DESIGN AND EFFICIENCY ASSESSMENT OF A DRIP IRRIGATION SYSTEM FOR COTTON IN THE CONDITIONS OF TASHKENT REGION

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Abstract. *This paper presents a scientific study on the design of a drip irrigation system for cotton cultivation on an 8-hectare field at the "Shukrullo-Yasmina Agro" farm, located in the Bo'ka district of Tashkent region. The research addresses the calculation of irrigation norms, hydraulic analysis of pipelines, selection of optimal pipe diameters, determination of pressure losses within the system, and criteria for selecting the appropriate pump model. The findings provide a comprehensive basis for the effective planning and implementation of drip irrigation in cotton farming under the local conditions of Tashkent region.*

Keywords: *drip irrigation, irrigation norm, modular plots, hydraulic calculation, pressure loss, irrigation system components, water consumption, computational layer, volumetric soil weight, field capacity, irrigation schedule.*

Introduction: In the context of global climate change and the decreasing availability of water resources, the rational use of water in agriculture has become one of the most pressing challenges of our time. Therefore, by widely implementing modern water-saving irrigation technologies, it is necessary not only to manage water resources efficiently but also to ensure high and stable yields of the main crops cultivated in the country.

To address these issues and promote the efficient use of existing water resources, several regulatory measures have been adopted in Uzbekistan. These include the Decree of the President of the Republic of Uzbekistan No. PF-6024 dated July 10, 2020, "On Approval of the Concept for the Development of Water Management in the Republic of Uzbekistan for 2020–2030," the Presidential Decree No. PQ-107 dated April 1, 2023, "On Measures to Promote the Introduction of Water-Saving Technologies in Agriculture," and the Decree No. PQ-344 dated September 30, 2024, "On the Organization of the Agro-Industrial Development Agency under the Ministry of Agriculture."

These legal frameworks prioritize the widespread adoption of drip irrigation systems under conditions of water scarcity to significantly reduce water consumption, provide economic incentives to farms and agribusinesses that implement drip irrigation technologies, integrate advanced foreign experiences, and increase agricultural production volumes [1], [2], [3].

At the same time, new policy initiatives adopted in 2025 were aimed at further enhancing the efficient use of water. In particular, the program "Water Resources Management and Development of the Irrigation Sector 2025–2028" approved on August 15, identified the introduction of water-saving technologies in agriculture as a priority. According to the program, it is planned to implement water-efficient irrigation methods across nearly 1.4 million hectares nationwide, including the widespread adoption of drip irrigation systems on approximately 293,000 hectares [4].

Therefore, under conditions of water scarcity, the proper design of drip irrigation systems, accurate calculation of their technical parameters, and adaptation to field conditions have become one of the most urgent tasks today.

Main Section: The effective implementation of modern irrigation technologies largely depends on their proper design. The design process is carried out in three main stages:

1. Research and Survey Stage
2. Technical Calculation Stage
3. Project Documentation and Cost Estimation Stage

1. Research and Survey Stage: Before designing the system, the location, shape, dimensions, and relief of the field, as well as the presence or absence of natural and artificial obstacles, soil conditions, and hydrogeological characteristics were examined. The field location was determined using Google Earth, and preliminary data on its contours and relief were obtained. The irrigated area was found to have a regular rectangular shape, with an average slope of the “Shukrullo-Yasmina Agro” lands of approximately i = 0.015–0.03. The soil texture of the planned field was identified as medium sandy, with a groundwater table deeper than 5 meters.

2. Technical Calculation Stage: Based on the preliminary data obtained during the research and survey stage, the elements of the drip irrigation system were determined. The planned 8-hectare field was divided into three modular plots ranging from 2.2 to 3.08 hectares each. The division into three modular plots was carried out to ensure hydraulic stability, manage water consumption for each plot, maintain pressure losses in the pipelines within acceptable limits, and adapt to the specific characteristics of the field relief.

