СЕКЦИЯ 2
ВОДОХОЗЯЙСТВЕННОЕ СТРОИТЕЛЬСТВО,
ТЕПЛОГАЗОСНАБЖЕНИЕ И ЭКОЛОГИЯ

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A DYNAMIC-STOCHASTIC APPROACH TO THE DETERMINATION OF THE OPTIMUM LEVEL FOR RESERVOIR FILLING

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Abstract

Possessing certain information and knowledge about the current hydrological state of a water body, it is possible to foresee the future state of the studied object and its main characteristics. On their basis it is possible to estimate the peculiarities of the given period and to carry out corresponding to these conditions the development of effective regimes of functioning of hydraulic structures with advance or mitigation of the onset of hydrological threats and risks.

The condition for optimal functioning of natural ecosystems is a close relationship between fluctuations in water levels and river and sea runoff - this is the specificity of the study of water bodies in the Aral Sea region.

The proposed work evaluates the reconstruction options for the Northern (Small) Aral Sea. To determine the quantitative characteristics of the parameters of the object under study (Northern Aral Sea - Saryshyganak Bay), the balance method was used by means of sequential solution of balance equations that allow indirectly assessing its dynamics, hydrological state and analysing the interrelationships of various components of the moisture balance.

Based on the dynamic-stochastic approach in solving the problems of determining the optimal level of filling of the retaining hydraulic structure, where in the balance calculations a temporary hydrological series ($n > 35$) made up of annual river inflow volumes by the method of statistical modelling (Monte Carlo method) is used, it can be concluded that out of two variants of the complex of considered engineering structures in the water area of the Northern Aral Sea, the most preferable is the variant of reconstruction of the NAS with the mark of the normal retaining level. The two-level variant of the reconstruction corresponds to the optimal parameters of the structure with a short period of filling of the bay 6–7 years, less water losses-up to 3,0 km^3 and moderate the system water exchange processes.

Keywords: Aral Sea, water balance, dynamic-stochastic approach, hydraulic structure, reconstruction, reservoir.

ДИНАМИКО-СТОХАСТИЧЕСКИЙ ПОДХОД К ОПРЕДЕЛЕНИЮ ОПТИМАЛЬНОГО УРОВНЯ ЗАПОЛНЕНИЯ ВОДОХРАНИЛИЩА

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Реферат

Обладая определенными сведениями и знаниями о текущем гидрологическом состоянии водного объекта, можно предвидеть будущее состояние изучаемого объекта и его основные характеристики. На их основе можно оценить особенности данного периода и провести соответствующую этим условиям разработку эффективных режимов функционирования гидротехнических сооружений с опережением или смягчением наступления гидрологических угроз и рисков.

Условием оптимального функционирования природных экосистем является тесная взаимосвязь колебания уровней воды и стока реки и моря – в этом заключается специфичность исследования водных объектов рассматриваемого региона.

В предлагаемой работе проведена оценка вариантов реконструкции Северного (Малого) Аральского моря (САМ). Для определения количественной характеристики параметров исследуемого объекта (Северное Аральское море – залив Сарышыганак) использован балансовый метод последовательного решения балансовых уравнений, позволяющих косвенным путем оценить его динамику, гидрологическое состояние и проанализировать взаимосвязи различных компонентов баланса влаги.

На основе динамико-стохастического подхода в решениях задач по определению оптимального уровня наполнения подпорного гидротехнического сооружения, где в балансовых расчетах использован временной гидрологический ряд ($n > 35$), составленный из годовых объемов речного притока методом статистического моделирования (метод Монте-Карло), можно заключить, что из двух вариантов комплекса рассматриваемых инженерных сооружений в акватории Северного Аральского моря наиболее предпочтительным является вариант реконструкции САМ с отметкой нормального подпорного горизонта (НПГ) – 50,00 м абс. Двухуровневый вариант реконструкции САМ соответствует оптимальным параметрам сооружения с коротким по времени периодом наполнения чаши залива – 6–7 лет, меньшими потерями воды – до 3,0 км^3 и умеренными водообменными процессами системы.

