MINISTERY OF EDUCATION AND SCIENCE OF GEORGIA
Akaki Tsereteli State University

Faculty of Technical Engineering

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STUDY OF SILTING THE RIONI RIVER'S RESERVOIRS AND MTHODS TO COMBAT IT

The Author's Abstract
of the Doctoral Thesis Nominated for Ph Doctor Degree
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MINISTERY OF EDUCATION AND SCIENCE OF GEORGIA

The given work is executed at the Department of Civil Engineering and Transport of the Faculty of Technical Engineering, at the Akaki Tsereteli State University.

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General Description of Work

The urgency of the problem. River discharges, as theconstantly renewable and available resources are widely used in power industry, construction, irrigation, water supply and in nearly all economic sectors. Stability and state of balance of sea and ocean coasts depend on river discharges. Economic and social development in society largely depends on the efficiency of water resource management and water reservoir regulation process. Thus, the rational use of river discharges and cleaned storage volume of reservoirs is a highly urgent and global problem.

Existence of contemporary civilization is impossible without intensive use of water bodies, for which the forms and scales of anthropogenic interference with hydrological objects are increasing immeasurably. In this context, assessment of the environmental impact of reservoir is a highly urgent problem.

The Rioni River is an essential riverine arteria of Georgia. There are arranged numerous reservoirs in its basin, as a result of operation of which river discharges have changed considerably, in both quantitative and qualitative terms. It is also important to reduce the amount of solid silt loads that is mostly conditioned by water-related use of rivers.

Studies of the Rioni River reservoirs have shown that they have lost a great part of their storage volume, and due to this, their everyday retention capacity has fallen sharply. In fact, they no longer perform the role of peaking capacity regulator, and they operate on naturalriver discharges, and because of this, in winter (November-March) the power grid loses the peak power.

Operation experience of reservoirs existing on the rivers abounding in silt demonstrates that cleaning of silted materials requires the use of a particular optimal way.

When using water resources and studying and determining their management parameters, we encounter two interesting aspects – environment and society. The main reason for such a collision consists in fact that the society seeks to change the volume, operating regime and quality of natural water in favor of its own interests.

Proceeding from this, one of the urgent problems is to upgrade and

improve the operating parameters of water-related systems.

Goal of Research. The goal of the proposed thesis work is to study the operation of the systems of large multi-purpose modern water reservoirs, as well as to improve methods for calculating optimal operation regimes of these reservoirs.

Analysis of different natural-economic changes and creation of data for their assessment represent a prerequisite for the effective functioning of the water reservoir systems. In order to reach the set goals, we should attainthe following interrelated objectives:

- Studying the hydrological and water-related management aspects of the Rioni River's basin water resources;
- Studying the effective functioning of the water-related systems;
- Studying theprogress in the siltation processes of the systems of multi-purpose water reservoirs;
- Studying themethods of addressing the silting of the systems of multi-purpose water reservoirs.

Scope and Object of Research. The objectof research is represented by the multi-purpose water-relatedsystems of the Rioni River, which comprise four reservoirs: Lajanuri HPP, Gumati HPP-I, Gumati HPP-II, Rioni HPP and cascade of Vartsikhe HPPs I, II, III and IV.

Research Novelty. Methodological part of the thesis work is represented by study of protection and rational use of the river basin resources taking into account the interests of the public and environmental protection.

The main research novelty consists in:

- developing methodology and analysis of operating modes of the multi-purpose water-related systems;
- developing and implementing research and diagnosis of silting of the reservoir systems;
- determining the volume of the silted part of the Rioni River basin reservoirs;
- generating the integral curves of silting of the Rioni River basin reservoirs;
- determining methodology of movement of the hydro-mass in the conditions of hydrotransprt in the pipelines;

- developing diagnosis of silting of the Rioni River's free flowing channel ata section of Gumati HPP;
- developing the methods of addressing silting of the systems of water reservoirs;
- presenting the methods of treating the Rioni River's reservoirs;
- determining and taking into account the values of the Rioni River's annual water discharge rate in explotative conditions of reservoirs;
- analyzing and scientific assessing the effective functioning of the Rioni River's reservoir systems.

Practical Bearing of Research. The use of the results of this works allows us for a science-based determination of diagnosis of silting of the Rioni River's basin reservoirs and problems related to their treatment. By using the obtained methods of treating reservoirs, it is possible to regulate reservoirs of the similar riversabounding in silt, as well as providing their operating modes.

Following research carried out, it has been established that of the methods addressing silting of reservoirs, the most convenient way is to treat soil by means of dredging machines, dredging of wet soil from the bottom of reservoirs and its transportation through the pipeline to the place of deposition. For the first time ever, there have been calculation of cleaning by siphon method the reservoir from silted material. The operating principle of this method is based on operating principle of siphon. A siphon pipeline which along with a short length, is characterized by inevitable vacuum at some segment of flow. Transfer of material silted by mens of pipelines from a upstream into down stream is carried at by means of water discharg and vacuum created in a siphon.

By applying the obtained methodology, it is possible to take back and preserve the designed capacity and mode of the operation of silted reservoirs, in order not to reduce environmental impact of reserveoirs and restore the ecological balance of the transportation of transported soil.

