Scientific and methodological substantiation of measures for environmental management of upstream area Tupolangsky waterworks

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Abstract. For the 8.2 hectares of the Tupolang hydroscheme near the dam, the measures for its landscaping with the help of a drip irrigation system have been developed. The source of irrigation is infiltration water from the old riverbed. After natural filtration, the water is clear, without mechanical impurities, with a salinity of 0.2 g/l and a flow rate of about 50 l/s. At the end of this pipe, the head is 4 MPa, which eliminates the traditional device of the pumping station to create the required head in a closed irrigation network.
This allows the application of these irrigation systems without a pumping station and water treatment. The article presents the initial data for the calculation of drip irrigation:
1. Soils are typical gray soils, non-saline, medium loam by mechanical composition;
2. Groundwaters are at a depth of > 3 m;
3. Mass volume of soils is 1.4 t/m^3;
4. Marginal field moisture capacity (MWC) - 28 %;
5. Ultimate moisture capacity is accepted at 85 % of FWP and makes 23.8 %. And most importantly, such irrigation saves water resources.

1 Introduction

The work was carried out under a contract with the management of the Tupolang Reservoir. The commissioned objects require creating an irrigation network for their landscaping.

The peculiarity of environmental management of this zone is the need to raise water for irrigation and the prevention of erosion processes, as the ground of the planting sites is mainly bulk. The work aims to substantiate and develop measures for creating a self-pressure closed irrigation network with drip irrigation through infiltration drainage water, led by a pipe into the construction tunnel with a head of 40 MPa. This makes it possible to eliminate the construction of a pumping station, mechanize the irrigation process, and prevent erosion [1-4].

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2 Methods

In the study, the state of irrigation systems and performance indicators were used [5]. The indicators cover water supply, water use efficiency, maintenance, irrigation sustainability, environmental aspects, socio-economic situation, and management.

Important points emerge that there was no steady or linear progression in techniques across time - instances of the transfer of ideas are balanced by cases of independent development - and that the correlations between irrigation systems structures require more complex explanations than are often proposed.

Moreover, using the MASSCOTE technique (this is the search for a solution to improve irrigation management and operation and better user service) [6-11]. The necessary materials were taken from annual reports of the Regional Department of Water Management of the Surkhandarya Region, also irrigation and drainage expeditions.

3 Results and discussion

Natural conditions of Tupolang reservoir. Tupolang Reservoir was built on the Tupolang River in the Saryasia District of Surkhandarya Region. The dam area of the Tupolang reservoir includes the hydropower plant, the outlet with the discharge, the site where the construction management, directorate, and hydrospetsstroy are located, and a village of operators located in the lower part of the site. The area of landscaping is 8.2 hectares.

The area's climate is characterized by moderately short winters and very hot summers. The average annual temperature is 15.7°C. Air humidity directly depends on the hydrothermal regime; the lowest values are observed in the summer and the highest in the winter months. In the Tupolang River valley, the greatest amount of precipitation is 520 mm/year, their annual distribution is uneven, and the greatest amount is from November to May. The annual amount of evaporation is over 1000 mm/year. The main climatic indicators for Harduri and Denau weather stations are given in Table 1.

The considered site comprises rocks of the Upper Cretaceous, Neogene, and Quaternary ages. Quaternary deposits are represented by fragments of terrace Q_{IV}, composed of boulder-pebble deposits with thicknesses up to 15-20 m, boulder-pebble deposits of a floodplain, and one floodplain terrace with thicknesses of up to 25 m.

Table 1. Main climatic indicators of the object

Indicators	Months						
	I	II	III	IV	V	VI	VII
Monthly average air temperature, °C	2.4	5.4	10.5	16.5	22.0	26.3	29.2
Air humidity, mm	5.57	6.4	8.0	11.9	13.6	3.15	15.2
Relative humidity, %	71	67	65	62	53	40	42
Precipitation, mm	63	66	103	92	52	12	5
Evaporation rate, mm	58.4	42.2	40	54.8	87.4	145.9	184.1
Average wind speed, m/s	2.8	3.2	3.2	2.6	2.4	2	1.6
Number of days with strong winds	0.3	0.2	0.8	0.9	0.6	0.2	0.2

Continuation of table № 2.

Indicators	Months					For the year
	VIII	IX	X	XI	XII	
Monthly average air temperature, °C	25.8	20.9	14.9	9.9	5.2	15.7
Air humidity, mm	14.2	10.6	8.4	6.5	5.9	9.9
Relative humidity, %	46	47	54	60	70	57
Precipitation, mm	0	2	24	47	54	520
Evaporation rate, mm	206.9	199.8	157.5	115.7	80.2	1373.5
Average wind speed, m/s	1.6	1.7	1.8	2.1	2.4	2.3
Number of days with strong winds	0.06	0.0	0.2	0.2	0.5	7

According to hydrometric conditions, the site belongs to the secured groundwater outflow with a depth of occurrence > 3 m. The overall groundwater table is close to the water level in the Tupolang River bed, has a slight downstream slope, and partially follows the topography. Predominantly fractured waters are developed, fed by infiltration of atmospheric precipitation, the Tupolang river bed, and the reservoir bed. According to the chemical composition, groundwater belongs to hydrocarbonate-calcium waters with 0.1 - 0.3 g/l of dense residue.

