Development and reconstruction of district water supply systems

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Abstract. The aim of the study is to develop a methodology for the comprehensive optimization of promising schemes of water supply systems, ensuring the selection of optimal water withdrawals taking into account water quality, structure and parameters of transporting facilities, as well as operating modes. An algorithm of theoretical, practical and methodological recommendations on optimizing promising schemes of water supply systems is presented. A new optimization technique for group water supply systems is proposed, which allows the complex to solve the following problems: to optimize the location and performance of water intake structures from surface and underground water sources; to optimize installation sites, productivity and composition of water treatment facilities; choose the route of group pipelines and their optimal diameters.

1. Introduction
Our country has huge water resources. However, due to their uneven distribution in many regions, there is an acute shortage of water, and where it is available, its quality does not always meet the requirements of SanPiN 2.1.4.1074-01 and GOST “drinking water”. As a result of man-made impacts, the hydrological situation deteriorates every year, water sources are polluted with untreated sewage, and due to significant fluctuations in the level of surface and underground water, many water intakes operate on the verge of failure or are completely exposed. One of the ways to solve this problem is the construction and development of group water supply systems (WSS). A large number of such systems have already been built in the southern and central regions of our country. Many of them are complex, capital-intensive water management systems designed to transport and supply water over long distances to heterogeneous and dispersed consumers over a wide area. When designing and developing such structures, the most important tasks are:
– justification of the location and performance of water intake and treatment facilities, parameters of pumping stations and control tanks;
– selecting the optimal route and diameter of the pipeline system, taking into account the increased reliability, manageability, and seismic stability of individual structures and WSS as a whole.
– optimal allocation of investments in the reconstruction of existing and construction of new group water supply facilities.

To date, we have accumulated a wealth of experience in the design and construction of WSS, developed various methods for justifying their structure, parameters and modes of operation. However, all of them do not allow us to fully solve these problems in a comprehensive manner and therefore require further development and development of new approaches.
The existing methodology for optimal design is based on a comparison of cost, technical, reliability, and environmental characteristics of the analyzed options for the construction and operation of WSS. The main technological parameters of the designed water supply systems are taken into account through their cost in the optimization criteria, which is used to select the best option for the subsequent construction and operation of the WSS. Reliability, manageability and seismic stability are taken into account in the form of restrictions of a certain type, both on technical parameters and on investments in the construction and operation of WSS.

2. Methods

A common criterion for optimization and comparison of options is the cost of construction and operation of the WSS (by one year), which is determined by the following process [1]:

$$Z_{np} = K \cdot E + \mathcal{E}_3$$

where $Z_{np}$ – given the costs; $K$ – investments in the network; $E$ – the coefficient of efficiency of investment, which in the conditions of market economy is identified with bank interest; $\mathcal{E}_3$ – annual operating costs (thousand rubles/year), defined as follows [2,3,4]:

$$\mathcal{E}_3 = C_{am} + C_{k,p} + C_{m,p} + C_{zplk} + C_{zpln} + C_{ce} + C_{n,e} + C_{np,}.$$  

where $C_{am}$ – amortization charge (takes 0.05*K through pipelines, 0.09*K for pumping stations and surface water intake, 0.14*K for wells and underground water intakes); $C_{k,p}$ – the cost of capital repairs (0.046*K), rubles/year; $C_{m,p}$ – cost of current repairs (0.01*K), rubles/year; $C_{zplc}$ – cost of electricity, thousand rubles/year:

$$C_{zplc} = 108 \cdot z_{pl} \cdot H \cdot x,$$

where $z_{plc}$ – unit cost of electricity (rub per kWh), $x$ - the amount of conveyed water (m³/s), $H$ – the pressure pumping station (m. the height of a column.),

$C_{\phi,m}$ – payroll of service personnel per 1 km of water pipe length:

$$C_{\phi,m} = 0.75 \cdot 3\Pi_{cp} \cdot x^{0.3},$$

where $3\Pi_{cp}$ - average projected salary for the company, thousand rubles/month.; $x$, system performance, in m³/s.

