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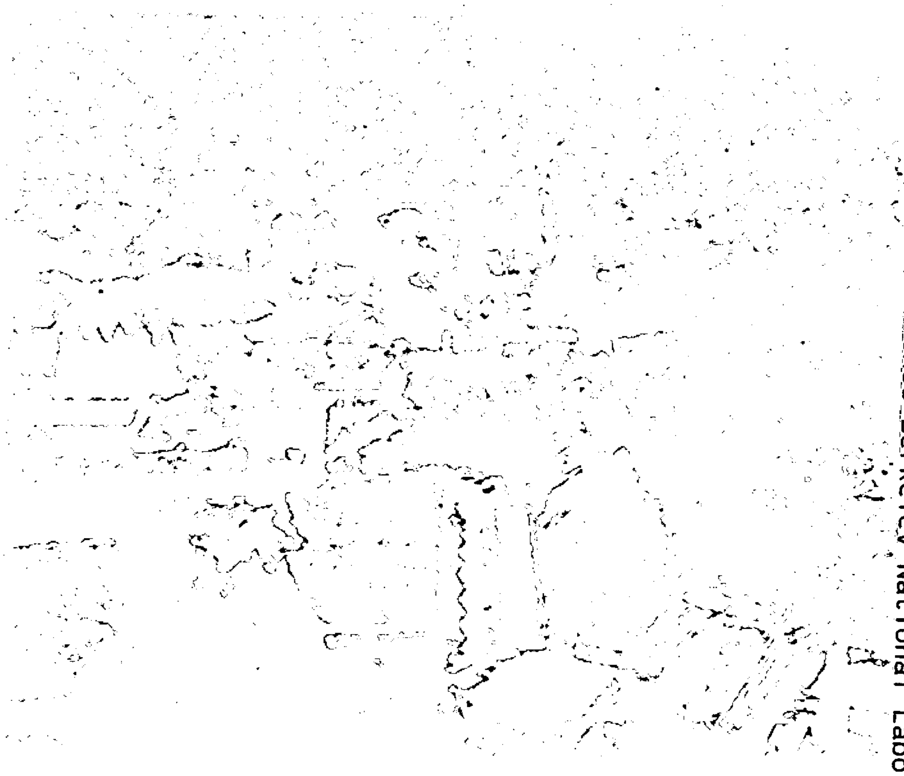

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Abstract

Regional data of groundwater levels for wells in the Lake Karachai area are presented. A method to analyze these data is proposed for the evaluation of hydrological parameters of fractured rocks in this area. The calculated parameters are used to obtain volume losses as a result of filtration into the bed of Lake Karachai, which are then compared with direct data.

Introduction

Lake Karachai has been used by the PA "Mayak" as a radioactive waste storage since October, 1951. As the result of such use, a large volume of contaminated industrial liquids from the lake penetrated into the groundwater of the surrounding area. The lake lies in the area between Rivers Techa and Mishelyak, which are supplied by the surface flows and underground discharge. The form of the contaminated flow from the lake depends on hydrologic properties and on the groundwater flow field in the rock massif. An examination of the actual conditions of the flow regime and mass balance between Lake Karachai, and the groundwater as related to filtration flows of groundwater, makes a strong case for the development of unconventional methods in the estimation of hydrologic parameters of rock mass and filtration loss volumes from Lake Karachai.

Determination of Hydrologic Parameters Based on Regional Groundwater Level Data

The most significant parameters governing groundwater flow in the fractured rock massif are the permeability (K_f), porosity (n_0), and transmissivity (T). These parameters could be determined in two ways: first, by designing a simple calculating scheme and using it for data processing, and second, by evaluating data from regional study, followed by data processing. Generally, the processing of the results obtained through regional study is very complicated and normally run through various trial-and-error methods. At the same time, the mathematical relationship for homogeneous media is not always acceptable for inhomogeneous media such as fractured rock mass, particularly in cases where the pressure depression area is comparable to the geometric scale, characterizing the inhomogeneity of the medium under investigation. Therefore, from this point of view, the use of regional study integrating medium characteristics in the investigated area is preferable to the first scheme, because it avoids some of the uncertainties and discrepancies in the application of filtration equations for fractured rock massif.

Lake Karachai lies at an elevation higher than the elevations of nearby ponds and rivers. Figure 1 shows a map of Lake Karachai and the investigation wells. The lake bed is porphyrite that is extensively fractured and overlapped by clay and loam, with a thickness of about 2 m. About 4% of the lake area is overlapped by a plane of clay with a thickness of only 0.7 m, resulting in a good hydraulic connection between the lake and the underlying groundwater. An analysis of the groundwater regime has revealed a number of main regime generating factors, which can be categorized into some genetic groups: geologic, climatic, biosoil, hydrologic, and a group of artificial factors. A phenomenological approach was employed for analyzing a groundwater regime involving the representation of the listed factors by generalizing parameters, followed by their analysis based on the solution of the equation for unsteady filtration. After the analysis of hydrohypsographical curves in the investigated area (see Figures 2–7), it was noted that the possibility exists for using a model of groundwater plane flow in the direction of their discharging zones. In such a case, the unsteady filtration regime of groundwater could be described by a one-dimensional equation of the following form (in approximation according to Verigin):

$$\frac{\partial^2 h^2(x,\tau)}{\partial_x^{\;2}} + \frac{2W(x,\tau)}{K_F} = \frac{1}{a} \cdot \frac{\partial h^2(x,\tau)}{\partial \tau} \tag{1}$$

where

h = height of groundwater free surface relative to the horizontal impermeable bed, m;

h_s = the same height averaged by Boussnesq equation linearization;

K_F = permeability values, m/day;

W = infiltration rate, m/day;

τ = time, days; and

$$a = \frac{k_F h_S}{\mu_S}; \qquad h_S = \frac{1}{2} \cdot (h_{\max} + h_{\min}).$$

The storage μ can be considered equal to water take-up and release, because the deformation capacity in rock mass could not be taken into account. Let us supplement Equation (1) with boundary and initial conditions. For the boundary conditions, let us take the condition of the first kind, namely, the temporally constant value of groundwater level at the boundary of the investigated area, in particular at south sector:

$$h(0, \tau) = h_k; \quad h(L_S, \tau) = h_M, \tag{2}$$

where h_k = Lake Karachai level relative to the watertight bed;

h_M = River Mishelyak level relative to the watertight bed;

L_S = distance between Lake Karachai and River Mishelyak.

Let us assume similar conditions for the north sector. As the initial condition, let us take the depression function of groundwater level, $h_0(x)$, meeting the boundary conditions (2) and the Equation (3):

$$\frac{\partial^2 h_0^2(x,\tau)}{\partial x^2} = 0. \tag{3}$$

The function $h_0(x)$ is a depression of groundwater level under the given boundary conditions and with the absence of infiltration feeding.