Typical non-saline grey soils with 0-20 cm topsoil thickness and 20-30 cm humus horizon thickness, and 0,2-0,4% humus content are developed on the territory of the plot. According to mechanical composition, soils are represented by medium loams, the bulk weight is 1.4 t/m^3, wellness is 52 %, and the maximum field moisture capacity is 28 %. On the planting sites of hydropower plants and hydroelectric complexes, bulk soil of medium loams is envisaged. Water intake and choice of irrigation method and irrigation technique. During the development of the excavation under the dam body below the reservoir bed level, a one-meter steel pipe Ø 57 mm, with an outlet into the construction tunnel, which has a valve at the end, was laid to divert infiltration water from the old Tupolang river bed and the reservoir bed. The water from the pipe is clean, without precipitation, with a salinity of about 0.2 g/l, and is used by construction workers as drinking water. At different reservoir filling, the head at the end of the pipe practically does not change and at measurement is 4.0 MPa. The water reserves are continuously replenished by infiltration through the reservoir bed, and the water flow rate can be tentatively determined by the formula:

$$Q = \omega \cdot \mu \cdot \sqrt{2gH} \quad m^3/\text{s} \qquad (1)$$

Where ω is the cross-sectional area of the pipe, m^2;

$$\omega = \frac{\pi d^2}{4} = \frac{3.14 \cdot 0.05^2}{4} = 0.00196\, m^2 \qquad (2)$$

μ is flow coefficient, with a free flow of water equal to μ = 1; g is gravity acceleration m^2/s; H is head in the pipe, H = 40 m.

$$Q = 0.00196 \cdot 1 \cdot \sqrt{2 \cdot 9.81 \cdot 40} = 0.055 \ \text{m}^3/\text{s} \qquad (3)$$

Significant head and flow, clean water without precipitation, allow drip irrigation for landscaping at the dam zone. With this method of irrigation, the process of water distribution is automated, which simplifies irrigation, and, in addition, there will be no erosion in the bulk soils.

On the levee zone, we allocated 7 plots depending on their location within the zone, the areas and names of which are given in Table 2.

Table 2. Characteristics of irrigation areas

№ sites	Location	Area, ha	Type of landscaping
I	Area GES	2.3	Lawns and garden area
II	Site between the spillway and the hydropower plant	0.4	Gardens
III	Site of the overflow	0.3	Gardens, ornamental trees
IV	Site from the water outlet to the mounting company base	0.9	Gardens
V	Plot near the canteen	0.6	Lawns and gardens
VI	Headquarters site	0.7	Lawns and gardens
VII	Operators' camp	3	Household plots and school
Итого:		8.2	

Irrigation regime of the greening zone. According to hydromodule zoning proposed by Sredazgiprovodkhlopk [2], the site belongs to the southern climatic zone Yu-II, by type of soil formation - to typical sierozem, by hydrogeological conditions - to the area "a" (provided groundwater outflow in conditions of their occurrence, not affecting soil formation), by the lithological composition of soils - III hydromodule district, III stage of development. The value of the irrigation norm and its distribution by months under surface irrigation for gardens and lawns is given in Table 3.

Let's consider a variant of landscaping using drip irrigation. Under drip irrigation, the slow water supply (drop by drop) is carried out strictly directed to the root system of plants during the whole vegetation period. A drip irrigation system allows full automation of the irrigation process; due to the absence of losses on discharge and deep filtration and strictly directed water supply, the irrigation rate is reduced by 40-60%. At the same time, with water, mineral fertilizers are supplied, and the optimum water regime is constantly maintained in the soil with moisture content corresponding to 85 % of PPV (maximum field moisture capacity). Due to creating an optimal water-air regime in the soil, crop yields increase; in particular, for orchards, the yields increase by 30-50 %.

Drip irrigation is proposed for the greening of the near-drainage zone due to the following considerations:

1. Plots of landscaping represent the bulk soil subjected to erosion processes under surface irrigation;
2. It is possible to use drainage water without pre-treatment and pumping station devices, which reduces the cost of a drip irrigation system.

The disadvantages of drip systems are the complexity of construction technology and primary material costs.

Calculation of the drip irrigation regime is based on the "Guidelines for designing, construction and operation of drip irrigation systems" VTR-P-28-81 and the manual and SNiP 2.06.03.85 Soyuzvodproekt [3].