Approbation of Work. Information on the results of research was presented on the following scientific conferences and workshops:

1) Scientific workshops of the Department of Civil Engineering and Transport at the Akaki Tsereteli State University (2009-2016);
2) The People's Friendship University of Russia, Moscow. Scientific

Conference "Dynamics and Thermal of Rivers, Reservoirs and Coastal Areas of the Seas" (RUDN, 25 November, 2009);

3) Perm State University. Perm, Russia. International Scientific-Practical Conference "Contemporary Problems of Reservoirs and Watersheds (May 26-28, 2008);
4) Perm State University. Perm, Russia. International Scientific-Practical Conference May 28-30, 2013);
5) Akaki tsereteli State University, Kutaisi, Georgia. International Scientific Conference "Sustainable Energy: Challenges and Development Prospects" (2015)

Publications. 21 research papers have been published concerning the subject of dissertation. The list of main publications (9) from them is given below at the end of this author's abstract.

Brief Content of Dissertation

The introduction describes the urgency of the problems, sets the main goal and objectives of the proposed thesis work, and shows reliability and practical bearing of the obtained results. There is also described the urgency of research of silting of the Rioni River's reservoirs and methods addressing it.

The author mentions the great respect and gratitude to Professor Otar shautidzes, which call for professional advice and caused the creation of this paper. Akaki Tsereteli State University expresses its gratitude to the staff for their support and help.

The first chapter refers to the methodology for determining the rational operating modes of the sytem of reservoirs. Naturally, the Rioni River stream channel creates good conditions for the construction of hydro-power plants. The use of these natural conditions for the creation of reservoirs allows the country for rapid developing, from both material and economic standpoints. However, when constructing water reservoirs, it is necessary to minimize their environmental impacts.

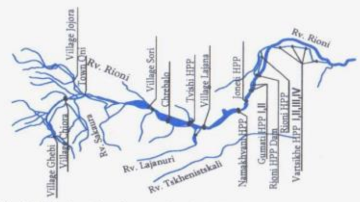
There are also described modern directions of designing and operating hydro-power plants. In accordance with the projects on the Rioni

River, the Namakhvani cascade comprises three HPPs, such as Tvishi, Namakhvani and Zhoneti.

The Namakhvani cascade, which will be constructed in the near future and will be added to the HPPs on the Rioni River basin, will cause changes in operating modes of reservoirs.

Thus, when we talk about normal operating conditions of resaervoirs of Gumati and Vartshikhe HPP cascade, it is necessary to consider the location of the Namakhvani cascade's reservoirs and their operating conditions.

Pic. 1.1 illustrates the Tvishi Dam axis of the Rioni River's Namakhvani cascade, where reservoir must be constructed, overall volume of which is 150 mln m^3.



Pic. 1.1. The location of reservoirs of the Rioni River basin cascades

There are examined the trends in the utilization of hydro-resources of rivers in Georgia, as well as their urgency. An aboundance of water in Georgian rivers, types of the river-valleys and large stream-channel slope condition a fairly high hydropower potential. The energy of the country's overall surface and transit run-off is approximately 229 bln kWh, but the appropriate capacity makes up 26 bln kWh. Similarly to water resources, hydropower resources are also quite unevenly distributed throughout the territories. West Georgia accounts for 72% of energy resources of large and medium rivers, but East Georgia accounts for 28%.

Georgia still has a great potential for hydropower development, which currently represents the most ecologically sound source of electric power. Due to this, in many countries rich in hydropower resources, these resources will be harnessed first of all.

The growth rates in the electricity consumption throughout the world are high enough. For example, according to the forecast of the International Energy Agency (IEA), after 2000, the electricity consumption by 2010 was increased from 15 trillionkWh to 21 trillion kWh, and the upward trends will continue in subsequent years as well. Here, we should note that the anuual amount of CO_2 emissions in Energy sector is mostly associated with the functioning of thermal power plants, and consequently, the use of hydro resources becomes even more urgent. The pusuit of harnessing hydropower resources is clearly reflected in the structure of the energy systems of the world's leading countries. According to The International Journal on Hydropower & Dams 1, the world's theoretical hydro potential is estimated at 40 204 865 gigawatt-hours, including technically feasible - 14 606 559 gigawatt-hours, and economically feasible - 8 721 093 gigawatt-hours. There are functioning more than 25 000 various-capacity HPPs throughout the world. [Published/hosted by Aqua Media International. ISSN: 1352-2523. Trans Electrica Ltd., 2013 2]

There have been studied the existing methods of rational determination of the operating modes of the systems of reservoirs. It has been established that 90-95% of solid run-off are deposited in reservoirs. Due to this, the available storage in reservoirs is gradually decreasing.

Study of hydraulic conditions of the movement of solid alluvial material on the mountain rivers involves some difficulties. In spite of this, the attention should be given to field studies carried out by L. Gvelesiani, N. Shmatsel and O. Shautidze, N.B. Kereselidze, R. Khachalov, G.I. Shamov, V.V. Romashin and Z.D. Kpaliani, J.V. Noselidze, K.I. Rossinskiy, Sh.R. Pozdnyakov and V.V. Romanovskiy, T.Sh. Mazhidov, who have been able to determine the share of the settled sediments in floating run-offat the stretch of particular rivers.

