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RELATIONSHIP BETWEEN QINGHAI LAKE LEVEL DESCENDING AND ARTIFICIAL WATER–CONSUMPTION

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ABSTRACT: Qinghai Lake is the largest inland lake in China. It is a closed–drainage saline lake located at 3194m above sea level in the northeastern Qinghai–Xizang (Tibet) Plateau. Qinghai Lake region, about 36°15′–38°20′ N and 97°50′–101°20′ E, is a closed basin surrounded by a few mountains. Drainage area is 29,661km^2. The area of lake body was 4304.5km^2 in 1986. The climate of this region belongs to the high–cold semiarid climate.

The human activities around Qinghai Lake from 1949 to 1987 and the change of the lake level from 1959 to 1987 and the change of the lake level from 1959 to 1987 are discussed in detail in this paper. The water–consumption processes by human activities around the lake are divided into four parts: Livelihood water–consumption (mean annual 868,576m^3), Stock–raising water–consumption (10,792,942m^3), Agricultural water–consumption (26,696,964m^3) and Industrial water consumption (117,421m^3). By comparing and analyzing, the artificial water–consumption just takes about 1%–2% of the total consumption in this region. There is no significant correlation between Qinghai Lake level descending and water–consumption by human activities around the lake. The result of this project clearly suggested that the descending of Qinghai Lake level was mainly caused by the climatic change in this region, not by the human activities around the lake.

KEY WORDS: Qinghai–Xizang Plateau (QXP), human activities, lake level change, climatic change

The lake played important roles in the early development of human. In recent 50–100 years, population increasing and technical development have led to a remarkable influence on lake systems and obviously aggravated the change of water resources[1–2]. In arid regions, human activities have become one of the most important reasons that caused the descending, even dryness, of lake level[3-5]. Qinghai Lake is the largest inland saline lake in China. It is a plateau lake that is paid attention to in worldwide. Qinghai Lake level recently showed a descending trend. According to the measure of Hydrological Station of Qinghai Province (HSQP), Qinghai Lake level descended 2.96m from 1959 to 1988, at a mean decreasing speed of 10.2cm one year. This project will study and analyze the relationship between the lake level descending and the artificial water–consumption on the basis of systematically investigating human activities around Qinghai Lake and water–consumption by these activities.

I. GENERAL SITUATION OF STUDIED REGION

The studied region in this project includes the whole drainage of Qinghai Lake (Fig.1). It is located in the northeastern Qinghai drainage area is 29,661km^2. The lake area was 4304.5km^2 in 1986. This region is a closed basin surrounded by a few mountains