Due to the relatively small size of the modular plots, water distribution is uniform. Once the modular plots were established, the drip irrigation system was designed using a double-row layout. Drip lines with emitters of 16 mm diameter and a flow rate of 1.6 L/h were selected. The spacing between irrigation pipelines was set at 0.76 m, and the spacing between emitters along the lines was 0.3 m.

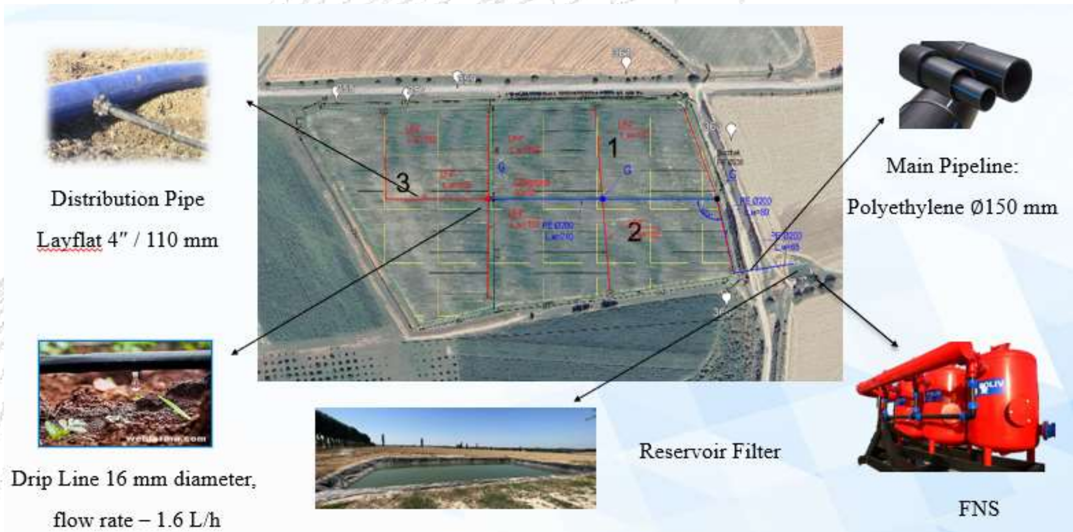


Figure 1. Scheme of the Drip Irrigation System

The locations of the filter-pump stations were determined. For the designed field, a hydrocyclone with a flow capacity of up to 100 m³/h, two sand filters each with a flow capacity of 50 m³/h, and two disc filters each with a flow capacity of 50 m³/h were selected [5].

 Hydrocyclone Filter	 Sand Filter	 Disc Filter

Figure 2. Filters Used in the Irrigation System

At the next stage, the drip irrigation norms were determined. According to the studied recommendations, for cotton cultivation under the conditions of Tashkent region, it is advised to use a pre-irrigation soil moisture (field capacity) of 70-70-60%.

In drip irrigation, the irrigation norm is determined as follows:

$$m^{net} = 100 \cdot h_x \cdot \gamma \cdot S \cdot (\beta_{ChDNS} - \beta_{\text{MAX}}),\ \text{m}^3/\text{ha}$$

bu yerda: $\boldsymbol{h_h}$– depth of the computational layer, m; depending on the cotton growth stage, $\boldsymbol{h_h}$**=0,5 m** $\boldsymbol{h_h}$**=0,7 m** $\boldsymbol{h_h}$**=0,5 m**

$\boldsymbol{\gamma}$ – volumetric soil weight, t/m^3; – for medium sandy soils, $\boldsymbol{\gamma = 1,37}$ t/m^3;

$\boldsymbol{S}$ – fraction of the total area to be wetted, S=**0,6**-0,7;

β_{ChDNS} – field capacity of soil, expressed as a percentage of the dry soil mass;

β_{ChDNS} – for medium sandy soils $\boldsymbol{\beta_{ChDNS} = 20\%}$

β_{MAX} – maximum molecular soil moisture, expressed as a percentage of the dry soil mass; $\beta_{\text{MAX}} = (0,6 - 0,8) \cdot \beta_{ChDNS} = 0,7 \cdot 20 = 14\ \%$