Ключевые слова: Аральское море, водный баланс, динамико-стохастический подход, гидротехническое сооружение, реконструкция, залив Сарышыганак.

Introduction

The crisis of the Aral Sea region is typical and characteristic of many drainless basins of arid zones, which are highly sensitive to climate change and anthropogenic impact and, at the same time, are extremely vulnerable elements of the aquatic ecosystem [1]. Ignoring these principles in the previous development stages led to severe environmental consequences in the region.

The ‘Basic Provisions of the Concept for Improving Socio-Economic and Environmental Condition in the Aral Sea Region’ approved by the Heads of the five

Central Asian countries substantiates the preservation of the Aral Sea region by creating a new sustainable natural and anthropogenic complex on its territory.

Within the framework of the programme 'Regulation of the Syrdarya river channel and preservation of the northern part of the Aral Sea (RSNASP-I), construction of the Kokaral dam in the former Berg Strait of the Aral Sea was completed in 2005. The construction of the hydraulic structure prevented the progressive lowering of the sea level and raised its level from 38,0 metres to 42,0 ± 0,5 metres abs. The area of the Aral Sea and the volume of water in it were fixed at more stable parameters (Figure 1).

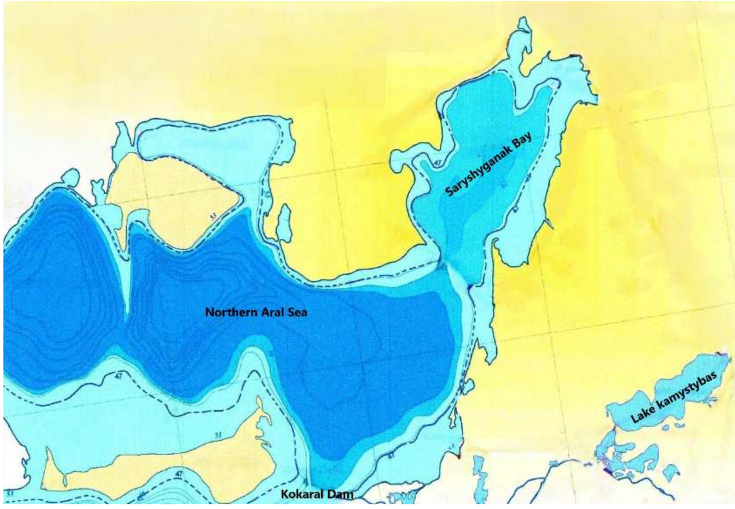


Figure 1 – Northern (Small) Aral Sea (NAS)and Saryshyganak Bay

In February 2012 the Ramsar Convention Secretariat included the 'Small (North) Aral Sea and Syr Darya river Delta by total area of 330 thousand ha in the list of Ramsar sites as the most important wetlands of the planet - Important Bird and Biodiversity Area (IBA).

However, about half of the total surface water resources of Kazakhstan come from neighbouring countries [2]. The Aral-Syrdarya river basin is the most dependent on transboundary runoff, with almost 90 % of the basin's resources coming from this component. The volume of transboundary flow entering the Shardara reservoir is determined by the operation mode of a whole cascade of reservoirs located in the upper reaches of the Syrdarya (Table 1).

Table 1 – Parameters of main reservoirs located in the Syrdarya river basin

Reservoir	Country	River	Volume	Year
Toktogul	Kyrgyzstan	Naryn	19,5	1975
Andijan	Uzbekistan	Karadarya	1,9	1978
Kayrakkum	Tajikistan	Syr Darya	4,2	1956
Charvak	Uzbekistan	Chirchik	2,0	1970
Shardara	Kazakhstan	Syr Darya	5,2	1965

According to the design operation regime of the Shardara reservoir, the highest flow rate is 1200 m^3/s and the lowest is 220 m^3/s in winter. During extremely high-water years, such as 1969, a significant part of the flow was discharged into the Arnasay depression (Uzbekistan).