Using the relationship (4)

$$h^2(x,\tau) = h_0^2(x) + h_1^2(x,\tau), \tag{4}$$

in Equation (1), we obtain

$$\begin{cases} \dfrac{\partial^2 h^2(x,\tau)}{\partial x^2} + \dfrac{2W(x,\tau)}{K_F} = \dfrac{1}{a} \bullet \dfrac{\partial h^2(x,\tau)}{\partial \tau} \\ h_1(0,\tau) = h_1(L_S,\tau) = 0 \\ h_1(x,0) = 0 \end{cases}, \tag{5}$$

and

$$\frac{\partial^2 h_0^2(x)}{\partial x^2} = 0 \quad ; \quad h_0(0) = h_k \quad ; \quad h_0(L_S) = h_M \tag{6}$$

The solution of the initial problem is shown as a superposition of two independent solutions. Equation (6) describes a stationary depression curve established in the area without infiltration sources. Equation (5) describes the influence of infiltration on the groundwater level, modifying the Equation (6). The solution of Equation (6) for *h(x)* takes the following form:

$$h_0^2(x) = h_k^2 \cdot \left(1 - \frac{x}{L_S}\right) + h_M^2 \cdot \frac{x}{L_S} \tag{7}$$

Considering that the velocity of groundwater infiltration is constant for the whole problem area and changing the problem area in (5) from $0 \le x \le 1$ to $-L_S/2 \le x \le L_S/2$, we get the following solution for $h_1{}^2(x,t)$:

$$h_1^2(x,\tau) = \frac{8a}{\pi k_F} \cdot \sum_{n=0}^{\infty} \frac{(-1)^n}{2n+1} \cdot \cos\left(\frac{(2n+1)\pi x}{L_S}\right) \cdot \int_0^{\tau} \left[W(\tau') e^{-\frac{4\pi^2 a(2n+1)^2}{L_S^2}(\tau-\tau')} \right] d\tau' \tag{8}$$

If $W(\tau) = W_0/\tau = \text{const}$

$$h_1(x) = \frac{W_0 L_S^2}{4\tau_d k_F} \left[1 - \frac{4x^2}{L_S^2} - \frac{32}{\pi^3} \sum_{n=0}^{\infty} \left(\frac{(-1^n}{(2n+1)^3} \cos\left(\frac{(2n+1)\pi x}{L_S}\right) e^{-a(2n+1)^2 \pi^2 \tau / L_S^2} \right) \right] \tag{9}$$

Taking into account the features of infiltration sources in the problem area (the scheme is given in Figure 8, and data are given in Figure 9), let us represent $h^2(x,\tau)$ as

$$h^2(x,\tau) = h_2^0(x) + h_s^2(x,\tau) + h_{i-1}^2(x,\tau) + h_i^2(x,\tau),$$

where h_s = defines the level change in spring season

h_{i-1} = defines the level change from precipitation of the last year;

h_i = defines the level change from precipitation of the current year.

$$h_{i-1}^2(x,\tau)=\begin{cases}\dfrac{W_{i-1}\varepsilon_{i-1}^* L_S^2}{4\tau_d k_F}\left(1-\dfrac{4x^2}{L_S^2}\right) & \tau\le\tau_2\\ ; \\ -\dfrac{W_{i-1}\varepsilon_{i-1}^* L_S^2}{4\tau_d k_F}\left(1-\dfrac{4x^2}{L_S^2}-F(x,\tau-\tau_1)\right) & \tau>\tau_2\end{cases}$$

$$h_S^2(x,\tau)=\begin{cases}\dfrac{W_Z\varepsilon L_S^2}{4k_F(\tau_2-\tau_1)}\left(1-\dfrac{4x^2}{L_S^2}-F(x,\tau-\tau_1)\right) & \tau_1\le\tau\le\tau_2\\ ; \\ \dfrac{W_Z\varepsilon L_S^2}{4k_F(\tau_2-\tau_1)}\left(-F(x,\tau-\tau_1)+F(x,\tau-\tau_2)\right) & \tau>\tau_2\end{cases} \qquad (10)$$

$$h_i^2(x,\tau)=\frac{W_i\varepsilon_i^* L_S^2}{4\tau_d k_F}\left(1-\frac{4x^2}{L_S^2}-F(x,\tau-\tau_1)\right)\quad ;\quad \tau>\tau_2\ ;$$

$$F(x,\tau-\tau_1)=\frac{32}{\pi^3}\sum_{n=0}^{\infty}\frac{(-1)^n}{(2n+1)^3}\cos\frac{(2n+1)\pi x}{L_S}e^{-\frac{4\pi^2 a(2n+1)^2}{L^2}(\tau-\tau_i)}$$

where $\tau_2 - \tau_1$ = snow-thawing period;

τ_d = rain feeding period (t = 1 year);

ε_i^* = infiltration coefficient of precipitation;

ε = infiltration coefficient during the snow thawing period for snow stocks W_Z;

W_{i-1} = annual precipitation in the previous year;

W_i = annual precipitation in the current year.

Determination of the Coefficient "*a*"

If we know the groundwater level H_0 before the spring elevation (at the moment τ_1), then we can write for the wells in the central sector at this time as

$$\left[H_0+\Delta h_S^{\max}\right]^2=H_0^2+\frac{W_z L^2}{4k_F(\tau_2-\tau_1)}\left(1-\frac{4x^2}{L_S^2}\right)\left(1-e^{-\frac{a\pi^2(\tau_2-\tau_1)}{L_S^2}}\right). \qquad (11)$$

For $\tau > \tau_2$

$$[H_0 + \Delta h_S(x,\tau)]^2 = H_0^2(x_i) + \frac{W_z L^2}{4k_F(\tau_2-\tau_1)}\left(1-\frac{4x^2}{L^2}\right)\left(1-e^{-b(\tau_2-\tau_1)}\right)e^{-b(\tau_2-\tau_1)} \quad (12)$$

where $b = \dfrac{a\pi^2}{L_S^2}$

After rearranging

$$\left[H_{0)} + \Delta h_S(x_i,\tau)\right]^2 - H_0^2(x_i) = \left(\left[H_0 + \Delta h_S^{max}(x_i,\tau)\right]^2 - H_0^2(x_i)\right)e^{-b(\tau_2-\tau_1)}. \quad (13)$$

After normalizing and logarithm taking

$$-\frac{a\pi^2(\tau_2-\tau_1)}{L^2} = \ln\left(\frac{\Delta h_S(x,\tau-\tau_2)}{\Delta h_S^{max}}\cdot\frac{1+\dfrac{\Delta h_S(x,\tau-\tau_2)}{2H_0}}{1+\dfrac{\Delta h_S^{max}}{2H_0}}\right). \quad (14)$$

With $\Delta h_S = \Delta h_S^{max}/2$ at the moment τ_0, we get $a = \dfrac{0.633L^2}{\pi(\tau_0-\tau_2)} = \dfrac{\lambda_{CM}L^2}{T_{1/2}}$, where $\lambda_{CM} = \dfrac{0.693}{T_{1/2}}$; $T_{1/2} = \tau_0 - \tau_2$.

Tables 1 and 2 show values of $a = \dfrac{kh}{\mu}$ in south and north directions from Lake Karachai using the results of regional examinations of groundwater level, shown in Figures 10–17.

Table 1. Coefficients "*a*" for Wells in South Direction.

Year	Well 202/64			Well 10/68		
	Δh_s^{max}, m	$T_{1/2}$, day	$a*10^{-3}$ m^2/day	Δh_s^{max}, m	$T_{1/2}$, day	$a*10^{-3}$ m^2/day
1972	1.6	65	6.8	1.0	45	9.8
1973	1.0	45	9.8	1.1	50	8.8
1974	1.2	50	8.8	1.0	50	8.3
1975	0.25	–	–	0.2	–	–
1976	0.4	45	9.8	0.5	40	11.0
1977	1.1	65	6.8	1.5	55	8.8
1978	1.5	–	–	1.6	–	–
1979	2.1	70	6.3	2.0	55	8.8
1980	1.5	50	8.8	1.5	–	–
1981	2.4	45	9.8	1.5	70	6.3
1982	0.7	40	11.0	0.9	35	12.6

Table 2. Coefficients "*a*" for Wells in North Direction.

Year	Well 15/70		Well 36/70		Well 38/70	
	$T_{1/2}$, day	a, m^2/day	$T_{1/2}$, day	a, m^2/day	$T_{1/2}$, day	a, m^2/day
1972	–	–	55	2.6	30	4.8
1973	75	1.9	70	2.0	60	2.4
1974	60	2.4	70	2.0	40	3.6
1975	50	2.8	–	–	60	2.4
1976	60	2.4	45	3.2	70	3.0
1977	65	2.2	60	2.4	–	–
1978	–	–	55	2.6	70	2.0
1979	–	–	65	2.2	70	2.0
1980	–	–	55	1.9	50	2.8

Evaluation of the Averaged Transmissivity

Although the conductivity characterizes the pressure fields, an openflow bed could be characterized by a value similar to conductivity notation by the linearization of unsteady filtration equation in the N.N. Verigin approximation.