The irrigation norm was calculated:

$$m_{70}{}^{net} = 100 \cdot 0,5 \cdot 1,37 \cdot 0,6 \cdot (20 - 14) = 246,6\ \text{m}^3/\text{ha}$$

$$m_{70}{}^{net} = 100 \cdot 0,7 \cdot 1,37 \cdot 0,6 \cdot (20 - 14) = 345,24\ \text{m}^3/\text{ha}$$

$$m_{60}{}^{net} = 100 \cdot 0,5 \cdot 1,37 \cdot 0,6 \cdot (20 - 12) = 328,8\ \text{m}^3/\text{ha}$$

The irrigation duration is determined using the following formula: $t = \frac{m^{net}}{q_t \cdot n \cdot \eta}$; hour

here: q_t – flow rate of the emitter L/h; $q_t = 1,6$ L/h

n – number of emitters per hectare, calculated as, $n = \frac{10000}{0,76 \cdot 0,30} = 43\ 860\ units$;

$\eta = 0,98$ – water use efficiency coefficient;

$$t_{70} = \frac{246600}{1,6 \cdot 43860 \cdot 0,98} = 3,59\ hours$$

$$t_{70} = \frac{345240}{1,6 \cdot 43860 \cdot 0,98} = 5,02\ hours$$

$$t_{60} = \frac{328800}{1,6 \cdot 43860 \cdot 0,98} = 4,78\ hours$$

At the next stage, the calculated water consumption of the drip irrigation networks was determined.

1. Water consumption of the irrigation pipeline:

$$Q^{net}_{pipeline} = n \cdot q_{emit} = 1{,}6 \cdot 433 = 692 \text{ L/h} = 0{,}2 \text{ L/s}$$

Where: q_{emit} – flow rate of a single emitter, L/h; $q_{emit} = 1{,}6$ L/h

n – number of emitters;

$$n = \frac{l_{pipeline}}{a} = \frac{130}{0{,}3} = 433 \text{ units}$$

2. Determination of Water Flow in the Distribution Pipeline:

$$Q^{net}_{d.p} = Q^{net}_{pipeline} \cdot n_{pipeline} = 0{,}2 * 132 \cdot= 26{,}4\ L/s$$

Where: $n_{pipeline}$ – number of irrigation pipelines supplied by the distribution pipeline, units; $n_{s.q} = \frac{l_{irrigation}}{a} = \frac{100}{0{,}76} = 132$ units

3. Water Flow in the Main Pipeline:

$$Q^{net}_{main\ pipeline} = Q^{net}_{distribution} \cdot n_{distribution} = 26{,}4 * 1 = 26{,}4 \text{ L/s}$$

Where: $n_{distribution}$ – number of distribution pipelines simultaneously supplied by one main pipeline, units;

For the 8 hectares allocated for drip irrigation, water is supplied through a single main pipeline. Therefore, it is possible to provide simultaneous water supply to all areas irrigated from this main line.

The design (gross) water discharge for all pipelines is determined as follows:

$$Q^{br}_{pipeline} = \frac{Q^{net}_{pipeline}}{\eta_{pipeline}} = \frac{0{,}2}{0{,}998} = 0{,}2004 \text{ L/s}$$

$$Q^{br}_{d.p} = \frac{Q^{net}_{d.p}}{\eta_{d.p}} = \frac{26{,}4}{0{,}996} = 26{,}5 \text{ L/s}$$

$$Q^{br}_{m.p} = \frac{Q^{net}_{m.p}}{\eta_{m.p}} = \frac{26{,}4}{0{,}994} = 26{,}56 \text{ L/s}$$

Here:

the efficiency of the irrigation pipelines is $\eta_{pipeline} = 0{,}998$;

the efficiency of the distribution pipelines is $\eta_{d.p} = 0{,}996$;

the efficiency of the main (magistral) pipelines is $\eta_{m.p} = 0{,}994$

Hydraulic Calculations of Drip Irrigation Pipelines. The hydraulic calculation of pressurized irrigation networks consists of determining the diameters of the pipelines.

