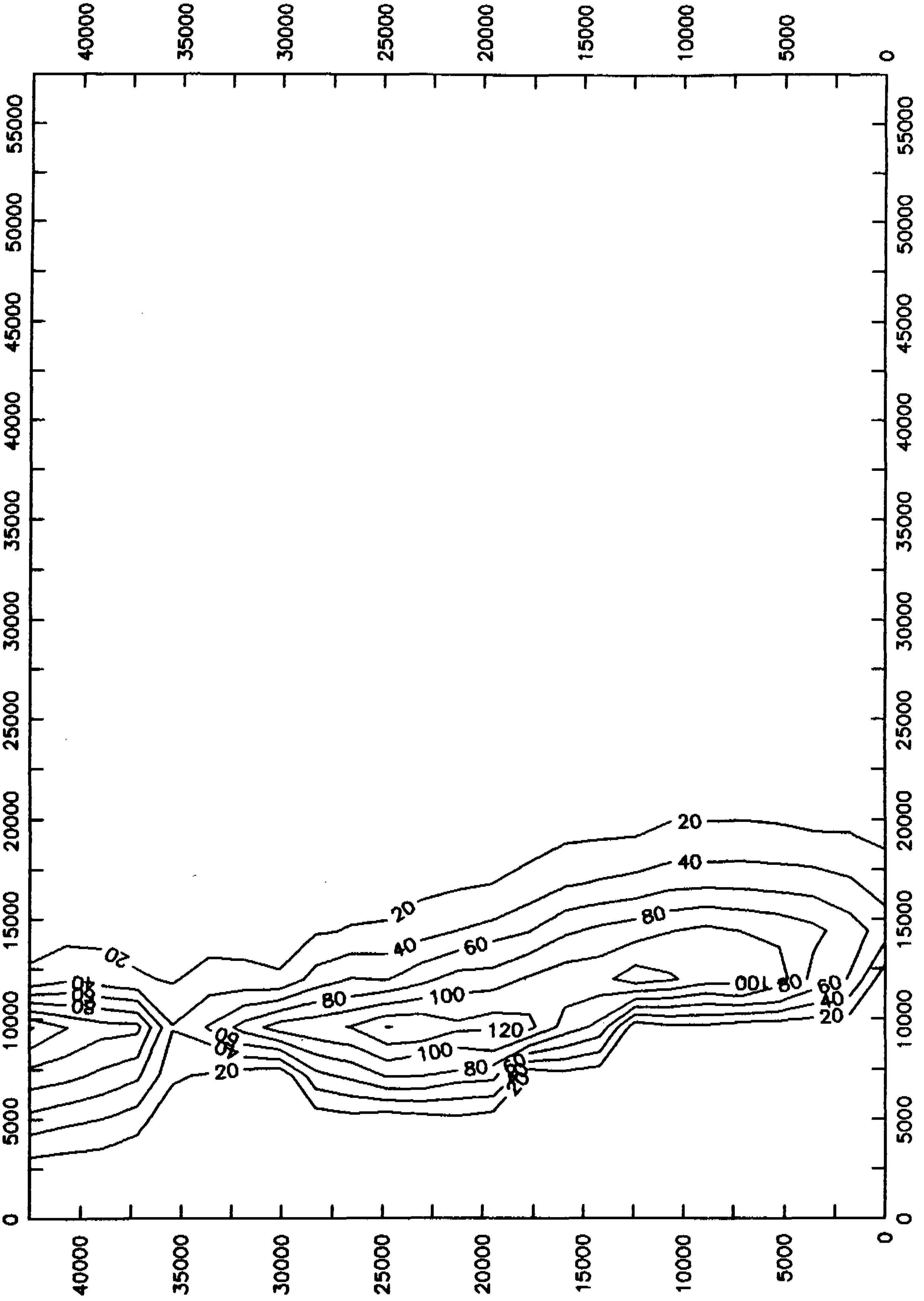
Annex C15: Upcoming of fresh / salt interface (m) after 100 years abstraction in central part.

elderh.46



Annex C16: Upcoming of fresh / salt interface (m) after 150 years abstraction in central part.

elderh.47



Annex C17: Upcoming of fresh / salt interface (m) after 200 years abstraction in central part.

elderh.48