For the evaluation of this value, we use the data over the period when the infiltration in this area was absent from 1975 to 1977. By using a depression curve, we shall get the following relationships for the filtration velocity from the Lake Karachai v_F of the front width l_0 and the same coefficient both to the south and north directions.

$$V_{FS} = \frac{l_0 \Delta H_S}{L_S} \overline{k_{FS} H_{SS}} \left(1 + \frac{L_S}{L_N} \cdot \frac{\Delta H_N}{\Delta H_S} \cdot \frac{a_N}{a_S}\right);$$

$$L_S = 1500\,;\ L_N = 4500\,;\ \Delta H_S = H_K - H_M = 6.5m\,; \tag{15}$$

$$\Delta H_N = H_K - H_T = 21m\,;\ H_{SS} = \frac{H_K + H_M}{2}\,;\ H_{SN} = \frac{H_K + H_T}{2}\,.$$

The maximum value of filtration velocity was observed in 1976–1977 and was about 950 m^3/d. We can calculate values $\overline{h_{SS} k_{FS}}$ and $\overline{h_{SN} k_{FN}}$ for this value of filtration velocity using (16). Then $T_S = \overline{h_{SS} k_{FS}} = 40 m^2/d,\ T_N = \overline{h_{SN} k_{FN}} = 110 m^2/d.$

We can evaluate the effective fracture porosity μ_s by using the water balance results of Lake Karachai for the period 1976 to 1977 and the values for $\overline{k_F h_S}$ and a. The evaluation for the south and north directions shows similar values for μ_s about 0.0044. These values are in sufficiently good agreement with direct data, as well as with the results of special hydrogeologic explorations (Figure 18).

Evaluation of Groundwater Infiltration Sources

By using the approximation $H(x_i)k_F \approx \overline{h_{SS} k_{FS}}$ and $H_0 >> Dh_i$, we get for the snow-thawing period

$$\varepsilon = \frac{8 h_S k_F \Delta h(x_i, \tau_2 - \tau_1)}{W_z L^2 \left[1 - \frac{4x_i^2}{L_j^2} - \frac{32}{\pi^3}\cos\left(\frac{\pi x_i}{L_j}\exp(-\lambda_{CM}(\tau_2 - \tau_1))\right)\right]}\,. \tag{16}$$

Table 3. Infiltration coefficients of precipitation for south direction in spring.

Year	W_z, mm	Well 202/64			Well 10/68			Well 3/68		
		$\tau_2 - \tau_1$, day	Δh_m, m	ε	τ, day	Δh_m, m	ε	τ, day	Δh_m, m	ε
1972	96	30	1.6	0.067	50	1.2	0.102	–	–	–
1973	112	40	0.8	0.049	20	1.2	0.069	20	0.8	0.07
1974	104	45	1.2	0.082	30	1.0	0.069	70	0.7	0.09
1975	80	55	0.4	0.039	60	0.5	0.054	45	0.5	0.107
1976	96	50	1.1	0.084	70	1.4	0.134	90	0.7	0.112
1977	106	60	1.4	0.105	90	1.6	0.156	60	1.0	0.127
1978	106	65	1.8	0.126	90	2.0	0.196	90	1.4	0.214
1980	162	40	1.4	0.059	30	1.5	0.103	55	1.3	0.103

For infiltration coefficient of precipitation

$$\varepsilon^* = \frac{8h_i\left(\overline{h_S k_F}\right)\tau_d}{L_j^2\left(1-\dfrac{4x_i^2}{L_j^2}\right)W_d} . \qquad (17)$$

where h_1 = elevation relatively $h_0(x_i)$.

Table 4. Infiltration coefficients in the rain period.

Year	Well 202/64		Well 10/68		Well 3/68	
	h_i	ε^*	h_i	ε^*	h_i	ε^*
1971	2.8	0.056	3.0	0.067	2.1	0.073
1972	2.2	0.044	2.1	0.047	1.5	0.052
1973	2.2	0.044	2.2	0.049	1.6	0.056
1974	1.4	0.028	1.1	0.024	0.8	0.023
1975	0.4	0.028	0.0	0.0	0.0	0.0
1976	0.0	0.0	0.0	0.0	0.0	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0
1978	1.0	0.020	1.3	0.029	1.1	0.038
1979	1.4	0.028	1.5	0.033	1.1	0.038
1980	1.5	0.030	1.6	0.036	1.4	0.049
1981	1.1	0.022	1.1	0.027	1.9	0.066
1982	0.7	0.014	0.7	0.016	1.7	0.059
1983	1.7	0.034	1.4	0.031	2.6	0.090

Water Balance

The solution of volume G_φ entering the groundwater flow could be defined by the relationship

$$G\varphi = \frac{k_F l_0}{2} \cdot \int_0^{\tau} \left. \frac{\partial h^2(x,\tau')}{\partial \tau'} \right|_{x=L/2} d\tau' \; . \tag{18}$$

For the flow towards south,

$$G\varphi_S = (k_F h_S)_S \left[l_0 \frac{H_K - H_M}{L_S} \tau_2 - \frac{4h_{i-1}\tau_2 l_0}{L_S\left(1 - \frac{4x_i^2}{L_1^2}\right)} \cdot \left(1 + \frac{L_S^2}{12\tau_d a_S}\right) - \right. \tag{19}$$
$$\left. - \frac{4h_{mi} l_0 (\tau_2 - \tau_1)}{L_S\left(1 - \frac{4x_i^2}{L_S^2}\right) e^{-\lambda_{CM}(\tau_2 - \tau_1)}} - \frac{4h_i(\tau_d - \tau_1)}{L_S\left(1 - \frac{4x_i^2}{L_S^2}\right)} \left(1 - \frac{L_S^2}{12\tau_d a_S}\right) \right],$$

where h_{i-1} = the elevation of groundwater level in x_i relative to the level $h_0(x_i)$ in winter of current year;

h_i = the same in autumn;

h_{mi} = the same in winter.

We can get a similar relationship for the north flow or we can use Equation (15).

Table 5. Solution Volume Entering the Groundwater from the Lake Well 202/64.

Year	h_1	h_{mi}	τ_1	$\tau_2 - \tau_1$	v_{eval} 10^3 m^3	v_{fact} 10^3 m3
1971	2.8	1.3	105	45	117	141
1972	2.2	1.6	105	65	130	117
1973	2.2	0.8	90	45	136	163
1974	1.4	1.2	90	60	177	116
1975	0.4	0.0	90	60	240	295
1976	0.0	0.4	90	45	230	255
1977	0.0	1.1	60	65	220	229
1978	1.0	1.4	90	90	186	178
1979	1.4	1.8	90	70	96	55
1980	1.5	1.4	90	50	122	98
1981	1.1	2.4	90	45	85	95
1982	0.7	0.7	90	75	137	191
1983	1.7	1.3	75	40	103	142

Surface run-off from the individual watershed is taken to be zero, because the lake water flow is intercepted by dams.

Summary

The evaluation performed shows a sufficiently good agreement between the calculated hydrogeologic parameters based on our approach and the experimental results obtained by various methods (see Table 5). A good correspondence between the calculated and the balance values of filtration losses from the lake verifies this conclusion also.