Problem statement Measures to prevent environmental problems in the Aral Sea region have been taken since the middle of the last century. Thus, in 1989, a feasibility study was approved for the construction of engineering structures to restore water availability in the Saryshyganak Bay.

Within the framework of implementation of the second phase of RSNASP -II, reconstruction of the Northern (Small) Aral Sea (NAS), water area was planned, aimed at improvement and restoration of the Aral Sea water ecosystem. Two alternative variants of the NAS reconstruction were identified:

• two-level option – by restoring the former Saryshyganak bay as a water body;

• one-level variant with a single Northern Aral Sea – by building up the Kokaral dam.

Both reconstruction options have positive and negative sides, both in construction and operation of the engineering structure complex [3, 4]. However, at present there is no unanimous opinion regarding the choice of reconstruction options. This paper considers the issues of solving practical problems on determining the filling of the optimum water level of the proposed retaining hydraulic structure. To solve the set problem, the dynamic-stochastic approach is applied, which allows describing a real system with sufficient accuracy without experimentation on a real object and obtaining data for further statistical processing, as well as anticipating future changes in the filling regimes of lake-type water bodies. The results of studies in the field of hydrology show that the prevailing direction in the development of hydrological processes is the stochastic concept [5].

Research methodology Methods of hydrological and water management calculations, dynamic-stochastic approach, and computer data processing methods were applied.

Data sources Materials of expeditionary works on water bodies of Aral region, scientific and project materials and publications were used.

Main part Knowing regularities in water flow fluctuations or possessing certain information about the current state of water availability, it is possible to foresee the future state of the studied object and its main characteristics. On their basis it is possible to estimate features of the given period and to carry out corresponding to these conditions development of effective modes of functioning of hydraulic structures with advance or mitigation of occurrence of hydrological threats and risks.

In the proposed work, the assessment of options for reconstruction of the NAS is carried out. To determine the quantitative characteristics of the object under study (Northern Aral Sea – Saryshyganak Bay), the balance method was used by means of sequential solution of balance equations, which allow indirectly assessing its dynamics, as well as identifying and analysing the interrelationships of various components of the moisture balance.

The balance equation for some time interval Δt is as follows

$$Q + X - E = \pm \Delta W, \qquad (1)$$

where Q – river runoff; X – precipitation; E – evaporation from the water surface; ΔW – change in water volume over the same time period.

It follows from the equation that if the inflow part of the balance is less than the outflow part $Q + X < E$, the water volume in the water body will decrease in time (i. e., $\Delta W < 0$), while at the other ratio ($Q + X > E$) it will increase (i. e., $\Delta W > 0$).

Since the volume (W), area (F) and level (Z) of water are interrelated with each other, the calculated change in water volume ΔW can be used to determine the ratio of change in the area of the water body and its level.

To assess the dynamics of the state of the studied water body in time, the balance equation (1) is used as

$$B^T = W_{n+1} = Q_n + W_n + X_n - E_n - V_n, \quad (2)$$

where, B^T – water balance; W_{n+1} – volume for the design year; Q_n – annual inflow volume; W_n – volume for the previous year; V_n – total runoff withdrawal volume; X_n и E_n – precipitation and evaporation volumes depending on the water surface area of the object; n - design time series (year).

In the equation, precipitation falling on the water surface (X) and evaporation from it (E) can be replaced by evaporation ($E_в$). It should be noted that visible evaporation in arid climates, when evaporation is tens of times higher than precipitation, is always positive. Then equation (2) will take the form

$$B^T = W_{n+1} = Q_n + W_n - E_в - V_n\ . \quad (3)$$

Simplified balance equation (3) is adopted as a mathematical model of the research object.

To solve the equation in the mathematical model, the mean annual evapotranspiration from the water surface of the NAS (E_n), is taken equal to 920 mm, average annual precipitation (X_n) falling on the water surface is taken equal to 126 mm.