The pipeline diameter is determined using the following formula:

$$d_{pipe} = 1{,}13\sqrt{\frac{Q^{br}_{pipe}}{v}}$$

Where: Q^{br}_{pipe}– water flow rate in the pipeline, m^3/s;

v– water velocity at the beginning of the pipeline, m/s;

The calculation results are presented in the table below

Table 1. Hydraulic Calculations of Pipelines

Pipeline Name	Water Flow, L/s	n	Material	d, mm
Irrigation Pipeline	0,2004	0,012	polietilen	16
Distribution Pipeline	26,5	–//–	–//–	110
Main Pipeline	26,56	–//–	–//–	150

The diameter of the distribution pipeline was determined as:

$$d_{dis.p} = 1{,}13\sqrt{\frac{0{,}0265}{3}} = 0{,}105 \text{ m}$$

$$d_{dis.p}^{st} = 110 \text{ mm}$$

Main Pipeline Diameter:

$$d_{m.p} = 1{,}13\sqrt{\frac{0{,}0265}{2}} = 0{,}127 \text{ m}$$

$$d_{m.p}^{st} = 150 \text{ mm}$$

The slope of the drip irrigation network pipelines along the pipeline length, which depends on the pressure loss, is determined using the following formula:

$$h_l^{pipeline} = K \cdot l_{pipeline} \cdot \Delta h = 0{,}351 * 130 * 0.15 = 6{,}84 \text{ m}$$

Where: Δh- pressure loss per 1 m of pipeline length; its value is taken from Shvilyov's table.

K – coefficient accounting for the reduction in water flow.

$$h_l^{dis.p} = K \cdot l_{dis.p} \cdot \Delta h = 1 * 100 * 0{,}058 = 5{,}8 \text{ m}$$

$$h_l^{main.p} = K \cdot l_{m.p} \cdot \Delta h = 1 * 385 * 0{,}014 = 5.4 \text{ m}$$

The local water pressure loss is determined as follows:

$$h_m = (0{,}05 - 0{,}1) \cdot h_l; \text{ m}$$

$$h_m^{pipeline} = 0{,}05 \cdot 6{,}84 = 0{,}342 \text{ m}$$

$$h_m^{distribution} = 0{,}05 \cdot 5{,}8 = 0{,}29 \text{ m}$$

$$h_m^{main} = 0{,}05 \cdot 5{,}4 = 0{,}27 \text{ m}$$

The pressure loss values in the pipelines of the drip irrigation networks are presented in the table below.

Table 2. Quantitative Values of Pressure Losses in Pipelines

T/r	Pipeline Name	Pressure Loss in Pipelines, m		
		Along the Length	Local	Total
1	Irrigation Pipeline	6,84	0,342	7,18
2	Distribution Pipeline	5,8	0,29	6,09
3	Main Pipeline	5,4	0,27	5,67
	Filter-Pump Station	-	10	10
	Total	18,04	10,9	28,9

The pressure losses along each pipeline and at the filter-pump station, based on length and local resistance, were calculated. The total pressure loss amounted to 28.9 m, and based on these calculations, a pressure loss graph was plotted.