The second chapter deals with research and diagnosis of the formation and functioning of river run-off flowing inthe multi-purpose reservoir systems of the Rioni River. The Rioni River is characterized by floods, regulation of which requires in-depth knowledge of characteristics of solid and and liquid run-off.

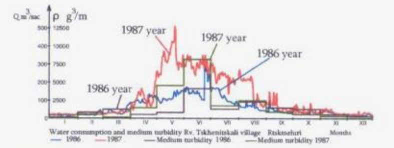
Data on the Rioni River's water discharge for the period between 1910 and 1993 are fixed at the Namakhvani Water Monitoring Station. The outpost

is arranged on the left bank, and is equipped with a staff and a water level controlling device "Valday". This device is of an island type. The conditions of discharge for 1954 have been changed because of Shaori HPP and the Chala (Sharaula) River. Along with the implementation of Shaori HPP project, the stream existing in a river channel was changed by5 m^3/sec. On the other hand, after constructction of Lajanuri reservoir in 1960, water discharge of the RionI River was increased by 60 m^3/sec, since the the stream from the Tskheniskali River was carried here.

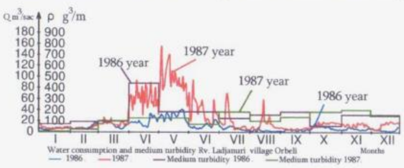
The ongoing processes of silting of the Rioni River basin cascades mostly depend on the volume of alluvial materials accumulated in the cahnnels of supplying rivers and on the transportation capacity of of river flows. In order to look into this problem, we should examine hydromorphological characteristics of supplying rivers.

According to hydrological data, the most abundance of water in the Rioni River's reservoir was observed in 1987, and the most low water level was observed in 1986.

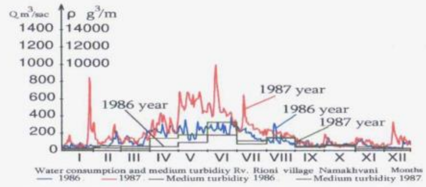
Pictures 2.1-2,3 illustrate the values of water discharge in the mentioned segments. The same drawings show the average decadic turbidities.



Pic 2.1. The Tskhenistskali River – according to data of the Rtskhmeluri Outpost

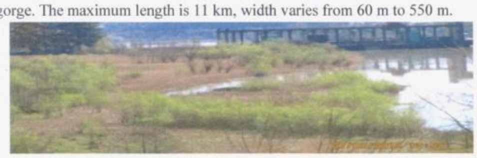


Pic. 2.2. The Lajanuri River – according to data of the Orbeli Outpost



Pic. 2.3. The Rioni River – according to data of the Namakhvani Outpost

Gumati reservoir has been lengthened in the direction to the river gorge. The maximum length is 11 km, width varies from 60 m to 550 m.



Pic. 2.4. The view in front of Gumati reservoir power intake

At a normal flooding level of reservoir, its length is 5-7 km. The minimum average level in reservoir is 199,5 m. At this level, the width of reservoir varies between 200 m and 300 m. The power intake operates without failing. The operating mode allows for local treatments just immediately after silting, the waher is taken out and silt practically doesn't end up in turbine.

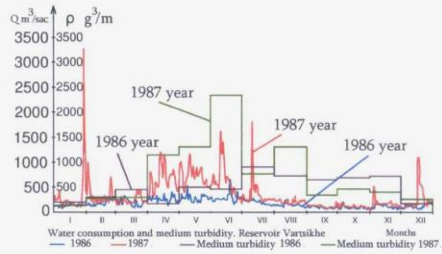
The stopping-up of a large bar screen of the intake heading of Rioni HPP causes water disconnections to HPP, the water-line intake is stopped-up, water discharge on HPP may be 75 m^3/sec. If discharge is high enough, for example 250 m^3/sec, there are taken the washer and large shields and the area adjacent to the dam is washing at a distance of 20-30 m, and in fact, this area is always without deposits, since it is treated periodically, just immediately after silting.

Pic. 2.5. The silted area of the Rioni HPP dam reservoir

The main available storage of Vatrtsikhe reservoir is silted. The average level of reservoir is 87.02 – 86.6 m. The level is treated if water discharge in reservoir is under 350 m^3/sec, and when there is a need to increase capacity.

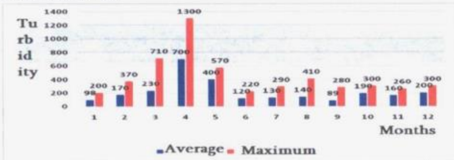
An excessive amount of solid deposits in reservoir causes further difficulties. Unless the dirt collector is washed, silt enters the water intake of channel. It damages the cooling system, the fridge radiators are filled with silt, and it becomes necessary to wash them by changing the direction of water flow. In this period, the HPP is shut down.

Pic. 2.6 illustrates the values of annual water discharge and the average decadic turbidities in the segments of reservoir of the Rioni-Vartsikhe rivers in 1986 and 1987.