Water exchange processes or system flowability is determined by the components of the water balance and is the most important indicator of the state of the aquatic ecosystem, characterising various dynamic processes occurring in water bodies.

Estimation of system flowability (P), calculated by the relative volume of capacity of the isolated bay Saryshyganak, as

$$P = W_r / W_b \quad (4)$$

where, W_r – average annual discharge volume in NAS; W_b – the full volume of Saryshyganak Bay.

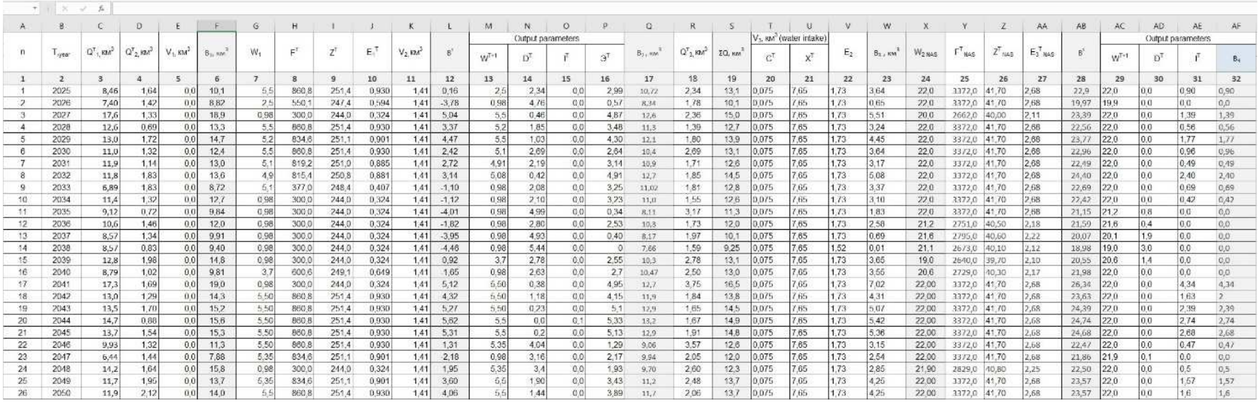
Considering river flow patterns are stochastic in nature, in the dynamic-stochastic approaches to solving the problems of scenarios of water body development and determining the optimal level of filling of the hydraulic retaining structure in the balance calculations, a temporary hydrological series ($n > 35$) made up of annual Volumes of river inflow using random number generation through statistical modelling (Monte Carlo method). The initial parameters of the studied water object are given in Table 2.

Table 2 – Initial parameters of input data of the object under study

Water object	H, m	F, thousand km²	W, km3	E, km3
Northern Aral Sea	42,00	3300	27,0	2,62
incl. Saryshyganak Bay		0,133	0,100	0,100

The average annual flow of the Syrdarya river as a guaranteed limit is accepted in the volume of 12,0 km^3 per year with a permissible reduction in dry years at 90 % availability – up to 10,0 km^3 per year and a coefficient of variation ($C_v = 0{,}26$).

In the calculation tasks, the average annual inflow to the NAS is assumed to be 3,80 km^3 per year. The results of solving water-balance problems are given in Figure 2 and Table 3.