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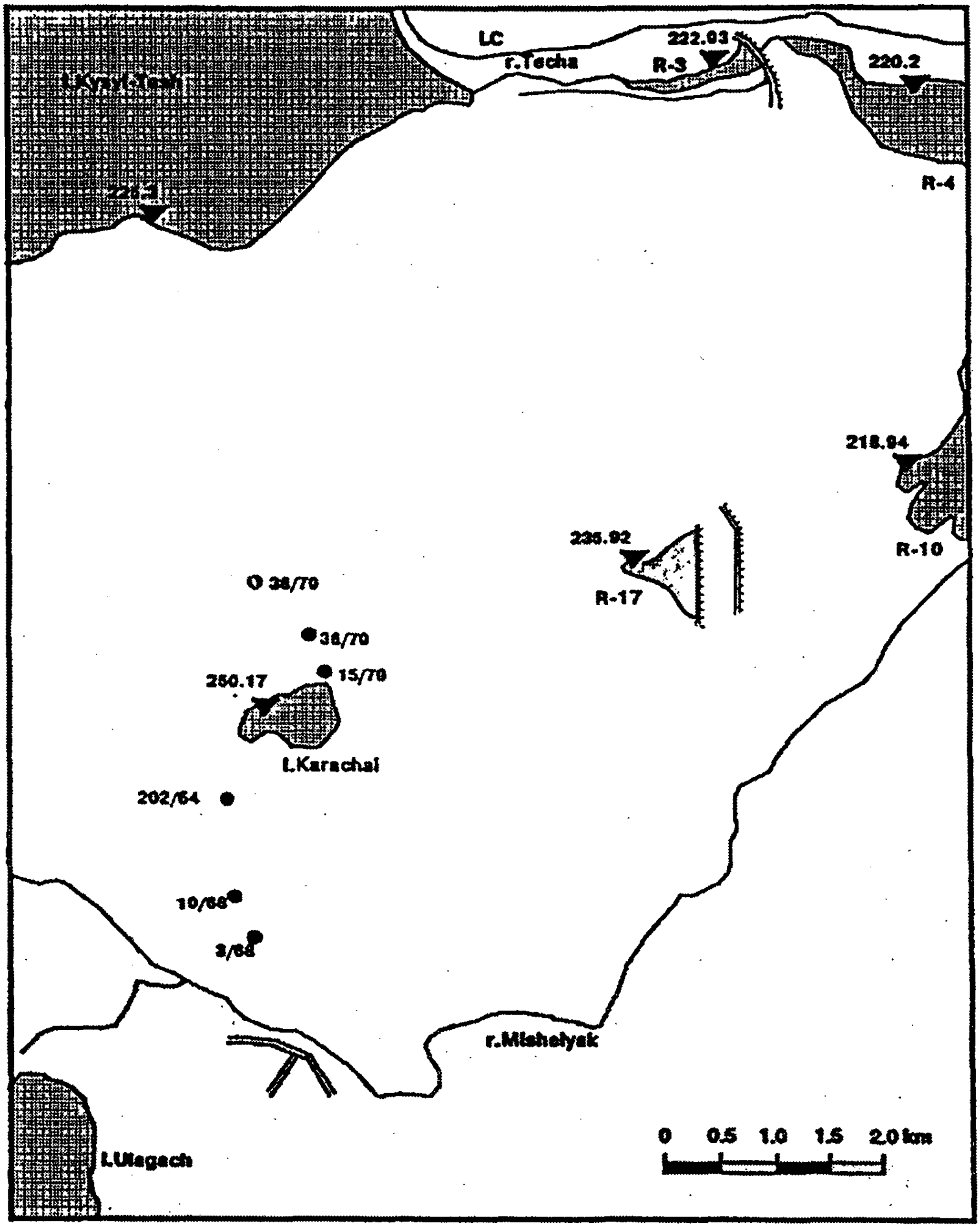

Figure 1. Scheme of investigation holes.

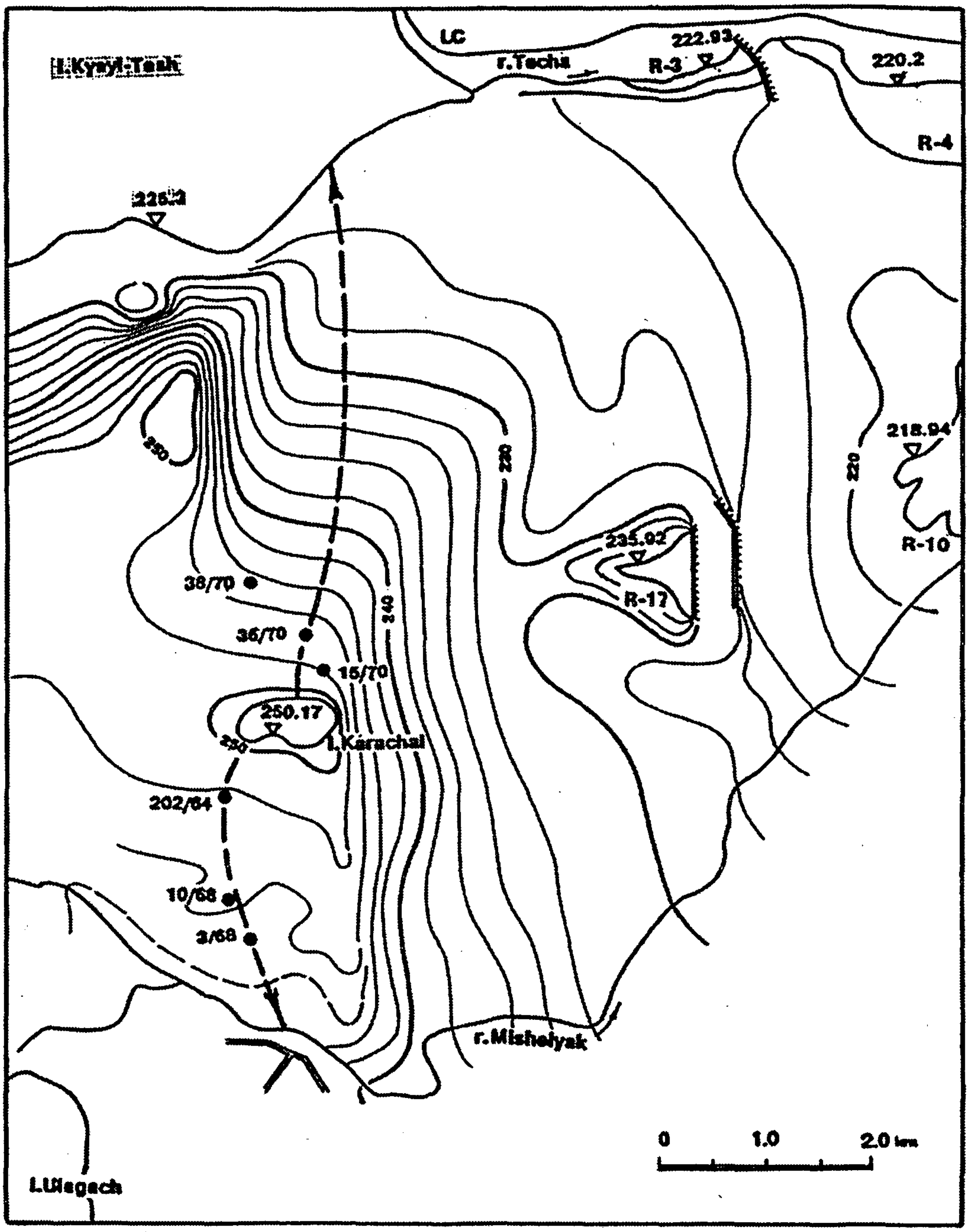

Figure 2. Hydrohypsographical curves of investigated area.

