Impact of Discharge Structure Carrying Capacity on the Velocity of Water Reservoir Drawdown

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Abstract. Water reservoir hydrosystems are built to control flow in time as well as to fight against flood. For this purpose, discharge structure carrying capacity is set with respect to structure class, water users water consumption schedule, provision percentage in accordance with regulations, not taking into account the impact of carrying capacity on operation of structures in water reservoir hydrosystem. The main goal of the given work is to determine the impact of discharge structure carrying capacity on drawdown velocity in Tupolang water reservoir. The task is accomplished with the account of discharge and outlet structure joint operation depending on water levels in the reservoir that drawdown velocity increases from 11.98 m/day to 16.1 m/day for low levels in the reservoir in narrow canyon. For other horizons drawdown velocity in the reservoir is observed to range from 4.62 m/day to 11.63 m/day. These velocities are tens of times higher than allowable normative velocities for drawdown (0.3÷0.5 m/day), and it decreases the reliability and safety of earth fill dams in particular.

1. Introduction

Heavy growth of population, volumes of agricultural and industrial production lead to the increase of water resource consumption [1,2]. Construction of water reservoir hydrosystems [3,4,5,6] has gained popularity in order to use and manage water resources as well as to protect from detrimental action of water flow. In the consequence of water reservoir construction development dangerous phenomenon are being observed, which are related with defects in creating, operation and imperfection of structural elements of structures within hydrosystems [7,8,9]. In the recent age water reservoir hydrosystem construction has reached tremendous scales, so the potential danger from them increased proportionally [10,11].

Solution of the tasks on increasing sufficiency of water supply to agricultural lands is closely related with the efficiency of the operation of existing water reservoir hydrosystems as well as the ones which are under construction [12].

In connection with it there is an increase in the topicality of issues, related with the improvement of earth fill dam operational conditions [7,13,14,15,16], discharge structure operation reliability [17,18,19], as well as the impact of unsteady filtration on the upstream slope stability [7,20].
2. Materials and methods
The studies were carried out for the conditions of Tupolang water reservoir with the use of design and operation materials. Summarized carrying capacity curve of discharge structures (Fig.1) was used to determine discharge values, corresponding to water levels in the reservoir. Water volume and level relationship curve was divided into 10 m layers, and only the top layer was taken 11.7 m. Then water volumes corresponding to water levels were determined, the difference between upper and lower layers is the volume of water within this layer. Then, using carrying capacity vs water level relationship curve, discharge for upper and lower layer and its mean value was determined. Drainage time of the given volume from the reservoir was determined by dividing ∆W into mean discharge Qср.
Discharge velocity Vср is determined as the ratio of layer depth ∆Н to discharge time of this layer Tср.

The computation results were used to construct the curve of reservoir discharge velocity as the function of mean discharge values of discharge structures Qср and reservoir water levels. The curves were constructed using Microsoft Excel.

3. Results
It is known that design discharge, which is meant to pass through discharge structures, that is spillway, discharge, construction and operation discharge structures, are determined based on maximal discharge of structure class, which is assigned on the basis of annual probability of water supply sufficiency in accordance with regulations [21,22,23].

Catastrophic spillway in Tupolang water reservoir is only being designed and the construction spillway is combined with operational discharge.

Summarized carrying capacities for all the discharge openings in Tupolanga hydrosystem are given in Table 1.

Table 1. Carrying capacities of discharge structures.

| Q, m³/s | \( \bar{V}H_1, \text{m} \) | \( \sum_{i} h_i, \text{m} \) | \( \bar{V}WLU \) |
|---------|-----------------|-----------------|-----------------|
| 156,5   | 815,0           | 10,70           | 825,7           |
| 183,5   | 820,0           | 14,70           | 834,7           |
| 226,0   | 830,0           | 22,20           | 852,2           |
| 263,0   | 840,0           | 30,60           | 870,6           |
| 295,0   | 850,0           | 38,90           | 888,9           |
| 324,5   | 860,0           | 46,70           | 906,7           |
| 351,0   | 870,0           | 54,40           | 924,4           |
| 376,0   | 880,0           | 62,80           | 942,8           |
| 399,5   | 890,0           | 71,70           | 961,7           |

Carrying capacity vs reservoir water level relationship curves are shown in Figure 1. Using reservoir volume and surface area vs its filling relationship curve, water reservoir drainage discharge was determined for maximal carrying capacity of drainage structures ‘figure 2’
**Figure 1.** Carrying capacity curves for drainage structures

**Figure 2.** Water reservoir volume and surface area vs reservoir depth relationship curves
The computation results are presented in Table 2.