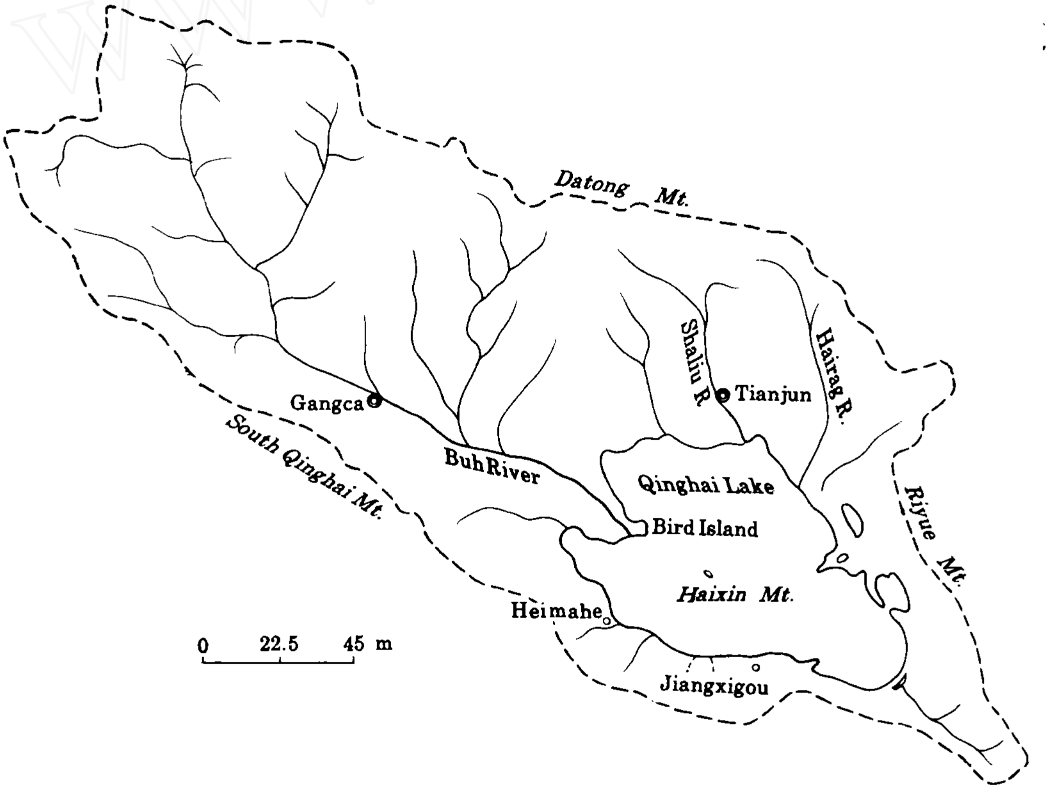

Fig.1 Diagram of Qinghai Lake basin

(Datong Mountain, Riyue Mountain and South Qinghai Mountain) with altitude of about 3194m to 5000m above sea level. There are more than 40 rivers in this region. The larger rivers include Buh River, Shaliu River, Hairag River, Uharlan River and Heima River. The climate belongs to the high–cold semiarid climate. The mean annual temperature is from −1.3℃ (in Tianjun) to 0.5℃ (in Jiangxigou). The mean annual precipitation is from 323.8mm (in Tianjun) to 384.6mm (in Jiangxigou). The mean annual evaporation is from 1378.7mm (in Jiangxigou) to 1767.4mm (in Tianjun).

Qinghai Lake is a new tectonic subside lake[6]. Its formation and development mainly happened in the Middle Pleistocene[7]. The reason why Qinghai Lake was taken sharp is relative sinking of the tectonic lake lowland and gradual rising of surrounding mountains. During the intensely rising processes of Qinghai–Xizang Plateau, Qinghai Lake region also showed the whole strongly intermittent rising. As one part of the Qinghai–Xizang Plateau, Qinghai Lake region is relatively similar to the plateau in the change trend of habitats.

II. HUMAN ACTIVITIES AND THEIR WATER CONSUMPTION IN THIS REGION

The water–consumption processes by human activities are very complicated and influenced by a lot of factors. In this paper, the water–consumed ways are divided into four parts in order to discuss and analyze conveniently. The situation about human activities related to the water–consumption was obtained on the basis of statistical data and relative materials (Table 1). The water–consumed criteria of the different ways were decided on the basis of relative materials and field investigation. The ways and criteria of different water–consumption by human activities are included as follows.

(1) Livelihood water–consumption: It is the consumption by daily life of the residents. The value of livelihood consumption is decided by the sum of population. Mean criterion of this consumption is 40 liters every person per day.

(2) Stock–raising water–consumption: It is the consumption by livestock husbandry and depends on the total of livestock in this region. The criterion is 15 liters every livestock per day.

(3) Agricultural water–consumption: It is the consumption by agricultural irrigation and depends on the irrigated area of farmland. According to the parameters provided by Station of Environmental Hydrography and Geology of Qinghai Province (SEHGQP), the criterion of agricultural consumption was calculated as follows.