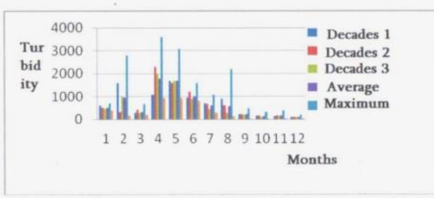
Pic. 2. 6. The segment of reservoir of the Tioni-Vartshikhe rivers

Pic. 2.7 illustrates the average decadic, maximal and minimal values of turbidities in the segment of the Kvirila River-Zestafoni Outpost in g/m^3, according to data of the year of 1987, which was characterized by an aboundance of water.



Pic. 2.7. The average monthly values of turbidity.

Pic. 2.8 illustrates the average decadic, maximal and minimal values of turbidities at the segment of the Rioni River-Sakochakidze Outpost in g/m^3, according to data of the year of 1987, which was characterized by an aboundance of water.



Pic. 2.9.The average decadic values of turbidity

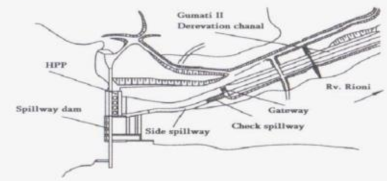
The third chapter dwells on studying the effectiveness of the functioning of dams system of the Rioni River reservoir. It was started up since1924, when construction of first HPP (Rioni HPP) began in the Rioni River basin. Due to the greatest proximity of the Tskhenistskali River, it made it possible to provide the combined hydropower application of these rivers near the middle part of the river. This possibility has become a reality.

For the first time ever, the arch dam was designed and constructed, and by this, there have been laid the groundwork for introducing a very important technical innovation in the construction of hydroelectric facilities.

Pic. 3.1. Diagram of the Lajanuri hydrological unit

The heading hydrological unit has been constructed at the Tskhenistskali River, near the town of Tsageri. The main structure of this unit is a dam executed from afour-span concrete. At the left side of this dam, there is a water intake, which provides channeling of 60 m^3/sec of water per second.

Gumati reservoir has been created on the Rioni River by a gravity-type dam. The waterfront in reservoir is created by a concrete dam and HPP building (Gumati HPP-I). Inside the dam's body, there are four 14-m culvert's spans with the carrying capacity of 2560 m^3/sec. A normal underflooding level is 200 m.



Pic. 3.2. Gumati HPP-1 hydrlogical unit plan

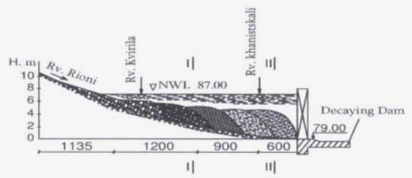
The Rioni HPP reservoir has been created on the Rioni River by a low-level concrete dam. The waterfront is created by a dam, siphon spillway, rafting canal and water intake. A normal underflooding level is 158 m.

Pic. 3. 3. The Rioni River's hydrological unit

The open-type water intake with the carrying capacity of 80 m^3/sec is located at the left of a dam, on the rocky coast of the river. Cleaning of the water intake from deposits is carried out by means of flushing sluices, which are capable of carrying 70 m^3sec of water. From this water intake, there begins the free-flow tunnel, whose length is 3860 m, and the carrying capacity is 80 m^3sec.

The Rioni River's reservoir is silted. The reservoir is washed simultaneously with other reservoirs.

The hydrological structures of the Vartsikhe reservoir comprise: the heading hydrological unit and four similar-type hydropower plants, which are located on the diversion canal. The design head of each HPP makes up 16 m, and the cascade's installed capacity is 184 MW.



Pic. 3.4. The Vartsikhe reservoir longitudinal profile.

The heading unit of Vartshikhe HPP is located near estuarities of the Rioni River's tributaries Kvirila and Khanistskali, and it provides channeling

of 360 m^3/sec design discharge, but in the lower pond – channeling of maximal discharge of 3640 m^3/sec.

Pic. 3.4 illustrates the Vartsikhe reservoir longitudinal profile. The drawing shows that reservoir is silted, and solid run-off is distributed in reservoir by granulemotric fractions. The fractions thickness is gradually decreasing as moving towards a dam. In reservoir, there is observed the flow, which creates the river channel in this reservoir.

The fourth chapter dwells on studying the methods for determining silted volumes of reservoirs. Toward this end, the required calculations during the performance of this thesis work we havemade at the length of 7,6 km. We have determined the silted area (m^2) at each profile, and the silted area between the segments we have averaged out by the formula:

$$F = \frac{F_n + F_{n+1}}{2} \quad (4.1)$$

where, F_n - is the silted area of the prervious segment, m^2;

F_{n+1} - is the silted area of the following segment, m^2.

In order to determine this volume, this value should be multilied by the length between the segments (this length is determined by means of topographical maps)

$$l = \frac{l_{left} + l_{right}}{2} \quad (4.2)$$

where, l_{right} - is the length of the right bank, m;

l_{left} - is the length of the left bank, m.