$C_{ce}$ – consists of insurance contributions to the pension Fund (0.22*$C_{\phi,m}$), social insurance fund (0.029*$C_{\phi,m}$) and the health insurance fund (0.051*$C_{\phi,m}$); $C_{n,e}$ – the tax on water (thousand rubles/year) is determined:

$$C_{n,e} = 31536 \cdot C_{n,sm} \cdot x,$$

where $C_{n,sm}$ – tax rate in rubles for 1 m³ for well water, collected from surface and underground sources (in Irkutsk in 2018, this rate is 0.122 rubles per 1 m³); $C_{np}$ – other expenses, thousand rubles/year, accepted in the amount of 20% of the amount of depreciation charges ($C_{am}$) and the cost of staff salaries ($C_{\phi,m}$).

$$C_{np} = 0.2 \cdot (C_{am} + C_{zpln}),$$ or $C_{np} = 0.01 \cdot K + 0.15 \cdot 3\Pi_{cp} \cdot x^{0.3}$

Taking into account (2), the operating costs will be as follows:

$$\mathcal{E}_3 = 0.116 \cdot K + C_{zplk} + 1.125 \cdot 3\Pi_{cp} \cdot x^{0.3} + 31536 \cdot C_{n,sm} \cdot x.$$

To specify one-time (capital) costs, we will use the information provided in the consolidated construction price standards [5,6]. For outdoor water supply networks with a length of 1 km made of polyethylene pipes, when developing dry soil to a depth of 3 m (which is typical for the Irkutsk region), it is not difficult to obtain the following dependence of investment on the diameter of the pipe wire:

$$K = (27329 \cdot d^2 + 7399.5 \cdot d + 2537.9) \cdot L,$$

$K$ - capital investment, in thousand rubles., $d$ – diameter, in m.
Taking into account \( d = \sqrt{\frac{4x}{\pi v}} \); \( v \) – speed in m/s; \( x \) – flow rate in m³/s.

\[
K = 34796.4x \cdot v^{-1} + 8346.6x^{0.5} \cdot v^{-0.5} + 2537.9.
\]

(7)

Calculation of energy costs requires separate consideration. In the theory of hydraulic circuits [7], the law of energy conservation for an arbitrary hydraulic circuit is formulated as follows: “All the energy brought in, minus the energy for pouring water, is spent on overcoming friction forces”:

\[
\sum_{i=1}^{J_1} Q_i \cdot H_j - \sum_{j=1}^{J_2} Q_j \cdot P_j = \sum_{i=1}^{n} h_i \cdot x_i, \tag{9}
\]

where \( J_1 \) – a set of nodes of pumping stations, \( J_2 \) – a set of nodes of water consumption, \( H_j \) – piezometric heads of pumping stations, \( P_j \) – piezometric water heads of consumers, in m. \( h_i \) – head losses on sections of the water supply network, \( x_i \) - the flow of transported water on the network sections, \( Q_i \) – water consumption of the consumer \( j \), m³/s.

Therefore, the annual cost of electricity for the water supply system can be represented as the sum of the cost of electricity for each section of the network:

\[
C_{ЭКС} = 108 \cdot Z_{ЭКС} \cdot \mathcal{E}_i, \quad \mathcal{E}_i = h_i \cdot x_i, \text{ for } x \text{ in } m^3/s.
\]

For simplicity of presentation and calculation of pressure losses along the length of the pipeline we use the formula of F. A. Shevelev for plastic pipes [8]:

\[
h_i = 1.1 \cdot Y_i \cdot L_i, \quad Y_i = 0.001052 \cdot \frac{x_i^{1.774}}{d_i^{4.774}},
\]

where \( Y_i \) – hydraulic gradient, \( L_i \) – network segment length, in m.

\[
h_i \cdot x_i = 0.0011572 \cdot L_i \cdot \frac{x_i^{2.774}}{d_i^{4.774}}, \text{ or taking into account (7):}
\]

\[
h_i \cdot x_i = 0.000642 \cdot L_i \cdot x_i^{0.378} \cdot v_i^{2.387}.
\]

\[
C_{ЭКС} = 108 \cdot Z_{ЭКС} \cdot \left(0.000642 \cdot x_i^{0.378} \cdot v_i^{2.387} \cdot L_i \cdot 1000\right), \text{ } L \text{ in } km.
\]

The given estimated costs for the section of the network \( i \) in thousand rubles:

\[
3_{cp} = 0.236 \cdot K + C_{ЭКС} + 1.125 \cdot 3\Pi_{cp} \cdot x^{0.3}. \tag{10}
\]