Table 1 The statistics of human activities around Qinghai Lake

Year	Population (person)	Number of livestock (head)	Farmland Area (ha)		Total output of industry (10^4 Yuan)
			Total	Irrigation	
1987	90458	2478869	22421	10921	1078.60
1986	87710	2463242	22192	15165	992.29
1985	87145	2439127	21205	11161	640.00
1984	85645	2456100	21262	11334	509.95
1983	82614	2369189	22656	11349	519.80
1982	82484	2454160	22778	11625	448.00
1981	81764	2479099	23045	11724	354.65
1980	81431	2376169	24051	12228	199.30
1979	80957	2307133	23392	11820	174.06
1978	79780	2496198	23564	12264	171.65
1977	77360	2354408	22250	10225	210.69
1976	74621	2288675	22051	10098	166.46
1975	72108	2161257	21993	9733	107.78
1974	69883	2272134	22033	9578	95.52
1973	68288	2283456	23176	8776	103.52
1972	66958	2157064	26568	8833	75.15
1971	64775	2160017	23456	10474	54.79
1970	61851	2021295	23279	15748	39.64
1969	62309	2233954	23576	15159	37.71
1968	60772	2293384	23228	15071	32.77
1967	59972	2294860	23538	16683	32.32
1966	58117	2230279	23753	15456	22.39
1965	56775	2098542	23296	15683	23.62
1964	56057	1932202	23384	15183	21.29
1963	54771	1775858	23232	14485	19.37
1962	53954	1600643	23893	16597	22.95
1961	54688	1412168	35516	23120	76.16
1960	54426	1431468	48959	34658	392.09
1959	47803	1371321	22887	9509	555.33
1958	40328	1457387	8036	1639	99.41
1957	36732	1883268	1428	360	2.86
1956	34949	1792943	1423	355	
1955	33100	1727301	1375	329	
1954	31084	1601802	1320	313	
1953	29199	1401531	1272	303	
1952	27402	1256524	1228	253	
1951	25571	1140166	1209	246	
1950	23771	1005621	1183	236	
1949	21971	921438	1136	228	

$$Q_{ic} = Q_{gi} - Q_{cr} - Q_{fr} = Q_{gi} - [Q_{gi} \cdot (1 - n_1) \cdot n_2] - [Q_{gi} \cdot n_1 \cdot n_3]$$
$$= 2614.5 \mathrm{m}^3 / \mathrm{ha}$$

Where, Q_{ic} is actual water–consumption by agriculture irrigation; Q_{gi} is irrigated amount per hectare farmland ($=4500\mathrm{m}^3$); Q_{cr} is mean return amount of water from irrigation canal system; Q_{fr} is the mean return amount from farmland. n_1($=0.4$) is effective utilization coefficient of the canal system; n_2 ($=0.565$) is the return coefficient of permeated water from the canal system; n_3($=0.2$) is the return coefficient from the farmland.

(4) Industrial water–consumption: It is the consumption in the processes of industrial production. Its mean criterion is $500\mathrm{m}^3$ every ten thousand gross value of industrial output.

On the basis of discussion above, the water–consumption from 1949 to 1987 by human activities in this region was calculated and listed in Table 2. The mean water–consumed value by human activities is about $0.38 \times 10^8 \mathrm{m}^3$. The consumptions both by irrigation and stock–raising take the higher ratio (more than 97.44% of the total water–consumption). Before 1958, the stock–raising consumption took a dominant position (about 85% of the total consumption). After 1958, the agricultural consumption has took the dominant position (about 65–85%). So agricultural irrigation and stock–raising are the main water–consumed ways by human activities around Qinghai Lake.

III. RELATIONSHIP BETWEEN THE LAKE LEVEL DESCENDING AND THE ARTIFICIAL WATER–CONSUMPTION IN THIS REGION

Both change curves of the lake surface altitude and the artificial water–consumption are drawn in Fig.2 on the basis of data from Table 3. It is very clear that (1) the lake level showed a tendency of gradual descending with fluctuation; and (2) the water consumption basically kept stable in spite that there was an obvious higher value about in 1960. In theory, if artificial water–consumption by human activities had a significant influence on the change of lake level, there would be a remarkable negative linear correlation between them. That is, the lake level would trend to decrease when the consumption increases; on the contrary, the lake level would increase with decrease of the consumption. In this region, however, there is no obvious descent of lake level in some years when the artificial water–consumption was higher; and no increase when lower. It could be inferred from this fact that the water–consumption by human activities around Qinghai Lake would not significantly influence the descending or ascending of Qinghai Lake level, and there is no significant correlation between them.