A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
												Output parameters			
n	T_{year}	Q^T_1, км³	Q^T_2, км³	V_1, км³	B_1, км³	W_1	F^T	Z^T	E_1^T	V_2, км³	B'	W^{T+1}	D^T	I^T	$Э^T$
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	2025	8,46	1,64	0,0	10,1	5,5	860,8	251,4	0,930	1,41	0,16	2,5	2,34	0,0	2,99
2	2026	7,40	1,42	0,0	8,82	2,5	550,1	247,4	0,594	1,41	-3,78	0,98	4,76	0,0	0,57
3	2027	17,6	1,33	0,0	18,9	0,98	300,0	244,0	0,324	1,41	5,04	5,5	0,46	0,0	4,87
4	2028	12,6	0,69	0,0	13,3	5,5	860,8	251,4	0,930	1,41	3,37	5,2	1,85	0,0	3,48
5	2029	13,0	1,72	0,0	14,7	5,2	834,6	251,1	0,901	1,41	4,47	5,5	1,03	0,0	4,30
6	2030	11,0	1,32	0,0	12,4	5,5	860,8	251,4	0,930	1,41	2,42	5,1	2,69	0,0	2,64
7	2031	11,9	1,14	0,0	13,0	5,1	819,2	251,0	0,885	1,41	2,72	4,91	2,19	0,0	3,14
8	2032	11,8	1,83	0,0	13,6	4,9	815,4	250,8	0,881	1,41	3,14	5,08	0,42	0,0	4,91
9	2033	6,89	1,83	0,0	8,72	5,1	377,0	248,4	0,407	1,41	-1,10	0,98	2,08	0,0	3,25
10	2034	11,4	1,32	0,0	12,7	0,98	300,0	244,0	0,324	1,41	-1,12	0,98	2,10	0,0	3,23
11	2035	9,12	0,72	0,0	9,84	0,98	300,0	244,0	0,324	1,41	-4,01	0,98	4,99	0,0	0,34
12	2036	10,6	1,46	0,0	12,0	0,98	300,0	244,0	0,324	1,41	-1,82	0,98	2,80	0,0	2,53
13	2037	8,57	1,34	0,0	9,91	0,98	300,0	244,0	0,324	1,41	-3,95	0,98	4,93	0,0	0,40
14	2038	8,57	0,83	0,0	9,40	0,98	300,0	244,0	0,324	1,41	-4,46	0,98	5,44	0,0	0
15	2039	12,8	1,98	0,0	14,8	0,98	300,0	244,0	0,324	1,41	0,92	3,7	2,78	0,0	2,55
16	2040	8,79	1,02	0,0	9,81	3,7	600,6	249,1	0,649	1,41	1,65	0,98	2,63	0,0	2,7
17	2041	17,3	1,69	0,0	19,0	0,98	300,0	244,0	0,324	1,41	5,12	5,50	0,38	0,0	4,95
18	2042	13,0	1,29	0,0	14,3	5,50	860,8	251,4	0,930	1,41	4,32	5,50	1,18	0,0	4,15
19	2043	13,5	1,70	0,0	15,2	5,50	860,8	251,4	0,930	1,41	5,27	5,50	0,23	0,0	5,1
20	2044	14,7	0,88	0,0	15,6	5,50	860,8	251,4	0,930	1,41	5,82	5,5	0,0	0,1	5,33
21	2045	13,7	1,54	0,0	15,3	5,50	860,8	251,4	0,930	1,41	5,31	5,5	0,2	0,0	5,13
22	2046	9,93	1,32	0,0	11,3	5,50	860,8	251,4	0,930	1,41	1,31	5,35	4,04	0,0	1,29
23	2047	6,44	1,44	0,0	7,88	5,35	834,6	251,1	0,901	1,41	-2,18	0,98	3,16	0,0	2,17
24	2048	14,2	1,64	0,0	15,8	0,98	300,0	244,0	0,324	1,41	1,95	5,35	3,4	0,0	1,93
25	2049	11,7	1,95	0,0	13,7	5,35	834,6	251,1	0,901	1,41	3,60	5,5	1,90	0,0	3,43
26	2050	11,9	2,12	0,0	14,0	5,5	860,8	251,4	0,930	1,41	4,06	5,5	1,44	0,0	3,89