Table 3. Distribution of irrigation norm by months and hydromodule values for Yu-II-B(a)-III

Type of landscaping	Q_p^n m^3/ha	Irrigation period	Indicators	Months					
				IV	V	VI	VII	VIII	IX
Gardens	7000	1.V – 26.IX	χ, % m, m^3/ha q, l/s ha	- - -	10 700 0.26	21 1470 0.57	28 1960 0.73	26 1820 0.68	15 1050 0.49
Lawns	10200	11.IV – 30.IX	χ, % m, m^3/ha q, l/s ha	4 408 0.24	10 1020 0.38	20 2040 0.79	25 2550 0.95	23 2346 0.88	18 1836 0.71

Initial data for calculation of drip irrigation:

Soils - typical gray soils, non-saline, medium loam by mechanical composition;

Groundwaters are at a depth of > 3 m;

Volume weight of soils is 1.4 t/m^3;

Marginal field moisture capacity (FLC) - 28 %;

Marginal moisture capacity is taken as 85 % of PPV and amounts to 23.8 %;

Absorption rate at the end of 1st hour is $v_1 = 0.03$ m/h, by the end of 4th hour – $v_2 = 0.015$ m/h.

Since the irrigation mode for gardens and lawns is different, as well as different distances between irrigation pipelines and drip heads, the calculation is done separately for each crop type.

The value of the elementary irrigation rate at strip-wetting for gardens is determined by the formula:

$$m = f \cdot \gamma \cdot b \cdot h \cdot l \cdot (\beta_{\text{ppv}} - \beta_i) \cdot K_1 \cdot K_2 \text{ , m}^3/\text{s} \qquad (4)$$

where f is the index of relative moisture;

$$f = \frac{b}{B} = \frac{2}{4} = 0.5 \qquad (5)$$

b is calculated width of the strip of the horizontal projection of moistening, we accept b= 2m;

B is width of inter-row space B = 4 m;

γ is volumetric mass of dry soil, 1.4 t/m^3;

h is calculated depth of moistening, for trees h = 1 m;

l is wetted length unit, l = 4 m;

β_{ppv} is marginal field moisture capacity in fractions of volume $\beta_{ppv} = 0.28$

β_i is pre-infiltration moisture content accepted as 85 % of PPV; $\beta_i = 0.238$

K_1 is coefficient, depending on the type of cultivated crop and climatic zone $K_1 = 0.65$ for orchards in Yu-II [2];

K$_2$ is coefficient depending on soil and meliorative zone, for the region "a", soil formation type "B" and III hydromodule district K$_2$ = 1.$t_{min} = \frac{2P\alpha}{v_1+v_2}$, hour
where P is saturation of vertical soil column, calculation of depth directly under drip

$$P = \varphi \cdot H \cdot (\beta_{ppv} - \beta_i) \qquad (6)$$

φ is coefficient taking into account water consumption for the time of moisture redistribution in the soil, for medium loam φ = 1.1

$$P = 1.1 \cdot 1 \cdot (0.28 - 0.238) = 0.046\ m^3 \qquad (7)$$

α is coefficient, taking into account the drip nature of water supply, for loamy soils α=1.25

$$t_{min} = \frac{2 \cdot 0.046 \cdot 1.25}{0.03+0.015} = 2.5 \text{ hour} \qquad (8)$$

The formula calculates water consumption for elementary irrigation rate:

$$q' = \frac{K \cdot m_n}{K_2 \cdot t_p}\ , m^3/\text{hour} \qquad (9)$$

K$_1$ is evaporation loss coefficient, K$_1$ = 1.1; K$_2$ is coefficient based on soil conditions for medium loams K$_2$ = 1.2.

Calculated irrigation duration t_p is:

$$t_p = \frac{1000 \cdot m_n}{n \cdot q} = \frac{1000 \cdot 0.15}{1 \cdot 4} = 37.5 \quad \text{hour} \qquad (10)$$

q is the flow rate of "Moldavia" drip q = 4 l/h (produced by SPA SANIIRI).
Irrigation rate for drip irrigation is determined by the formula:

$$m_k = \frac{m_n \cdot 10000 \cdot K}{B \cdot \alpha} = \frac{0{,}15 \cdot 10000 \cdot 1{,}1}{4 \cdot 4} = 103\ \ m^3/ha \qquad (11)$$

- B = 4 m (the width of the row spacing);
- α = 4 m distance between rows.