Table 2 Water-consumption by human activities around Qinghai Lake (Unit: m^3)

Year	Livelihood		Stock-raising		Agriculture		Industry		Total
	Volume	%	Volume	%	Volume	%	Volume	%	
1987	1320687	3.00	13571808	30.85	28552955	64.92	0	1.23	18984750
1986	1280566	2.33	13486250	24.56	39648893	72.21	496145	0.90	54911854
1985	1272317	2.88	13354220	30.26	29180435	66.13	320000	0.73	44126972
1984	1250417	2.81	13447148	30.16	29632743	66.46	254975	1.57	44585283
1983	1206164	2.73	12971310	29.41	29671961	67.27	259900	0.59	44109335
1982	1204266	2.66	13436526	29.69	30393563	67.16	224000	0.49	45258355
1981	1193754	2.62	16573067	29.77	30652398	67.22	177325	0.39	45596544
1980	1188893	2.57	13009525	28.12	31970106	69.10	99650	0.21	46268174
1979	1181972	2.64	12631553	28.19	30903390	68.98	87030	0.19	44803945
1978	1164788	2.48	13666684	29.09	32064228	68.25	85825	0.18	46981525
1977	1129456	2.76	12890384	31.55	26733263	65.43	105345	0.26	40858448
1976	1189467	2.72	12530496	31.24	26401221	65.83	83230	0.21	40104414
1975	1052777	2.74	11832882	30.83	25446929	66.29	53890	0.14	38386478
1974	1020292	2.65	12439934	32.27	25041681	64.96	47760	0.12	38549667
1973	997005	2.73	12501922	34.26	22944852	62.87	51760	0.14	36495539
1972	977587	2.72	11809925	32.88	23093879	64.30	37575	0.10	35918966
1971	945715	2.35	11826093	29.43	27384273	68.15	27395	0.07	40183476
1970	903025	1.70	11066590	20.80	41173146	77.45	19820	0.04	53162581
1969	909711	1.72	12230898	23.17	39633206	75.07	18855	0.04	52792670
1968	887271	1.68	12561555	23.76	39403130	74.53	16385	0.03	52868341
1967	875591	1.53	12564359	22.02	43617704	76.42	16160	0.03	57073814
1966	848508	1.59	12210778	22.83	40409712	75.56	11195	0.02	53480193
1965	828915	1.56	11489517	21.54	41003204	76.88	11810	0.02	53333446
1964	818432	1.66	10578806	20.70	39695954	77.68	10654	0.02	51103837
1963	798781	1.65	9722823	20.09	37871033	78.24	9685	0.02	48402322
1962	787728	1.49	8763520	16.55	43392857	81.94	11475	0.02	52955580
1961	798445	1.16	7731620	11.20	60447240	87.59	38080	0.05	69015385
1960	794620	0.80	7837386	7.88	90613341	91.12	196045	0.20	99441392
1959	697924	2.09	5707982	22.52	24861281	74.56	277665	0.83	33344852
1958	588789	4.56	7979194	61.84	4285166	33.21	49705	0.39	12902854
1957	536287	4.55	10310892	87.46	941220	7.98	1430	0.01	11789829
1956	509817	4.53	9816363	87.22	928148	8.25			11254328
1955	483260	4.48	9456973	87.56	860171	7.96			10800404
1954	453826	4.52	8769866	87.33	818339	8.15			10042031
1953	426305	4.79	7673382	56.30	792194	8.91			8891881
1952	400069	5.04	6879469	86.63	661469	8.33			7941007
1951	373337	5.14	6242409	86.00	643167	8.86			7258913
1950	347057	5.36	5505775	85.10	617022	9.54			6469854
1949	320777	5.38	5044873	84.62	596106	10.00			5961756
Mean	868576	2.26	10792942	28.05	26696964	69.39	117421	0.31	38475903