A	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF
				V_3, км³ (water intake)									Output parameters			
n	B_2, км³	Q^T_3, км³	ΣQ, км³	C^T	X^T	E_2	B_3, км³	$W_{2\,NAS}$	F^T_{NAS}	Z^T_{NAS}	$E_3^T{}_{NAS}$	B'	W^{T+1}	D^T	I^T	B_4
1	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	10,72	2,34	13,1	0,075	7,65	1,73	3,64	22,0	3372,0	41,70	2,68	22,9	22,0	0,0	0,90	0,90
2	8,34	1,78	10,1	0,075	7,65	1,73	0,65	22,0	3372,0	41,70	2,68	19,97	19,9	0,0	0,0	0,0
3	12,6	2,36	15,0	0,075	7,65	1,73	5,51	20,0	2662,0	40,00	2,11	23,39	22,0	0,0	1,39	1,39
4	11,3	1,39	12,7	0,075	7,65	1,73	3,24	22,0	3372,0	41,70	2,68	22,56	22,0	0,0	0,56	0,56
5	12,1	1,80	13,9	0,075	7,65	1,73	4,45	22,0	3372,0	41,70	2,68	23,77	22,0	0,0	1,77	1,77
6	10,4	2,69	13,1	0,075	7,65	1,73	3,64	22,0	3372,0	41,70	2,68	22,96	22,0	0,0	0,96	0,96
7	10,9	1,71	12,6	0,075	7,65	1,73	3,17	22,0	3372,0	41,70	2,68	22,49	22,0	0,0	0,49	0,49
8	12,7	1,85	14,5	0,075	7,65	1,73	5,08	22,0	3372,0	41,70	2,68	24,40	22,0	0,0	2,40	2,40
9	11,02	1,81	12,8	0,075	7,65	1,73	3,37	22,0	3372,0	41,70	2,68	22,69	22,0	0,0	0,69	0,69
10	11,0	1,55	12,6	0,075	7,65	1,73	3,10	22,0	3372,0	41,70	2,68	22,42	22,0	0,0	0,42	0,42
11	8,11	3,17	11,3	0,075	7,65	1,73	1,83	22,0	3372,0	41,70	2,68	21,15	21,2	0,8	0,0	0,0
12	10,3	1,73	12,0	0,075	7,65	1,73	2,58	21,2	2751,0	40,50	2,18	21,59	21,6	0,4	0,0	0,0
13	8,17	1,97	10,1	0,075	7,65	1,73	0,69	21,6	2795,0	40,60	2,22	20,07	20,1	1,9	0,0	0,0
14	7,66	1,59	9,25	0,075	7,65	1,52	0,01	21,1	2673,0	40,10	2,12	18,98	19,0	3,0	0,0	0,0
15	10,3	2,78	13,1	0,075	7,65	1,73	3,65	19,0	2640,0	39,70	2,10	20,55	20,6	1,4	0,0	0,0
16	10,47	2,50	13,0	0,075	7,65	1,73	3,56	20,6	2729,0	40,30	2,17	21,98	22,0	0,0	0,0	0,0
17	12,7	3,75	16,5	0,075	7,65	1,73	7,02	22,00	3372,0	41,70	2,68	26,34	22,0	0,0	4,34	4,34
18	11,9	1,84	13,8	0,075	7,65	1,73	4,31	22,00	3372,0	41,70	2,68	23,63	22,0	0,0	1,63	2
19	12,9	1,65	14,5	0,075	7,65	1,73	5,07	22,00	3372,0	41,70	2,68	24,39	22,0	0,0	2,39	2,39
20	13,2	1,67	14,9	0,075	7,65	1,73	5,42	22,00	3372,0	41,70	2,68	24,74	22,0	0,0	2,74	2,74
21	12,9	1,91	14,8	0,075	7,65	1,73	5,36	22,00	3372,0	41,70	2,68	24,68	22,0	0,0	2,68	2,68
22	9,06	3,57	12,6	0,075	7,65	1,73	3,15	22,00	3372,0	41,70	2,68	22,47	22,0	0,0	0.47	0,47
23	9,94	2,05	12,0	0,075	7,65	1,73	2,54	22,00	3372,0	41,70	2,68	21,86	21,9	0,1	0.0	0,0
24	9,70	2,60	12,3	0,075	7,65	1,73	2,85	21,90	2829,0	40,80	2,25	22,50	22,0	0,0	0,5	0,5
25	11,2	2,48	13,7	0,075	7,65	1,73	4,25	22,00	3372,0	41,70	2,68	23,57	22,0	0,0	1,57	1,57
26	11,7	2,06	13,7	0,075	7,65	1,73	4,25	22,00	3372,0	41,70	2,68	23,57	22,0	0,0	1,6	1,6