As shown by the research, the optimization criterion in the form of the estimated costs shown is mainly aimed at minimizing one-time capital investments. Although it is known that the operating costs for the life cycle of water disposal systems exceed one-time investment by 10-20 times. Obviously, when justifying the project for the reconstruction and development of the WSS, it is necessary to take into account the costs of the entire life cycle of the system (LCC). For a WSS consisting of \( n \) sections, these costs over the lifetime of the system can be represented as the following terms [9-11]:

\[
C = \sum_{i=1}^{n} \left(C_{i}^{TP} + \frac{T}{(1 + r)^{T}} \cdot (C_{ЭКС}^{TP} + C_{op})\right) + \sum_{i=1}^{n} \left(C_{i}^{HC} + \frac{T}{(1 + r)^{T}} \cdot (C_{ЭКС}^{HC} + C_{op})\right) + \sum_{i=1}^{n} \left(C_{di}^{TP} \cdot (1 + r)^{T}\right),
\]

(11)

where \( C_{i}^{TP} \), \( C_{i}^{HC} \) – costs associated with the design, purchase of equipment, construction and installation of water supply systems; \( C_{ЭКС}^{TP}, C_{ЭКС}^{HC} \) – operating costs for pipelines, pumping stations, and other structures. These costs are calculated according to the guideliness [12], \( C_{op} \) – annual costs for restoring an emergency structure or network section, including the cost of delivering water to
consumers during the emergency response; $C_{3P}$ – annual energy costs for pumping water; $C_{D}$ – costs for disassembly and disposal of expired equipment; $T$ – life cycle time (the time interval corresponding to the equipment with the longest service life is accepted); $r$ – discount rate (the value of the refinancing rate CB RF, which in 2018 is 7.25%), plays the role of the base level, in comparison with which the economic efficiency of the project option is evaluated. It should be noted that for equipment with a shorter service life, a one-time investment is required $C_{I}^{TP}, C_{II}^{HC}$ increase by the multiplicity factor in relation to the equipment with the longest service life.

The life cycle costs can be represented as follows:

$$LCC = K + T \cdot \mathcal{E}_3,$$  \hspace{1cm} (12)

where $T$ - the service life of the water supply system in years is assumed to be equal to the service life of the longest-lasting element of the water supply system, $K$ – investments equal to one-time costs, plus the cost of restoring individual elements of the system whose life span is less than the estimated (multiple costs).

Taking into account the values of operating costs (4), the life cycle costs (in thousands of rubles) can be represented:

$$LCC = K + T \left(0.116 \cdot K + C_{3P} + 1.125 \cdot 3\Pi_{cp} \cdot x^{0.3}\right),$$  \hspace{1cm} (13)

or taking into account (8):

$$LCC = (34796.4 \cdot x_i \cdot v_i^{-1} + 8346.6 \cdot x_i^{0.5} \cdot v_i^{-0.5} + 25379.9) \cdot L + T \cdot [0.116 \cdot (34796.4 \cdot x_i \cdot v_i^{-1} + 8346.6 \cdot x_i^{0.5} \cdot v_i^{-0.5} + 25379.9) \cdot L + C_{3P} + 1.125 \cdot 3\Pi_{cp} \cdot x^{0.3}].$$

As a result, the given costs and life cycle costs are obtained as a function of the flow rate and speed of the transported water, the length of the pipeline and the specific cost of electricity. SP 31.13330.2012 and a number of guidelines recommend that the speed of water movement be taken in the range of 1.5-3 m/s. However, in each case, the optimal speed can be determined by calculation. To do this, you need to take a partial derivative of the reduced costs and life cycle costs by speed and equate it to zero. Then the resulting equation is resolved relative to the speed.

To select the optimal speeds, we will conduct numerical experiments on the reduced costs and life cycle costs, varying the unit values of electricity costs and pipeline lengths. The unit cost of electricity will change from the lowest for the Irkutsk region – 1.06, to the maximum for Chukotka – 8.2 rubles per kWh. the results of numerical experiments are presented in table. 1, which implies that the electricity tariff has a significant impact on the optimal speed values. The length of the networks practically does not affect the speed of water movement. The life cycle cost criterion reduces the optimal speed but 30%.