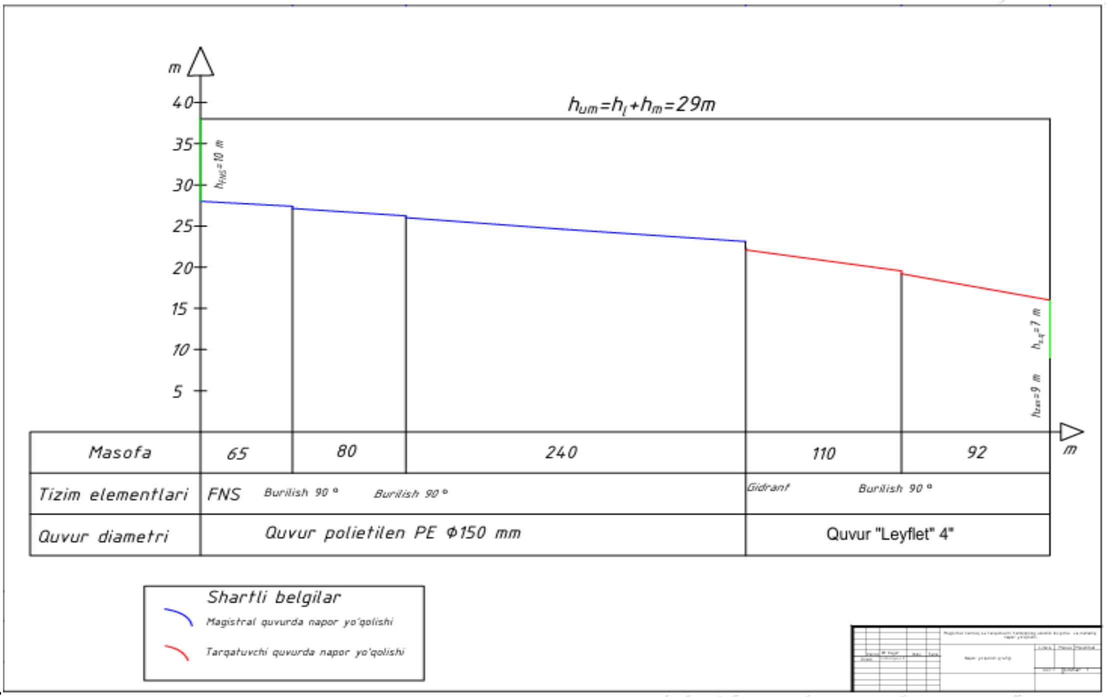


Figure 3. Pressure Loss Graph in Pipelines

Selecting the appropriate pump model is also crucial when designing a drip irrigation system. Typically, “K” type cantilever pumps are recommended for use in drip irrigation systems. Based on the calculation results, the following pump model was selected.

 Pump Model: K125-100-400b	“K” type electric pumps are suitable for water (excluding seawater) with appropriate solubility and chemical activity, containing suspended solids up to 0.2 mm. They are designed for liquids with solid admixtures, provided the volumetric concentration does not exceed 0.1%. These pumps are used in municipal, industrial, and agricultural water supply, construction, communal services, farming, as well as in mining and metallurgical industries.

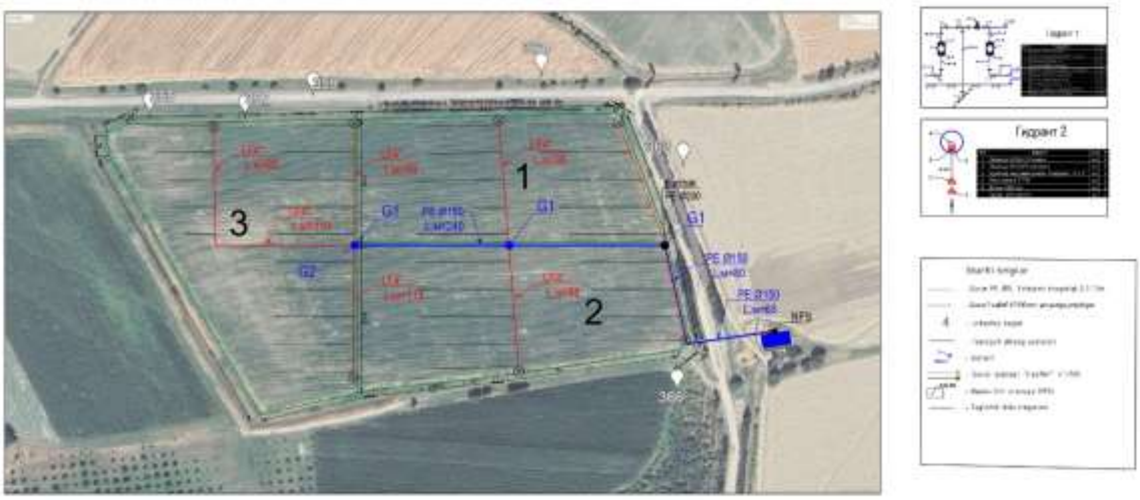
Table 3. Technical Specifications of the K125-100-400b Pump Model