The volume of the deposited alluvial materials was calculated by the formula:

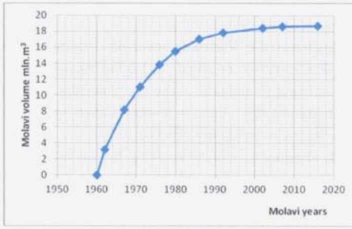
$$W = F \cdot l \quad (m^3) \quad (4.3)$$

where, F - is the area of the averaged segment (m^2); l - is the distance between the segments, (m).

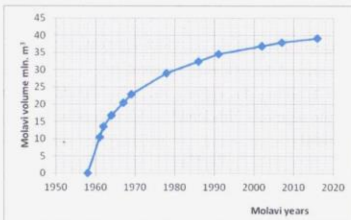
In the same way we continue calculations for other segments as well:

As a result of calculations, ithas been established that by 2016, the volume of silted area oif Gumati reservoir will make up 39,2 mln m^3.

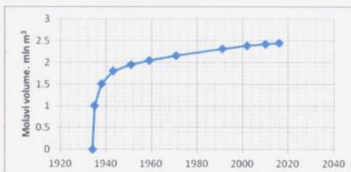
Pic. 4.1-4.4 illustrate the integral curves for the above mentioned reservoirs.



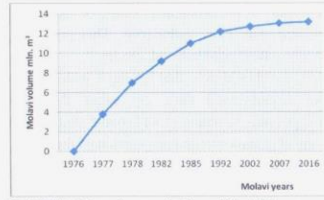
Pic. 4.1. The integral curve of silting of Lajanuri reservoir



Pic. 4.2.**The integral curve of silting of Gumati reservoir**



Pic.4.3.**The integral curve of silting of Rioni HPP reservoir**



Pic.4.4. **The integral curve of silting of Vartsikhe reservoir**

There are shown in Table 4.1. data of the bottom and floating deposits of the Rioni River in the segment of the outposts: the basin area*F* km^2, overall consumption of alluvial materials, t, transported soil module t/m^3.

The volume of alluvial materials increases with the increase in the river's catchment basin, and as shown in Table 4.1, it reaches the maximum volume near the Black Sea estuary.

When studying the silting of the Rioni River's reservoirs, we have used the method of statistical approach based on a software package Mathcad for calculation of silting of the river's flow channel.

Table 4.1

Data of the Rioni River's bottom and floating deposits

№	Years of monitoring	The Rioni River's outposts	The catchment basin's area*F* km^2	Consumption of transported soil, t	Transported soil module t/m^3
1	1985	Utsera village	707	190	270
		Oni town	1060	310	1060
		Khidikari village	2010	850	420
		Alpana village	2830	910	320
		Namakhvani village	3450	1900	550
		Sakochakidze village	13300	4700	350
		Poti town, north branch	13400	6600	490
		Poti town, south branch	13400	-	-
		Lajanuri River,Orbeli village	231	91	390
		Kvirila River, Zestafoni village	2490	600	240
		Dzirula river, Tseva village	1190	230	190

An analytical study of the problem of silting of the open-type river flow channels is associated with flow turbulence. This problem is solving by respecting the rules of a Reynold-Businesk model.

In conclusion, we should note that having a wide range of tachograms of the expensive experimental data, by using the above mentioned considerations, it is possible to obtain more broad-based information on share of separate fractions of granulometric composition of the Rioni River.

Because of developments taking place in Georgia since 1989, the hydrological works on the Rioni River have been practically stopped. Consequently, the hydrological data have been stopped as well. Based on this, it has become necessary to organize field monitoring activities and use modeling methods.

When designing reservoirs at the unexplored or scarcely explored segments of the mountain rovers, the design characteristics of solid deposits are determined by modeling methods, which implies determination of the ratio of solid deposits by the ratio of explored and design segments of catchment basins of the exploring rivers.

$$R_x = R_0 \frac{F_x}{F_0} \qquad (4.4)$$

where, R_x - and R_0 are the mean annual consumption of solid deposits in the design and exploring segments, accordingly, kg/sec; F_x and F_0 - the areas of the river's catchment basins at the appropriate segments, km^2.

By using this method, with the purpose of justifying the expediency of the design values of the rivers' solid run-off, we have carried out the analysis of parameters of floating run-off at the mountain and piedmont segments of rivers, in accordance with variation of the water catchment area of the length of the river.

This study was done by using the examples of Georgian rivers: Bzipi, Kodori, Enguri, Rioni, Acharistskali, Mtkvari, Tetri Aragvi, Alazani and Pambak Riverin Armenia.

The study has shown that the 0,1 and 1% modulus coefficients by the length of the intial water-flow record radically differ one from another, but the 5, 10 and 20% coefficients – did not differ significantly.

Based on the foregoing, we can conclude that for determining the 5, 10 and 20-% coefficients of mean annual consumption of floating deposits at the

unexplored and scarcely explored segments of the mountain areas of rivers, we may consider the use of the method of analogy, but using this methodfor determining the 0,1 and 1-% coefficients of mean annual consumption is unreliable and insufficient. Thus, in this case, further studies should be conducted.