Figure 2 – Working fragment of water-balance calculations

Table 3 – Calculation parameters of NAS and isolated Saryshyganak bay

Northern (Small) Aral Sea			Saryshyganak Bay		
Option I. Single-level dam			Option II. Two-level dam		
At a level of 46.0 metres abs.					
F, thousand km2	W, km3	E, km3	F, thousand km2	W, km3	E, km3
4180	42,0	3,32	0,600	1,73	0,476
At 50.00 m level					
5200	61,0	4,13	0,853	4,77	0,677
At the level of 52.00 metres					
–			0,980	7,45	0,778

Under the RSASP-II Project, water intake to the Saryshyganak Bay is envisaged in the amount of 1.42 km³ per year. Water transport to the bay will be carried out by means of a supply canal, which has two delivery routes from the Syrdarya River: through the Tushchibas or Kamystybas reservoirs. Under any variant of water transfer route selection, flowing water will be created in one of the lake systems of the delta, which will have a favourable impact on the aquatic ecosystem of the Aral region.

Main conclusions. Water-balance calculations show that under a single-level dam, taking into account the reality of water regime of the Syrdarya river lower reaches, the duration of AMU filling up to 46,0 m abs. mark will be 26–27 years. The period of filling up to the design mark of 50,0 m abs. – more than 35 years, at those losses will exceed 106 km³ (annual water loss for evaporation on average 3,0 km^3). The critical water level is clearly limited by the bottom topography to 43,0 m abs., at which a further decrease in the level will lead to the separation of the Saryshyganak Bay from the northern Aral Sea (Figure 3).

At a two-level dam, the optimum water level of the NAS remains the design level of 42,00 m abs. For the isolated bay Saryshyganak 3 characteristic marks of water levels are considered: 46,00; 50,00 and 52,00 metres abs. (Table 3, Figure 4).

1. The bay will reach the elevation of 46,00 m abs. with a capacity of 2,2 million m³ within 3 years, with evaporation averaging 440 million m³ per year or 1,3 km³ for the entire filling period. Thereafter, unproductive discharges to the BAS (Big Arak Sea) through the NAS will continuously increase.

2. Saryshyganak Bay will reach the level of 50,00 m abs. within 6–7 years. To create favourable conditions of aquatic ecosystem by salinity close to river water it is enough to carry out annual water discharge into the NAS in the volume of 740 million m³. When filling the bay up to the design level, the total water losses for evaporation will be up to 3,8 km³ or 550 million m³ per year, which is insignificant for structures of such scale.

3. The bay will reach a level of 52,00 m abs. within 10 years, with evaporation losses of 8,0 km³ or 800 million m³ per year during the filling period.

Calculated data on the assessment of the flowability of the aquatic environment show that at water level elevations up to 50,0 m abs., water exchange processes occur in the zone of moderate flowability (0,16), and at 51,0 m abs. and above, the flowability in the system decreases (0,08).