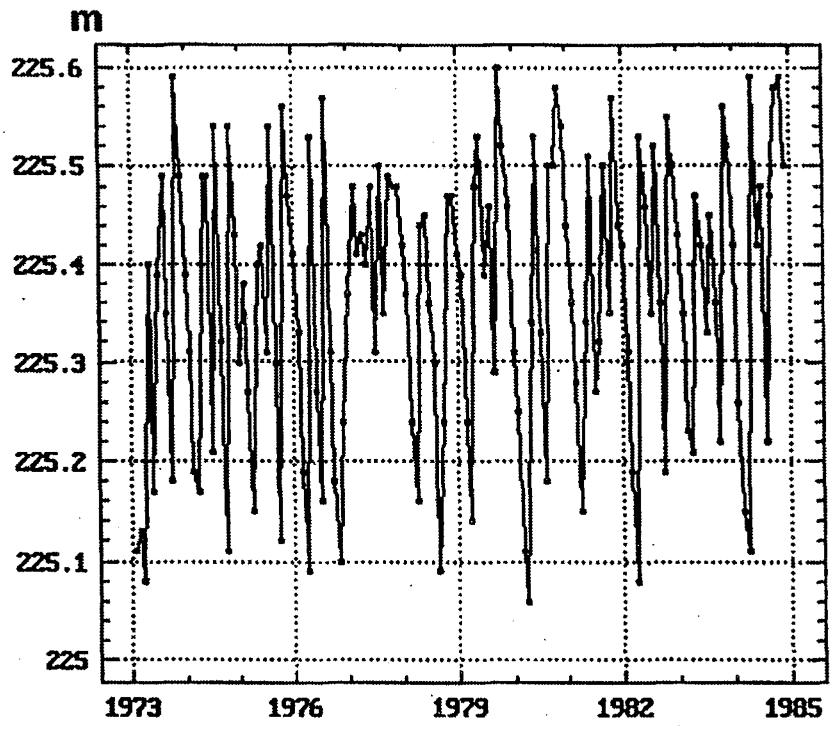

Figure 3. Water level at Lake Kyzyl-Tash (No. 2) in 1973–1985.

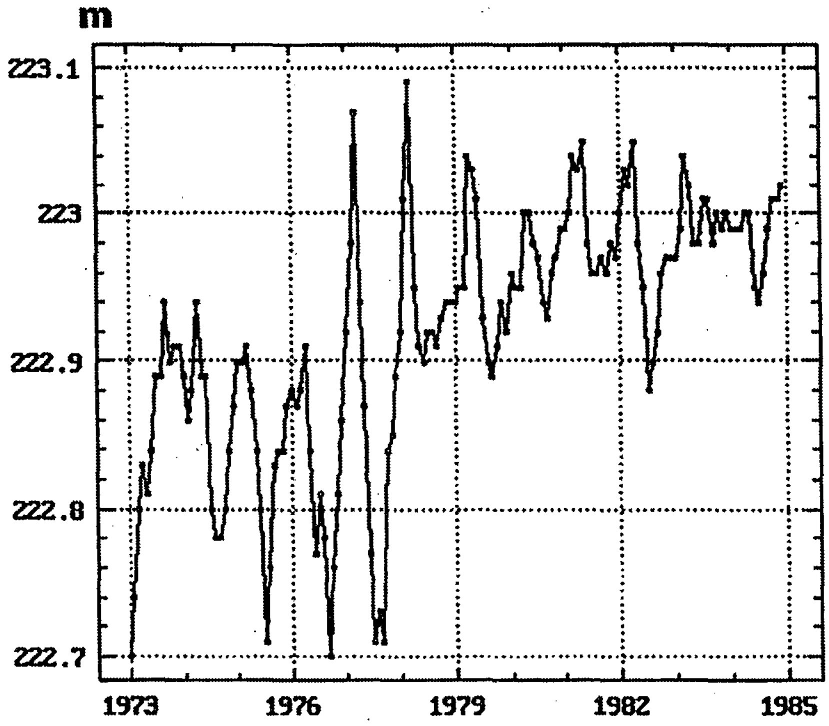

Figure 4. Water level in Lake No. 3 (r. Techa) in 1973–1985.

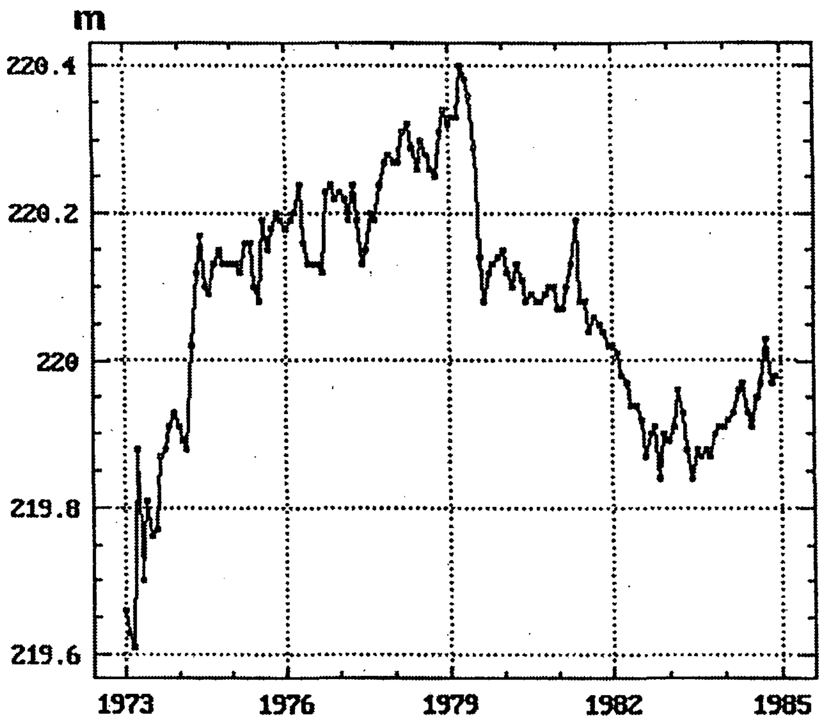

Figure 5. Water level in Lake No. 4 in 1973–1985.

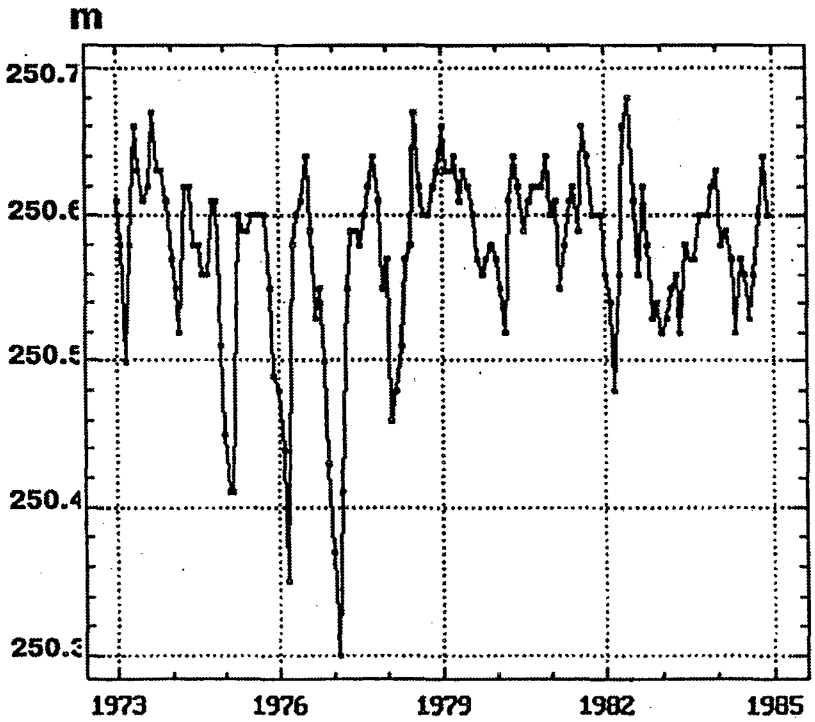

Figure 6. Water level in Lake Karachai in 1973–1985.