The fifth chapter describes the methods of combating silting of the system of reservoirs in the Rioni River basin. To solve the problem, we use the diffusion equation.

$$U\frac{\partial C}{\partial x} = \frac{\partial}{\partial x}(K_x \frac{\partial C}{\partial x}) + \frac{\partial}{\partial y}(K_y \frac{\partial C}{\partial_y}) + \frac{\partial(\omega C)}{\partial c} - \frac{\partial C}{\partial t} \qquad (5.1)$$

It appears from the above stated that solving the problem set in such a way can be used for calculating reservoir washing processes.

To determine turbidity of washing stream, we use the following formula:

$$\rho = 8.97 \frac{\upsilon^3}{R \cdot \omega} \qquad (5.2)$$

where, υ – The average speed of the flow stream m/sec

R – The hydraulic radius m

ω – The avarege-weighted hydraulic thickness of buoy sag.

The estimated (average multiyear) data for the mentioned period of time:

in Lajanuri - 6 mln m^3 ; in Gumati - 1,5 mlnm^3 ; in Rioni HPP - 1,0 mlnm^3; in Vartsikhe - 1,6 mlnm^3. When washing the Rioni River's reservoirs according to the above mentioned scheme, their volumes will be increased, accordingly, in Lajanuri – by 1 mln m^3; in Gumati – by 0,5 mln m^3 and in Vartsikhe – by 0,5 mln m^3.A general description of the volume of water poured out during the experiment of washing reservoirsin the Rioni River cascade is presented in Table 5.1.

The silting time of the restored (washed) volumes, and consequently the intensity of washing are calculated by the formula:

$$W_{sag} = \frac{V_{wat} + V_{gr}}{V_{wat}} W_{lim} \left(1 - e^{-\frac{V_{w}}{W_{lim}} t}\right) - W_{gr} \sum_{k=1}^{n} f(t - t_k) e^{\frac{V_{w}}{W_{lim}}(t - t_k)} \qquad (5.3)$$

Table 5.1

Hydraulic washing charactristics

№	Name of reservoir	Water discharge, m^3/sec	Anticipated volume of water in reservoir, mln m^3.	Duration of hydraulic washing, hours	Reservoir emptying time, hours	Increas in the volume of reservoir, mln m^3.
1	2	3	4	5	6	7
1	Lajanuri	30	6,0	108	24,0	1,0
2	Gumati I	Alpana, 70. Gumati, 100.	1,5	67	2,0	0,5
3	Gumati II	70	1,2	67	2,0	
4	Rioni reservoir	100	1,0	66	HPP stopped working	
5	Vartsikhe	180	1,6	74	HPP stopped working	0,5

By inserting the appropriate data into this formula, we obtain that the time of silting of the washed volume in Gumati reservoir is 1 year.

The thesis studies hydro-mass transportation hydraulically (hydro-transport), whichby dependence on the location oftrrain, can be free-flow and under pressure. In case of free-flow transportation, for calculation of the critical speed of the hydro-mass movement we use the following formula:

$$\upsilon_{lim} = B\sqrt[4]{\frac{1}{F_r}}\cdot\sqrt[9]{\frac{\gamma_{gr}-\gamma_0}{\gamma_0}\cdot\left(\frac{\gamma_{sol}-\gamma_{gr}}{\gamma_0}\right)^2} \qquad (5.4)$$

where, $B = 3.85$ is coefficient for sandy-gravel soil; $B = 2.86$ - coefficient for bulk material.

The method of free-flow hydrotransport is commonly used in practice. In this case, the cross-section of the pipeline is completely filled, and the hydro-mass moves under pressure. For determining the critical speed of the hydro-mass, when the volumetric weight is $\gamma_{gr} \geq 1{,}05$ t/m^3, we use the A.P Yufin's formula:

$$\upsilon_{cr} = 7{,}5\sqrt[3]{\frac{\omega D}{\sqrt{gd}}\left(\frac{\gamma_{gr}}{\gamma_0}-\frac{\gamma_0}{\gamma_{sol}}\right)} \text{ m/sec} \qquad (5.5)$$

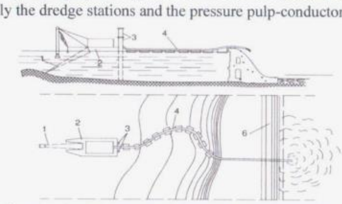
where, D - is a diameter of pipeline (m); d - the weight-average diameter of solid part (m); ω - hydraulic thickness of particle, m/sec; γ_{gr} - the hydro-mass

(pulp) volumetric weight t/m^3; the volumetric weight of water t/m^3; the volumetric weight of solid material, t/m^3.

If $Q_{cr} < Q_{volume}$ transportation regime is non-silting, but when $Q_{cr} > Q_{volume}$, we obtain silting regime.

The economic and effective method of cleaning HPP reservoirs from deposits is represented by a hydro-mechanical method of cleaning reservoirs from silted material.

During the pulp transportation under pressure, there organized additionally the dredge stations and the pressure pulp-conductors.



Pic. 5.1. Soil treating by a hydro-monitor through the pulp transportation by a dredge-pump:

The pressurized pump station (with a pressure of 4-12 atmospheres) supplies water to the hydro-monitors, which wash off the bottom deposits by the jet of water inside reservoir, and then transform it into the hydro-mass.