Table 1. Estimation of optimal water flow rates through pressure pipelines

| Cost of electricity, rub per KWh | Optimal water flow rate (m/s) for a flow rate of 1 m$^3$/s |
|---------------------------------|--------------------------------------------------------|
| $Z_{3P}$                        | For the reduced cost criterion | For life cycle costs (T = 50 years) |
|                                 | L = 1 km | L = 50 km | L = 100 km | L = 1 km | L = 50 km | L = 100 km |
| 1                               | 3.40     | 3.35     | 3.30       | 2.85     | 2.80     | 2.80       |
| 2                               | 2.78     | 2.74     | 2.72       | 2.31     | 2.30     | 2.30       |
| 3                               | 2.40     | 2.40     | 2.37       | 2.08     | 2.07     | 2.07       |
| 4                               | 2.23     | 2.20     | 2.20       | 1.89     | 1.89     | 1.89       |
| 5                               | 2.10     | 2.07     | 2.04       | 1.78     | 1.79     | 1.79       |
| 6                               | 2.00     | 2.00     | 1.98       | 1.70     | 1.68     | 1.68       |
| 7                               | 1.90     | 1.88     | 1.88       | 1.60     | 1.58     | 1.58       |
| 8                               | 1.80     | 1.80     | 1.78       | 1.54     | 1.50     | 1.50       |
| 9                               | 1.78     | 1.77     | 1.77       | 1.49     | 1.49     | 1.48       |
Therefore, optimal speeds can be taken in the range from 1 to 3 m/s, depending on the cost of electricity in the region for which the water supply system is being designed.

Consider the construction region of the Irkutsk region. The length of the water supply network is 1 km made of polyethylene pipes. Let's construct the functions of the reduced costs as a function of water flow, while varying the speed from 0.5 to 3.5 m/s. These functions and their linear approximations are presented in picture 1.

**Picture 1.** Dependence of the reduced costs on the flow rate and speed water flows through pipelines and their linear approximations

For life cycle costs, these dependencies are also shown in picture 2.

Similar calculations and transformations can be made for underground water intakes with treatment facilities. In recent years, with the advent of new technologies for water treatment, pumping equipment, block configuration of treatment facilities and pumping stations, their pricing policy and efficiency have changed significantly, expensive auxiliary rooms and enclosing structures are no longer required, and maintenance personnel and operating costs have been significantly reduced due to automatization. At the same time, the configuration and cost of treatment facilities depend significantly on the quality of the source water and, therefore, must be determined for each specific case.
Determine the unit cost for underground water intake from an artesian well with a depth of 100 m with a maximum flow rate of 40 m³/hour. As a result, we get a function of the following type:

\[ K = 31500.0 \times x. \]

At the same time, operating costs:

\[ \mathcal{E}_a = 0.2 \times K + C_{an} + 15 \times 3 \mathcal{P}_{cpc} \times x^{0.3}. \]

Energy costs will be as follows:

\[ C_{an} = 108 \times z_a \times 100 \times x = 10800 \times z_a \times x. \]

The estimated costs for network section \( i \), in thousands of rubles:

\[ \mathcal{E}_{ri} = 51840 \times x_i + C_{an} + 15 \times 3 \mathcal{P}_{cpc} \times x_i^{0.3}. \]

Life cycle costs:

\[ LCC = 162000 \times x_i + T \times \left( 32400 \times x_i + C_{an} + 15 \times 3 \mathcal{P}_{cpc} \times x_i^{0.3} \right). \]

Consider a sewage treatment plant for iron removal and softening (removal of calcium and magnesium salts) produced by CC “Rosa” - typical water treatment stations based on pressure filters for de-Ironing and softening. The principle of degreasing-softening is based on catalytic oxidation and filtration of impurities in the loading layer.

\[ K = 178085 \times x. \]

Operating cost:

\[ \mathcal{E}_a = 0.2 \times K + C_{an} + 15 \times 3 \mathcal{P}_{cpc} \times x^{0.3}. \]

In this case, the energy costs will be as follows:

\[ C_{an} = 108 \times z_a \times 50 \times x = 5400 \times z_a \times x. \]
The estimated costs for network section $i$, in thousands of rubles:

$$3_{np} = 56987 \cdot x_i + C_{slk} + 15 \cdot 3\Pi_{cp} \cdot x_i^{0.3}.$$  

Life cycle costs:

$$LCC = 178085 \cdot x_i + T \cdot \left(35617 \cdot x_i + C_{slk} + 15 \cdot 3\Pi_{cp} \cdot x_i^{0.3}\right).$$