Table 3 The water consumption by human activities around Qinghai Lake and profit/ loss volume of water in the lake (Unit: $10^8 m^3$)

Year	Profit or loss of water	Alt. of lake (m)	Human consumption		Agri. consumption	
			Total	%	Total	%
1959		3196.55	0.33		0.25	
1960	−10.39	3196.31	0.99	9.53	0.91	8.76
1961	−10.84	3196.07	0.69	6.37	0.60	5.54
1962	−7.68	3195.90	0.53	6.90	0.43	5.60
1963	−6.77	3195.75	0.48	7.09	0.38	5.61
1964	−0.45	3195.74	0.51	113.33	0.40	88.89
1965	−1.36	3195.71	0.53	38.97	0.41	30.15
1966	−7.68	3195.54	0.53	6.90	0.40	5.21
1967	8.13	3195.72	0.57		0.44	
1968	14.46	3196.04	0.53		0.39	
1969	−8.58	3195.85	0.53	6.18A	0.40	4.66
1970	−11.75	3195.59	0.53	4.51	0.41	3.49
1971	−6.73	3195.44	0.40	5.94	0.27	4.01
1972	1.31	3195.47	0.36		0.23	
1973	−9.19	3195.26	0.36	3.92	0.23	2.50
1974	−11.38	3195.00	0.39	3.43	0.25	2.20
1975	0.0	3195.00	0.38		0.25	
1976	1.75	3195.04	0.40		0.26	
1977	−6.13	3194.90	0.41	6.69	0.27	4.40
1978	−4.82	3194.79	0.47	9.75	0.32	6.64
1979	−14.44	3194.47	0.45	3.12	0.31	2.15
1980	−14.89	3194.13	0.46	3.09	0.32	2.15
1981	−9.19	3193.92	0.46	5.01	0.31	3.37
1982	0.87	3193.94	0.45		0.30	
1983	3.94	3194.03	0.44		0.30	
1984	0.44	3194.04	0.45		0.30	
1985	−9.63	3193.82	0.44	4.57	0.29	3.01
1986	−1.75	3193.78	0.55	31.43	0.40	22.86
1987	−3.27	3193.70	0.44	13.46	0.29	8.87
1988	−4.49	3193.59				

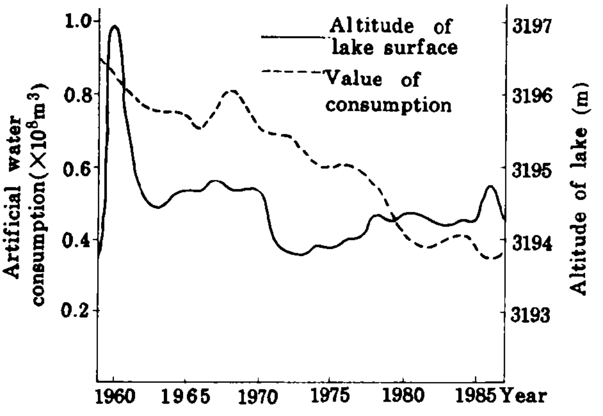

Fig.2 The elevation of Qinghai Lake level and artificial water consumption around Qinghai Lake from 1959 to 1987

In order to prove the deduction above, the correlative coefficient was calculated between the profit/ loss volume of lake water and the total artificial water–consumption ($r=-0.1202$). This result indicates that there is no significant correlativity between them. Agricultural water–consumption is one of the most important factors that caused lake level descending in arid region. It also takes a higher ratio of the water–consumption in Qinghai Lake region. The correlative coefficient also was calculated between the profit/ loss volume of lake water and the agricultural consumption ($r=-0.1402$). This similarly indicates that there is no significant correlativity between them. Thus, it can be found that there is no internal direct connection between descending or ascending of lake level and the water–consumption by human activities in this region.