Wasing of soil by a hydro-monitor is carried out in two ways: by a counter headway from bottom to top, and by a co-current headway from top to bottom. The use of the second way is more effective when treating unstable soil.

There has been developed the methodology of washing reservoir from silted material: the volume, which is treated when a dredge-pump stands in one position, is calculated by the formula: $W_{tp} = b\cdot h\cdot l_{mov}$

The required productivity of a dredge-pump with the dependence on pulp

$$Q_s = \frac{\Pi(1-m+q)}{n\cdot K_{geh}} \text{ m}^3\text{/h} \qquad (5.8)$$

The required pressure of a dredge-pump with the dependence on pulp is calculated by the formula:

$$H_p = h_p \cdot \gamma_{gr} + 1{,}1K \cdot i \cdot L_p + 2 \text{ m} \quad \text{of water column}. \qquad (5.9)$$

The required capacity of a dredge-pump

$$N = H_p \frac{Q_p}{367\eta} \quad \text{kW} \qquad (5.10)$$

Here, η is dredge-pump efficiency ($\eta = 0.7$)

We shall calculate a hydro-monitor hydraulic capacity

$$Q'_{s} = \frac{\Pi \cdot q}{n \cdot K_t} \qquad (5.11)$$

We shall select the technical characteristics of hydro-monitors from Table.

For the first time ever, by using the hydro-mechanical method, in his thesis, there have been calculated the prospects for cleaning Gumati reservoir from silted material.

Gumati reservoir's daily cleaning alluvial material by soil type m^3/daily; soil type – heavy sand-clay: difference between the geodesic symbols full length of a pulp-conductor m; number of working hours, daily $n = 15$ h; dredge-pump efficiency $\eta = 0{,}7$ soil porosity $m = 0{,}19$; soil density $\gamma_{gr} = 1{,}85$ t/m^3; height of sediments $h = 13$ m; face width $b = 50$ m; we determine the treated volume.

$$W_{sp} = b \cdot h \cdot l_{mol} = 50m \cdot 13m \cdot 38m = 24700 \qquad (5.12)$$

The required productivity of a dredge-pump with the dependence on pulp:

$$Q_p = \frac{\Pi(1 - m + q)}{n \cdot K_t} = \frac{2350 \cdot (1 - 0{,}19 + 8)}{15 \cdot 0.676} = 2050 \text{ Day/night} \qquad (5.13)$$

We choose a ГМСД – 300 monitor, for which, the used head piece diameter varies within 100-140 mm.

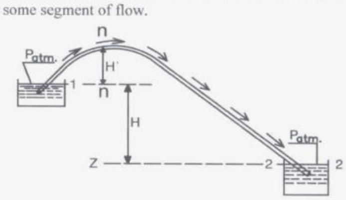
If we transfer daily by means of a dredge-pump from a head pond into a lower pond $Q_p = 2\ 350$ m^3, then during one year, there will be cleaned

$$.Q'_{s} = 20508^3 \cdot 360 = 738000 \qquad (5.14)$$

The mentioned two aggregates are required for the normal functioning of Gumati reservoir. Amount of the work performed by these two aggregates will be $Q = 1{,}476$ mln.m^3.

Very important method of reservoir washing is represented by a siphon method. The operating principle of this method is based on operating principle of siphon. A siphon pipeline belongs to the group of the short

pipelines, which, along with a short length, is characterized by inevitable vacuum at some segment of flow.



Pic. 5. 2. Siphon calculation scheme

The value of vacuum is calculated by the formula:

$$H_{vac} = H' + \frac{\upsilon_n^2}{2g}(a + \xi) \qquad (5.15)$$

The thesis also describes a simulatin model of the functioning of a system of reservoirs. (The works by Archil Geguchadze should be especially highlighted in this regard). Transfer of material silted by means of pipelines from a head pond into a lower pond is carried out by means of water discharge and vacuum created in a siphon.

Pic. 5.2. A simulation of model of reservoir washing

The dissertation discussed soil combating methods in the reservoirs, economical and practical method of clean reservoirs the siphon method.

Basic conclusions

1. As a result of foreign and local literature review, we can conclude that a prerequisite for the normal functioning of reservoirs located on the rivers with an abundance of deposits is a regular removal of solid deposits or blocking them in the water cathchment area of the river.
2. There have been presented the water discharge data and average anual turbidites at Lajanuri, Gumati, Riopni HPP and Vartsikhe reservoir segments, the years of most abundance of water (1987) and lowest level.
3. There have been presented the average decadic, maximum and minimum values of turbidities at the segment of the Kvirila River-Zestafoni outpost and the Rioni River-Sakochakidze outpost (g/m^3) according to data of 1987.
4. There have been developed the methods of determining the silted volumes of the Rioni basin reservoirs. Toward this end, the required calculations during the performance of this thesis work we havemade at the length of 7,6 km. We have determined the silted area (m^2) at each profile, and by summing – we have obtained the overall silted area. By our calculations, ithas been established that by 2016, the volume of silted area of Gumati reservoir will make up 39,2 mln m^3.
5. There have been obtained the values of the integral curves of silting at the segment of Lajanuri, Gumati, Rioni HPP and Vartsikhe reservoir.
6. There have been determined the values of granulometric composition and density along the full length of the Rioni River basin, as well as the compositions (%) and diameters (mm) of particles. (The Rioni River outposts: Utsera, Oni, Khidikari, Namakhvani, Sakochakidze, Lajanuri-Orbeli, Kvirila-Zestafoni, Dzirula-Tseva).
7. There have been determined the values of variation of the volume of alluvial materials moving along the entire length of the Rioni River's water catchment area.As a result of research, it has been established that the intensive volume of moving mass of alluvial materials reaches its maximum value near the Black Sea estuary.
8. When studying the silting of the Rioni River's reservoirs, we have By using the method of statistical approach based on a software package Mathcad, we have determined the volumed of the silted mass of the Rioni Rivber's reservoirs. It should be noted that having a wide range of tachograms of the expensive experimental data, by using the above mentioned considerations; it is possible to obtain more broad-based information on share of separate fractions of granulometric composition of the Rioni River in surroundings of Gumati HPP.