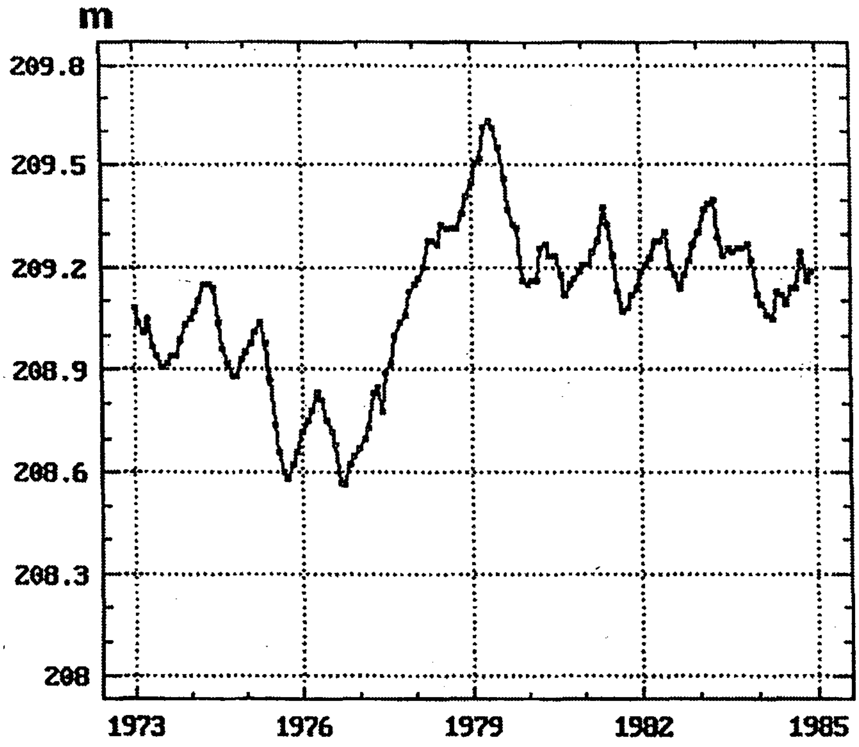

Figure 7. Water level in Lake No. 10 in 1973–1985.

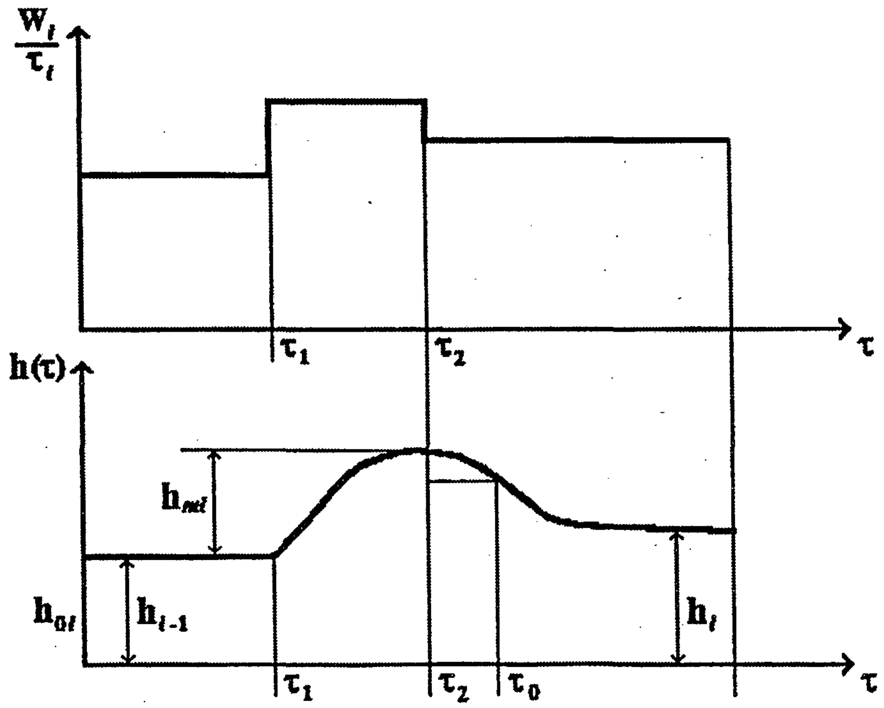

Figure 8. Scheme of infiltration feeding.

Figure 9. Precipitation in 1970 to 1984, mm.

	Snow						Rain						Sum through the year	
Year	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	X	snow	rain
70-71	24.6	10.2	8.5	28.6	41.5	6.4	25.4	39.4	149.8	81.1	22.2	68.5	113.4	392.8
71-72	19.6	43.1	14.7	5.3	18.3	20.1	39	116.9	126.2	31	35.3	33.2	101	401.7
72-73	43.4	11.6	22.4	6.6	14.6	16.2	20.6	56	58.4	76.1	87.2	12.8	98.6	327.3
73-74	23	21.4	13.5	15.6	10.7	26.5	35.9	58.1	23.8	64.9	27.6	21.1	84.2	257.9
74-75	18.3	2.5	9.7	13	18.9	16.3	23.9	24.8	15.7	25.5	7.3	24	62.4	137.5
75-76	8.9	27.8	48.2	8.4	1.6	13.4	13.5	26.7	96.5	54.5	13.4	29.5	94.9	247.5
76-77	30	4.1	8.5	28.2	15.3	70.2	72.8	15.9	32.5	45.4	22.4	49.3	86.1	308.5
77-78	14.2	45.9	11.5	15.7	4.4	38.6	45.8	64.1	155.4	46.4	34.3	34.1	91.7	418.7
78-79	25.5	39.9	28.4	30.2	4.6	33.5	29.7	100.7	103.1	56.7	29.6	37.1	128.6	514.4
79-80	19	11.8	12	5.7	24.3	39.4	32.4	50.9	72	57	49.8	57.3	72.8	358.8
80-81	18.8	27.5	4.9	12.4	38.9	11.2	101	61.4	30.5	32.3	54.4	17.2	102.5	308
81-82	22.1	17.1	28	5.5	11.8	16.7	64.1	88.1	54.8	45.3	48.7	60.7	84.5	378.4
82-83	3.6	20.4	19.7	34.9	12.6	31.8	34.6	64.5	133.1	115	62.6	11.6	91.2	443.2
83-84	17.2	37.5	11.3	3.8	3.2	6.5	70.2	64.6	62	64.3	76.7	68.7	73	413