The profit/ loss values of lake water from 1959 to 1988 (29 years) were listed in Table 3, including 20 water–deficient years, 8 water–surplus years and 1 water–balance year. In spite that the water was consumed every year by human activities, but there is no deficit of water in about 1/ 3 statistical years. Although the values of artificial water–consumption were identical in 1968 and 1969, the lake water increased $14.46\times10^8m^3$ in 1968 and decreased $8.58\times10^8m^3$ in 1969 respectively. There were higher values of the water–consumption in 1967 and 1968, but the lake water respectively increased $8.13\times10^8m^3$ and $14.46\times10^8m^3$. In 1973, the value of water–consumption was the lowest, but the lake water decreased $9.19\times10^8m^3$. These facts indicate that the change of lake water value will not be decided by whether th is artificial water–consumption or not, and how much water will be consumed by human activities around the lake.

According to the calculation, the water–consumption by human activities just takes a low ratio in the total water–consumption (about 1%–2%, mean 1.16%) (Table 4). In

Table 4 The statistics of water consumption in Qinghai Lake region (Unit: $10^8 m^3$)

Year	Total water consumption	Lake surface evaporation		Artificial water consumption			
		Volume	%	Volume	%	Agriculture Volume	Agriculture %
1988	38.75	35.96					
1987	38.44	35.65	92.74	0.44	1.14	0.29	0.75
1986	38.41	35.51	92.45	0.55	1.43	0.40	1.04
1985	36.76	33.97	92.41	0.44	1.20	0.29	0.79
1984	39.45	36.65	92.90	0.45	1.14	0.30	0.76
1983	35.30	32.51	92.10	0.44	1.25	0.60	0.85
1982	38.52	35.72	92.73	0.45	1.17	0.60	0.79
1981	41.94	39.13	93.30	0.46	1.10	0.31	0.79
1980	44.14	41.33	93.63	0.46	1.04	0.32	0.72
1979	45.01	42.21	93.78	0.45	1.00	0.31	0.69
1978	39.95	37.13	92.94	0.47	1.18	0.32	0.80
1977	34.95	32.19	92.10	0.41	1.17	0.27	0.77
1976	41.07	38.32	93.30	0.40	0.97	0.26	0.63
1975	39.65	36.92	93.11	0.38	0.96	0.25	0.63
1974	41.00	38.26	93.32	0.39	0.95	0.25	0.61
1973	45.51	42.80	94.05	0.36	0.79	0.23	0.51
1972	44.13	41.42	93.86	0.36	0.82	0.23	0.52
1971	44.97	42.22	93.88	0.40	0.89	0.27	0.60
1970	44.80	41.92	93.57	0.53	1.18	0.41	0.92
1969	47.47	44.59	93.93	0.53	1.12	0.40	0.84
1968	40.96	38.08	92.97	0.53	1.29	0.39	0.95
1967	38.00	35.08	92.32	0.57	1.50	0.44	1.16
1966	43.57	40.69	93.39	0.53	1.22	0.40	0.92
1965	41.66	38.78	93.09	0.53	1.27	0.41	0.98
1964	40.09	37.23	92.87	0.51	1.27	0.40	1.00
1963	44.80	41.97	93.68	0.48	1.07	0.38	0.85
1962	42.66	39.78	93.25	0.53	1.24	0.43	1.01
1961	42.93	39.89	92.92	0.69	1.61	0.60	1.40
1960	43.25	39.91	92.28	0.99	2.29	0.91	2.10
1959	43.38	40.70	92.82	0.33	0.76	0.25	0.58

the water–deficient years, the ratio of artificial consumption was less than 10% of the total water–deficient value. Such a little ratio will have no significant effect on the ascending or descending of Qinghai Lake level.

On the basis of discussion above, it is suggested that the water–consumption by human activities in Qinghai Lake region is not a leading and dominative factor for the lake level descending. So human activities could not be considered as a primary reason why Qinghai Lake level continues to decrease.