Water consumption of orchards at wetting coefficient at drip irrigation f = 0.5 is determined

$$E = f \cdot m_m^n \cdot K\ ,\ m^3/ha \qquad (12)$$

where m_m^n is monthly value of irrigation rate for surface irrigation

Daily water consumption by month is:

$$E_{day}^m = \frac{E}{t}\ , m^3/ha \cdot \text{day} \qquad (13)$$

t is duration of irrigation in given month (at surface irrigation).
Inter-irrigation period under drip irrigation is determined:

$$t_k = \frac{m_k}{E_{day}^m}\ , \text{ day} \qquad (14)$$

Number of waterings in each month:

$$n = \frac{t}{t_k} \tag{15}$$

Results of the calculation of the drip irrigation regime of orchards are given in Table 4.

Table 4. Irrigation regime under drip irrigation

Indicators	Months				
	V	VI	VII	VIII	IX
Monthly irrigation norm under surface irrigation, m^3/ha	700	1470	1960	1820	1050
Duration of irrigation in a month, days	31	30	31	31	25
Monthly water consumption under drip irrigation, m^3/ha	385	808	1078	1001	578
Daily water consumption m^3/hectare/day	12.4	26.9	34.8	32.2	23.1
Inter-irrigation period at drip irrigation, daily	8.3	3.8	3.0	3.2	4.5
Number of irrigations per month	4	8	10	10	6

A similar calculation of drip irrigation is carried out for lawns, where the irrigation mode at surface irrigation is taken as for alfalfa (Table 4). The distance between the irrigation pipelines is 2 m, and the distance between the droppers in the row is 2 m.
We set the value of the elementary irrigation rate at strip-wetting:

$$m_n = f \cdot \gamma \cdot b \cdot h \cdot l \cdot (\beta_{ppv} - \beta_i) \cdot K_1 \cdot K_2\,, \quad m^3/s \tag{16}$$

$$f = \frac{b}{B} = \frac{1}{2} = 0.5 \tag{17}$$

B is the calculated width of the strip width of the horizontal projection of moistening, $b = 1\,m$; B is width of inter-row space, $B = 2\,m$; h is calculated depth of moistening, $h = 0.7\,m$; l is wetted length unit, $l = 2\,m$; $K_1 = 0.95$ (for alfalfa); $K_2 = 1$.

$$m_p = 0.5 \cdot 1.4 \cdot 1 \cdot 0.7 \cdot 2 \cdot (0.28 - 0.238) \cdot 0.95 \cdot 1 = 0.04\,m^3/s \tag{18}$$

Minimum permissible time for pouring an elementary irrigation rate:

$$t_{min} = \frac{2P\alpha}{v_1 + v_2{}'} \quad hour \qquad\qquad P = \gamma \cdot H \cdot (\beta_{ppv} - \beta_i) \tag{19}$$

$$P = 1.1 \cdot 0.7 \cdot (0.28 - 0.238) = 0.032\,m^3 \tag{20}$$

$$\mathrm{t_{min}} = \frac{2 \cdot 0.032 \cdot 1.25}{0.03 + 0.015} = 1.78 \text{ hour} \tag{21}$$

The estimated duration of irrigation is:

$$\mathrm{t_p} = \frac{1000 \cdot \mathrm{m_n}}{\mathrm{n \cdot q}} = \frac{1000 \cdot 0{,}04}{1 \cdot 4} = 10 \text{ hour} \tag{22}$$

Obtained value t_p is more than t_min, required by absorption rate.
Determine irrigation rate for drip irrigation:

$$m_k = \frac{m_n \cdot 10000 \cdot K}{B \cdot \alpha} = \frac{0.04 \cdot 10000 \cdot 1.1}{2 \cdot 2} = 110\,m^3/\text{ha} \tag{23}$$

All calculations on lawn irrigation regime at drip irrigation are given in Table 5.

Table 5. Lawn irrigation regime under drip irrigation

Indicators	Months					
	IV	V	VI	VII	VIII	IX
Monthly irrigation norm under surface irrigation, m^3/ha	408	1020	2040	2550	2346	1836
Duration of irrigation, days	20	31	30	31	31	30
Monthly water consumption under drip irrigation, m^3/ha	224	561	1122	1402	1290	1010
Daily water consumption, m^3/hectare/day	11.2	18.1	37.4	45.2	41.6	33.7
Inter-irrigation period, day	9.8	6.1	2.9	2.4	2.6	3.3
Number of irrigations per month	2	5	11	13	12	9

4 Conclusion

We propose using drip irrigation to landscape the Tupolangsky hydro scheme's levee zone. Infiltration water is used to irrigate the dam zone, which is taken below the bottom of the reservoir by a one-meter steel pipe and is led by a pipe Ø 57 mm into the construction tunnel. At the end of this pipe, the head is 4 MPa, so the traditional pumping station device to generate the required head in a closed irrigation network is dispensed with. At a flow rate Q=15 l/s, and a head of 4 MPa, a cantilever pump K = 80-50-200A with a power of 11 kW is required. Regarding vegetation period T = 183 days and round-the-clock operation of the pumping station, we will need 48312 kWt/h annually.

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