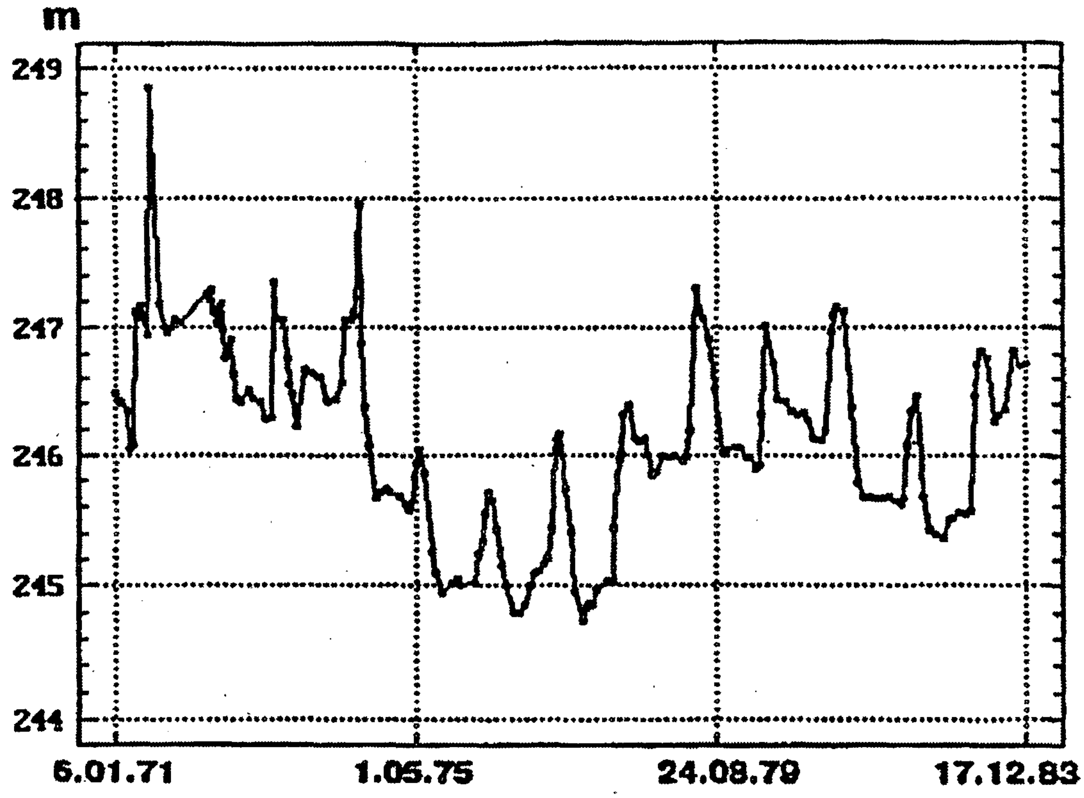

Figure 10. Water level in Well 3/68 in 1971–1983.

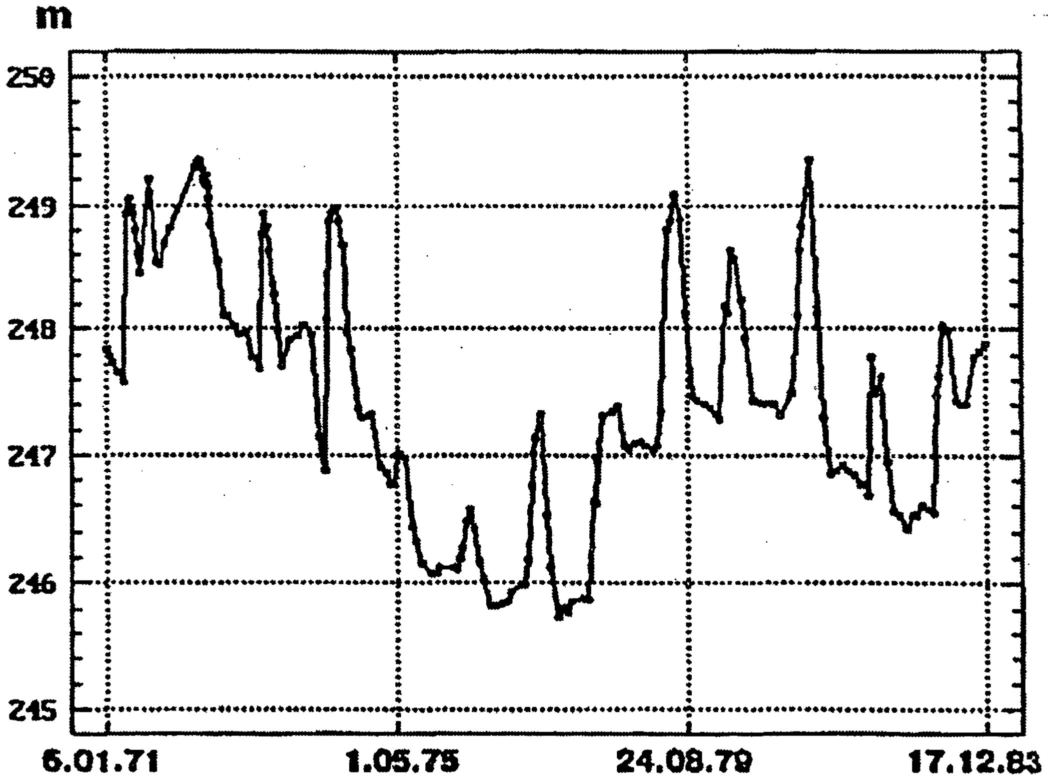

Figure 11. Water level in Well 10/68 in 1971–1983.

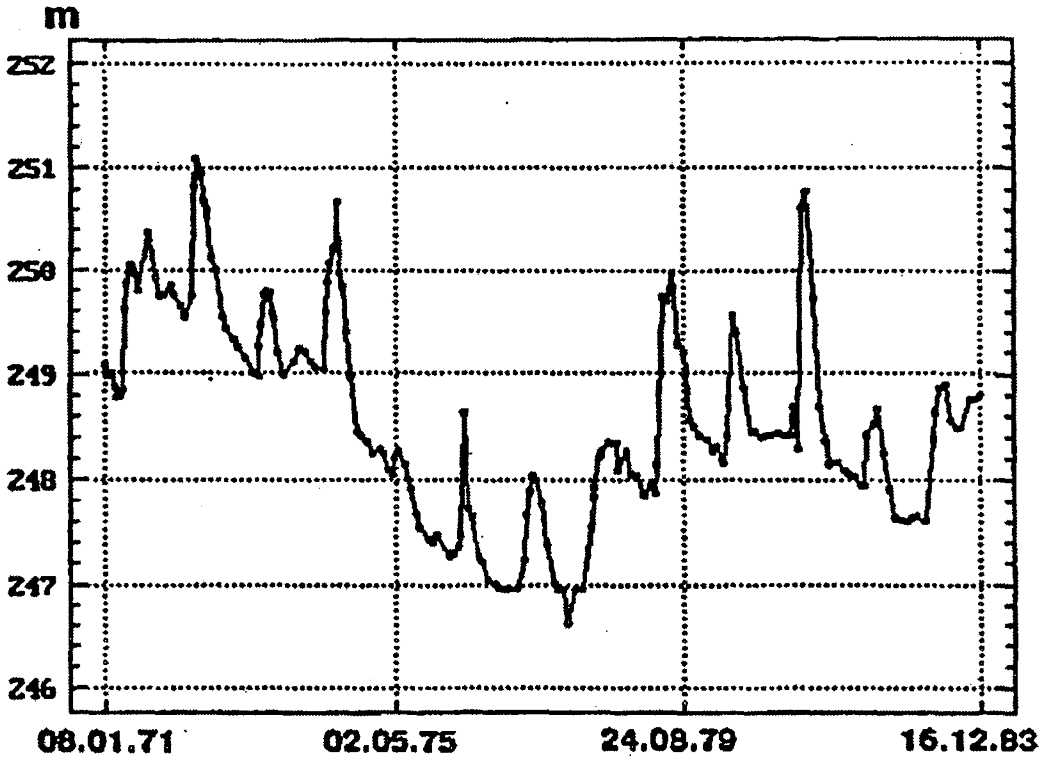

Figure 12. Water level in Well 202/68 in 1971–1983.