Table 2. Reservoir drainage velocities

| Lev., m | ∆H, m | W, mln.m³ | ∆W, mln.m³ | Q, m³/sek | Qdr, m³/sek | Tdr, day | Vdr, m/day |
|---------|--------|-----------|-------------|-----------|-------------|---------|------------|
| 1       | 2      | 3         | 4           | 5         | 6           | 7       | 8          |
| 961.7   | 11.7   | 500.0     | 86.0        | 400.0     | 393.3       | 2.53    | 4.62       |
| 950.0   | 10.0   | 414.0     | 64.2        | 386.6     | 379.3       | 1.96    | 5.12       |
| 940.0   | 10.0   | 348.0     | 64.1        | 372.0     | 364.9       | 2.03    | 4.93       |
| 930.0   | 10.0   | 285.7     | 53.6        | 357.8     | 351.1       | 1.77    | 5.65       |
| 920.0   | 10.0   | 232.1     | 46.6        | 344.4     | 336.7       | 1.6     | 6.25       |
| 910.0   | 10.0   | 185.5     | 35.5        | 328.9     | 321.6       | 1.28    | 7.81       |
| 900.0   | 10.0   | 150.0     | 32.1        | 314.3     | 306.5       | 1.21    | 8.26       |
| 890.0   | 10.0   | 117.9     | 29.8        | 298.7     | 290.5       | 1.31    | 7.63       |
| 880.0   | 10.0   | 85.1      | 28.2        | 282.2     | 272.4       | 0.86    | 11.63      |
| 870.0   | 10.0   | 64.9      | 20.2        | 262.5     | 252.9       | 0.94    | 10.64      |
| 860.0   | 10.0   | 44.3      | 20.6        | 243.3     | 232.1       | 0.78    | 12.82      |
| 850.0   | 10.0   | 28.6      | 15.7        | 220.8     | 220.0       | 0.62    | 16.1       |
| 840.0   | 10.0   | 17.9      | 10.7        | 179.2     | 200.0       | 0.62    | 16.1       |
| 830.0   | 10.0   | 8.7       | 9.2         | 179.2     | 133.5       | 0.8     | 12.5       |
| 830.0   | 10.0   | 8.7       | 8.7         | 87.8      | 87.8        | 0.5     | 11.98      |

Based on Table 2, we construct relationship curve for reservoir drainage velocity vs mean discharge values of discharge structures ‘figure 3’ and relationship curve for reservoir discharge velocity vs reservoir water level ‘figure 4’
Figure 3. Relationship curve for reservoir drainage velocity vs mean discharge values of discharge structures.

Figure 4. Relationship curve for reservoir discharge velocity vs reservoir water level
4. Discussion
Construction of water reservoir hydrosystems has gained wide popularity around the world recently and more than 45 thousand of them are functioning in present. Nowadays 55 water reservoir and 25 mud flow reservoir hydrosystems are operating in Uzbekistan and construction of 10 additional water reservoir hydrosystems has started. Carrying capacity of drainage structures within these hydrosystems are set with the account of structure class, provision percentage in accordance with regulations. Very often due to high water demand during vegetation periods the discharge passage is performed based on maximal carrying capacity of discharge structures, which is the reason for occurrence of unsteady filtration in the dam body within hydrosystem and consequent failure of stability, reliability and safety of dam upstream slope.

The impact of discharge facility carrying capacity on water reservoir drainage velocity was analyzed for Tupolang water reservoir hydrosystem. It was determined that for design carrying capacity of drainage structures the drainage velocities can reach up to 16,1 m/day. At minimal water levels of 824,0 m and 825,0 m in the reservoir the drainage velocity increases from 11,98 m/day to 16,1 m/day due to the fact that the reservoir is located in a narrow canyon. The determined values are tens of times higher than allowable drainage velocities for upper layers, which is 0,3 m/day, for mean layers - 0,5 m/day and for lower layers – 1 m/day.

It can cause the occurrence of unsteady filtration in the core of rock fill dam of Tupolang water reservoir and decrease the reliability and safety of the water reservoir hydrosystem.

5. Conclusion
Maximal velocity of water reservoir drainage increases from 11,8 to 16,1 m/day at low water depths. It is explained with the fact that the reservoir is located in a narrow canyon, where decrease of the depth result in significant decrease of reservoir volume. The design carrying capacity of drainage structures are quite high, that is they are ten or more times higher than allowable values of 0,3÷0,5 m/day. Unsteady filtration occurs in the core of rockfill dams, directed to water reservoir, and as the result the reliability and safety of the whole hydrosystem decreases.

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