9. There have been presentedthe diagnosis of silting of the open flow channel at the segment of Gumati HPP reservoir. Theoretical calculations (due to silting of the weighted riverianparticles) can be carried out on the basis of a model of incompressible liquid. Viscose incompressible liquid movement equation, we present in the form of three Navier-Stokes equations system $\frac{\partial u_i}{\partial t}+u_\alpha\frac{\partial u_i}{\partial x_\alpha}=f_i-\frac{1}{\rho}\frac{\partial p}{\partial x_i}+\nu\frac{\partial^2 u_i}{\partial^2 x_\alpha}$; $\alpha, i=1,2,3$.as well as by means of three projections of speed (u_1, u_2, u_3).
10. By taking model simulations, there have been determined the design characteristics of solid silt that implies determining the ratio solid silt consumption of the explored and design sections of the exploring river by the ratio of water catchment basins.
11. There have been presented in the prescribed formula stream turbidity by me:

$$\rho = 8.97\frac{\upsilon^3}{R\cdot\omega}$$

12. For the first time ever, there have been made calculation sof cleaning by hydro-mechanical method the Gumati reservoir from silted material. If we transfer daily by means of a dredge-pump from a head pond into a lower pond $Q_з = 2050\,\text{m}^3$, then during one year, there will be cleaned

$$Q'_{\text{dp}} = 2050m^3 \cdot 360 daily = 738000 \text{ m}^3\text{/year}$$

If we transfer daily by means of a dredge-pump from a head pond into a lower pond $Q'_{\text{dp}} = 2050\,\text{m}^3$, then during one year, there will be cleaned. $Q'_{\text{dp}} = 1.476$ mln. m^3

13. There has been presented a hydraulic , siphon and hydro-mechanical methods of cleaning reservoirs. There have been presented the positive and negative aspects of the commonly used method of reservoir washing – the hydraulical method of washing. The operating principle of this method

is based on consumption of a large volume of water and emptying the entire volume of this reservoir, as a result of which the HPP is out of operation for the period of three days.

There have been presented the positive and negative aspects of this method reservoir washing – the hydro-mechanical method of washing. The positive side of the mentioned method is that hydropower of full operation for the period of when is reservoir washing. The negative side of the existent method of the operation for the period much time.

For the first time ever, there has been calculation of cleaning by siphon method the reservoir from silted material. The operating principle of this method is based on operating principle of siphon. A siphon pipeline which along with a short length, is characterized by inevitable vacuum at some segment of flow. Transfer of material silted by mens of pipelines from a upstream into down stream is carried at by means of water discharg and vacuum created in a siphon. The negative side of mentened method is the start of operation of siphon.

14. The calculation ways and studying the Rioni Rive reservoirs silting and the obtained methods for combating it proposed in this thesis can be used in the construction and designing of hydrological units and HPPs similar to the existing currently being under construction reservoirs too.

The main contents of this thesis are reflected in the following publications:

1. Noselidze J.V., Shautidze, O.D., Momtsemlidze Sh.A. Silting of Gumati HPP reservoirs and the fight against it. Proceedings of the International Scientific-Practical Conference. Vol. I, Perm, 2009. Pp. 108-111.
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5. Mamasakhlisi V., Noselidze J., Momtsemlidze Sh. Analysis of the operation of the Chorokhi River coast-protecting structures. "Science and technologies". Scientific peer-reviewed journal of the Academy of Science of Georgia, №4-6, 2011. Tbilisi pp.73-77.
6. Noselidze J., Mamasakhlisi V., Momtsemlidze Sh. Determining critical narrowing of rivers with unwashable flow channels during one-sided bank consolidation. "Science and technologies". Scientific peer-reviewed journal of the Academy of Science of Georgia, №4-6, 2012. Tbilisi pp.65-69.
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11.Geguchadze A ; Noselidze J.; Momtsemlidze Sh; Kaladze D; Noselidze G; Kurashvili S; Kamkamidze N. Dam reservoir bottom sediments from the Self-cleaning siphon device. National Intellectual Property Center "Sakpatenti". Stationery № 182901 Date: 2016-06-24.gamogonebis acceptance of the application materials. Identification number: 14189/01.