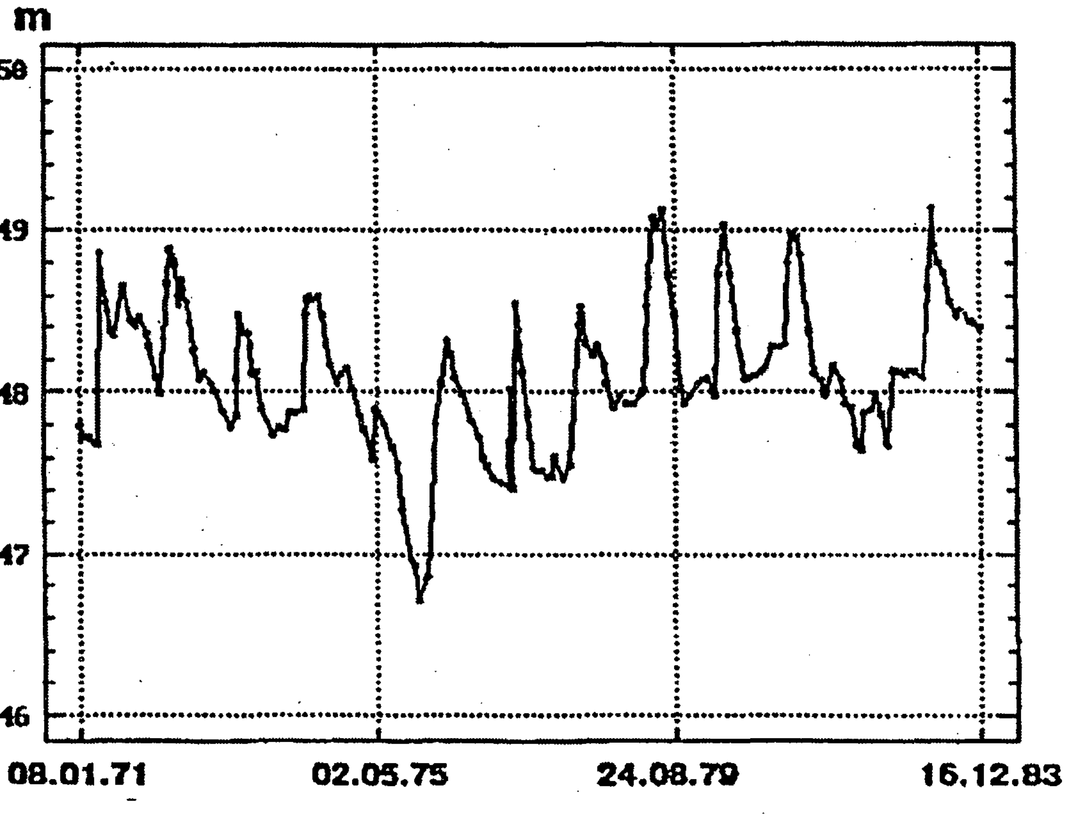

Figure 13. Water level in Well 36/70 in 1971–1983.

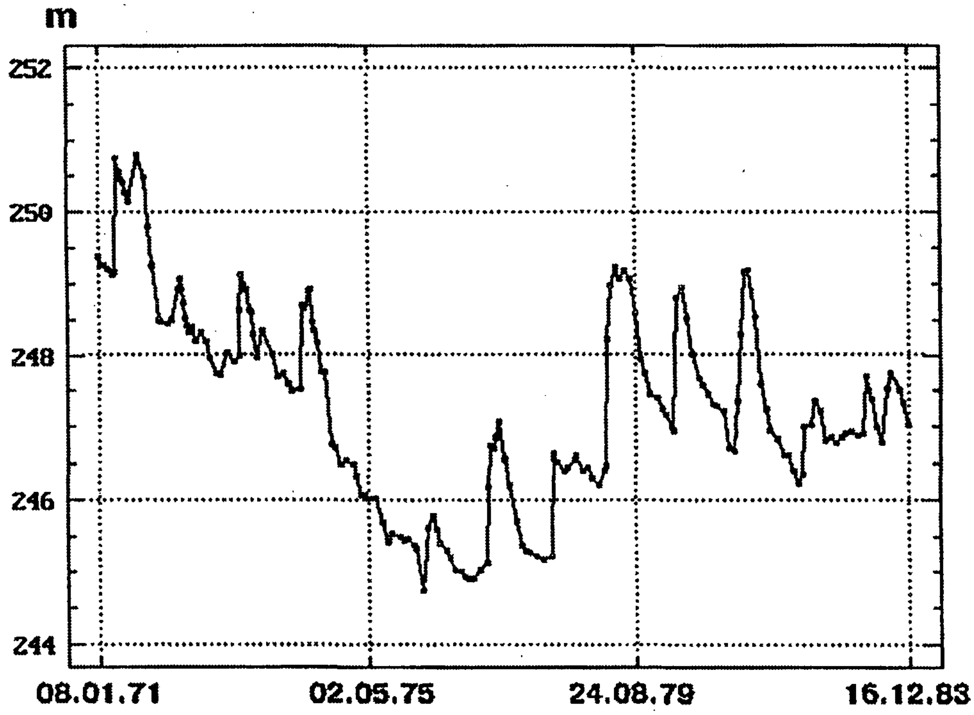

Figure 14. Water level in Well 38/70 in 1971–1983.

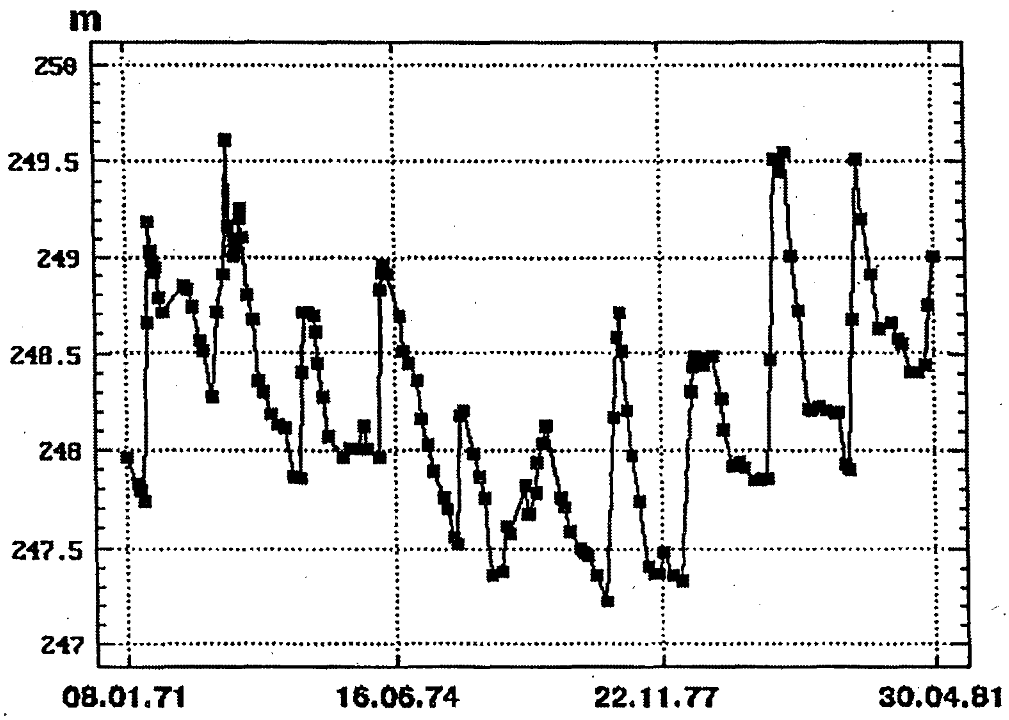

Figure 15. Water level in Well 15/70 in 1971–1983.

Figure 16. The distance from Lake Karachai to the holes.

No. of the well	From the shore line	From the center of the lake
202/64	700	950 South
10/68	1750	2000 South
3/68	2190	2440 South
15/70	350	600 North
36/70	550	800 North
38/70	1050	1300 North

Figure 17. Lake elevations of Lakes No. 2, 3, 4, 10. Water level in the lakes, absolute elevations, m.

Lakes (basin)	Maximal	Minimal	Middle (operational)
No. 2	225.6	225	225.4
No. 3	223.05	222.7	223
No. 4	220.4	219.9	220.2
No. 10	218.8	219.84	219.5

Hydrogeologic Parameters

	Water condactivity, m^2/day			Water capacity, parts		
№ of hole	by concurrent pump out	by isolated pump out	by injection	by indicator method	by balance method	infiltration, m/day
202/64	-	70	-			
10/68	-	-	94		0.0063-0.0101*	$2.1*10^{-4}$
3//68	-	-	220			
15/70	190	-	-	0.0020		
36/70	-	20	-		0.0064-0.01*	
38/70	-	5	3			

* The water capacity is determined for south and north flows of the Lake Karachai by balance method. In the whole - by distribution of nitrate ion in the underground water horizont

Figure 18.

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