Pump Model	At Present	K125-100-400b
Efficiency Coefficient	%	61
Parameters	pressure, m	38

Electric Motor	Rotational Speed, rev/min	1450
	Model	АИР160М4
	Power, kW	18.5
	Voltage, V	220/380
Overall Dimensions, mm	Pump	675x510x635
	Pump Unit	1460x510x635

3. Project Documentation and Cost Estimation Stage: At this stage, the final layout of the drip irrigation system is prepared, clearly indicating the location of the main, distribution, and irrigation pipelines, their lengths, bend points, and connection elements. In the design scheme, the pond, filter-pump station, hydrants, and pipelines, as well as their interconnections, are represented using conventional symbols.

Additionally, a list of materials required for the system construction (specification) is prepared, indicating the quantities of pipelines, connecting components, filters, main facility elements, and other accessory parts. Based on this information, the project's estimated costs are calculated. When estimating expenses, factors such as earthworks volume, labor, transportation costs, fuel consumption, and other related costs are taken into account.



Yer fondi taqsimlanishi

№ uchastka	Qishloq xo'jaligi ekin turi	Qator orasi m	Sug'orish quvuri turi	Maydon ga	Maydon suv sarfi m3/soat	Taktdagi suv sarfi m3/soat	Sug'orish takti	Sug'orish davomati 60 м3/га/сутки / 1 ga uchun
1	Paxta	0,76м СКО ч/з 0,76м	16/0,3м/1,6л	2,21	154,9	77,4	2	0,5 часа / 70,2 м3/час
2	Paxta	0,76м СКО ч/з 0,76м	16/0,3м/1,6л	2,20	154,4	77,2	4	0,5 часа / 70,2 м3/час
3	Paxta	0,76м СКО ч/з 0,76м	16/0,3м/1,6л	2,30	161,4	80,7	6	0,5 часа / 70,2 м3/час
4	Paxta	0,76м СКО ч/з 0,76м	16/0,3м/1,6л	0,78	54,7	54,7	7	0,5 часа / 70,2 м3/час

Figure 4. Layout of the Drip Irrigation System for an 8-Hectare Cotton Field

Conclusion.

As a result of the conducted project work, the optimal diameters and lengths of the main, distribution, and irrigation pipelines were determined to ensure the stable operation of the drip irrigation system on an 8-hectare area.

Accordingly, a polyethylene pipe with a diameter of 150 mm was selected for the main line, a 110 mm diameter pipe for the distribution networks with a length of 100 m, and, following a double-row layout scheme, 16 mm diameter drip pipes were laid along each row pair with a length of 130 m.

Under the conditions of medium-loam soils in the Tashkent region with a groundwater table deeper than 5 m, the optimal irrigation rates for drip irrigation of cotton were determined.

Accordingly, during the budding stage, the recommended irrigation rate is 246.6 m^3/ha, during flowering and boll formation 345.24 m^3/ha, and during ripening 328.8 m^3/ha. These rates were calculated based on the accepted effective root zone depths for the cotton growth stages (0.5 m, 0.7 m, 0.5 m), soil bulk density of 1.37 t/m^3, and the scientifically recommended field capacity prior to irrigation (CHDNS) values of 70-70-60%. According to hydraulic calculations, the total pressure loss along the main and distribution pipelines and the filter-pump station amounted to 28.9 m.

The seasonal irrigation rate using the drip irrigation method was determined to be 4036 m^3/ha, whereas with furrow irrigation it amounted to 6800 m^3/ha. This indicates that the drip irrigation system can save approximately 41% of water.

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