IV. PRELIMINARY ANALYSIS OF THE REASON OF QINGHAI LAKE LEVEL DESCENDING

In the Middle of Asia, majority of lakes are in a serious shrinking state; the shrinkage of lake in plane area is caused mainly by artificial factors (for example, irrigation), but in alpine area mainly by natural factors (for example, climatic change)[8]. As an inland lake, the ascent or descent of Qinghai Lake level is mainly decided by the revenue and expenditure situation of lake water. When the supply of water is more than the expenditure, lake level will show increasing. Conversely, the lake level decreasing. According to the discussion in last paragraph above, it is clear that the human activities are not the main reason of Qinghai Lake level descending. It could be found from Table 4 that the evaporation water–consumption from lake surface takes more than 92% of the total consumption. In Qinghai Lake region, the evaporation is much more, about 2.5–3 times that of the precipitation[9]. According to the calculation by HSQP, the mean annual surface evaporation of Qinghai Lake is $38.64 \times 10^8 m^3$, the mean annual surface precipitation is only $16.29 \times 10^8 m^3$ (Table 5); the evaporation is 2–3 times that of the precipitation, mean 2.37 times. This situation will undoubtedly lead to continue decreasing of the lake level obviously. The intense evaporation of lake surface have significant influence on the decreasing of the lake level.

With the strong lift of the Qinglhai–Xizang Plateau, the plateau habitats trend to drier and cooler. As one part of the Qinghai–Xizang Plateau, the habitats of this region also show the same change tendency. The results from the research on water body environment[10], lake sediment[11–12], and palynological analysis[13–14] indicate that palaeoclimate of Qinghai Lake region showed the characteristics tending to be drier and cooler with fluctuation. This climatic change certainly will cause increase of the evaporation and decrease of the precipitation. According to the research of SEHGQP and HSQP, the difference between mean water consumption and water supply is about $4.5 \times 10^8 m^3$ one year. The remarkable reduction of marsh area in this region also provides another evidence that the climate around Qinghai Lake tend to be driver[15].

Table 5 The surface evaporation (Ev) and precipitation (Pr) in Qinghai Lake (Unit: $10^8 m^3$)

Year	Evaporation	Precipitation	$Ev-Pr$	Ev/Pr
1959	40.70	17.46	23.24	2.33
1960	39.91	14.15	25.76	2.82
1961	39.89	16.56	23.33	2.41
1962	39.78	12.46	27.32	3.19
1963	41.97	14.66	27.31	2.86
1964	37.23	16.67	20.56	2.23
1965	38.78	18.42	20.36	2.11
1966	40.69	18.02	22.57	2.26
1967	35.08	25.07	10.01	1.40
1968	38.08	13.60	24.48	2.80
1969	44.59	15.26	29.33	2.92
1970	41.92	14.78	27.14	2.84C
1971	42.22	17.67	24.55	2.39C
1972	41.42	15.13	26.29	2.74
1973	472.80	12.41	30.39	3.45
1974	38.26	16.51	21.75	2.32
1975	36.92	17.22	19.70	2.14
1976	38.32	17.54	20.78	2.18
1977	32.19	14.00	18.19	2.30
1978	37.13	15.84	21.29	2.34
1979	42.21	14.03	28.18	3.01
1980	41.33	13.33	28.00	3.10
1981	39.13	19.14	19.99	2.04
1982	35.72	16.39	19.33	2.18
1983	32.51	17.49	15.02	1.86
1984	36.65	14.81	21.84	2.47
1985	33.97	19.33	14.64	1.76
1986	35.51	17.36	18.15	2.05
1987	35.65	17.56	18.09	2.03
Average	38.64	16.31	22.33	2.37

All of these facts obviously suggest that the main reason why Qinghai Lake level continues to descending is due to the climatic change, not human activities around Qinghai Lake. Because of drier and cooler climate, deficient volume of lake water is larger than the supply, Qinghai Lake level shows a trend of descending. The change of climate to be driver and cooler resulted from the strong lift of Qinghai–Xizang Plateau and Himalayas Mountains in the Quaternary Period[16].

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