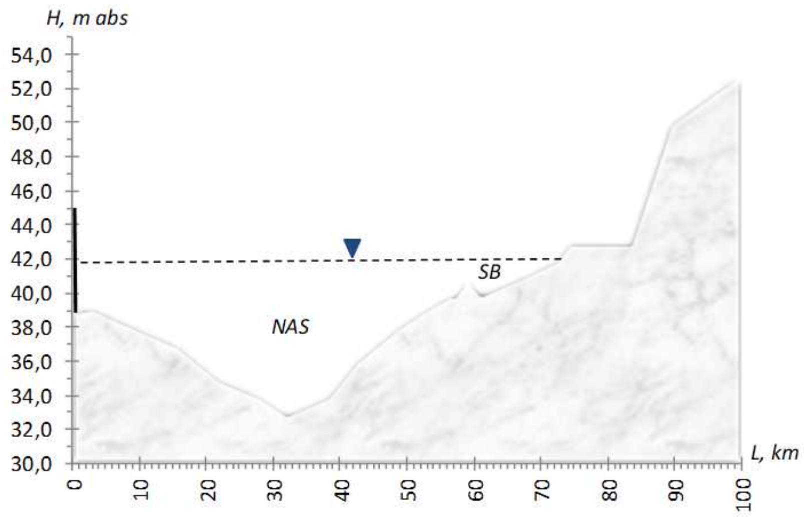


Figure 3 – Critical levels of Saryshyganak Bay NAS

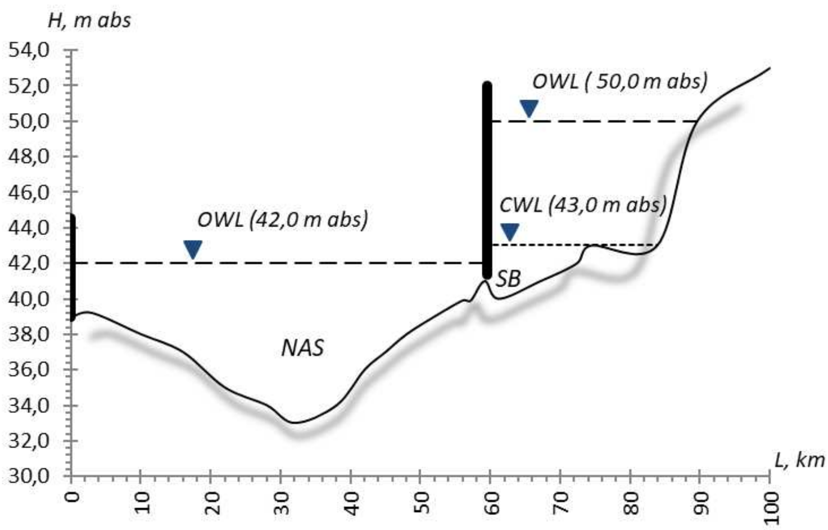


Figure 4 – Longitudinal profile of NAS and Saryshyganak Bay, characteristic reconstruction levels

Conclusion

Based on the dynamic-stochastic approach in solving problems on determining the optimal level of filling of a hydraulic structure, it can be concluded that of the two options for the construction of hydraulic structures in the water area of the Northern Aral Sea, the most preferable is the second option of reconstruction with the mark of the normal retaining horizon (NRH) – 50.00 m abs.

The two-level variant of the NAS reconstruction is characterised by a short period of filling of the bay bowl – 6–7 years, less water losses - up to 3.0 km³ and moderate water exchange process of the system – P 0,16.

The proposed parameters of the structure maintain high level stability providing good water transport connection, close to natural level fluctuations.

The proposed engineering measures will:

– improve the condition of the aquatic ecosystem of the Northern (Small) Aral Sea;

– significantly improve the socio-ecological and economic situation in the region, and increase the recreational attractiveness of the Aral Sea region;

– effectively manage limited water resources in the Aral-Syrdarya basin.

The significance is to improve natural properties and optimal functioning of the aquatic ecosystem with full provision of ‘ecosystem service’.

It should be especially mentioned that the Aral Sea region with its unique flora and fauna play a peculiar role of ‘reserves’ in preserving the gene pool of biodiversity in the Aral Sea region. They also carry a solution to the problem of water supply and increase of bioproductivity of the ecosystem and help to better adapt to global climate change under conditions of uncertainty and in mitigation of unfavourable effects on the environment.

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