For underground water intake with water treatment facilities:

$$K = 209585 \cdot x.$$

Operating cost:

$$\varnothing_3 = 0.2 \cdot K + C_{slk} + 30 \cdot 3\Pi_{cp} \cdot x^{0.3}.$$  

In this case, the energy costs will be as follows:

$$C_{slk} = 108 \cdot z_s \cdot 150 \cdot x = 16200 \cdot z_s \cdot x.$$

The estimated costs for network section $i$, in thousands of rubles:

$$3_{np} = 67067 \cdot x_i + C_{slk} + 30 \cdot 3\Pi_{cp} \cdot x_i^{0.3}.$$  

Life cycle costs:

$$LCC = 209585 \cdot x_i + T \cdot \left(41917 \cdot x_i + C_{slk} + 30 \cdot 3\Pi_{cp} \cdot x_i^{0.3}\right).$$

**Pumping plant.** Capital investment:

$$K = 498053 \cdot x.$$

Operating cost:

$$\varnothing_3 = 0.2 \cdot K + 15 \cdot 3\Pi_{cp} \cdot x^{0.3}.$$  

The estimated costs for network section $i$, in thousands of rubles:

$$3_{np} = 15377 \cdot x_i + 15 \cdot 3\Pi_{cp} \cdot x_i^{0.3}.$$  

Life cycle costs:

$$LCC = 48053 \cdot x_i + T \cdot \left(9610 \cdot x_i + 15 \cdot 3\Pi_{cp} \cdot x_i^{0.3}\right).$$

Such calculations and transformations can be made in relation to underground water intakes with or without treatment facilities and expressed as functions of the form:

$$3_{np} = C \cdot x$$  

and $LCC = C \cdot x$.

For pipelines and structures on them, the $C$ values are shown in table 2.

**Table 2.** Specific flow costs by value $1\text{ m}^3/\text{s}$

| $v$ (m/s) | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 |
|----------|-----|-----|-----|-----|-----|-----|-----|
| $C$, for pipelines, per 1 km | 18592,0 | 9870,0 | 6961,0 | 5558,0 | 4795,0 | 4381,0 | 4194,0 |
| $C$, operating costs, per 1 km | 9155,0 | 4886,0 | 3491,0 | 2858,0 | 2562,0 | 2463,0 | 2503,0 |
| $C_{well}$ | 21224,0 | | | | | | |
| $C_{treat. fac.}$ | 62731 | | | | | | |
| $C_{well} + C_{treat. fac.}$ | 83954 | | | | | | |
| $C_{u.c.}$ | 15721 | | | | | | |

For life cycle costs

| $V$ (m/s) | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 |
|----------|-----|-----|-----|-----|-----|-----|-----|
| $C$, for pipelines, per 1 km | 536405,0 | 285829,0 | 20347 | 165403,0 | 14671 | 13915  | 13923 |
| $C_{well}$ | 903675,0 | | | | | | |
| $C_{treat. fac.}$ | 2246100 | | | | | | |
| $C_{well} + C_{treat. fac.}$ | 3149800 | | | | | | |
| $C_{u.c.}$ | 545728 | | | | | | |

Taking into account the obtained dependencies, we can formulate a mathematical formulation of
the problem of optimizing the structure and parameters of group water pipes as a problem of finding the maximum flow of the minimum cost [13,14,15]:

\[ \min \sum_{i=1}^{n} C_i \cdot K_{gen} \cdot x_i \rightarrow \min , \quad \Theta_i \leq x_i \leq \Theta_i , \quad A \cdot x = q_{cp} \]  

(14)

when \( n \) – number of network sections, \( C_i \) - cost per unit of flow. For example, at a speed of 3 m/s for the reduced cost criterion, the specific flow costs will be as follows: for new pipeline sections of the network 4381.0 thousand rubles per 1m\(^3\)/s on 1 km length; for existing pipeline sections of the network (operating costs) 2463.0 thousand rubles per 1m\(^3\)/s on 1 km length; for the device of wells 21224.0 thousand rubles per 1m\(^3\)/s; for underground water intakes with water treatment system 1165500.0 thousand rubles per 1m\(^3\)/s. \( K_{gen,i} \) – total coefficient of unevenness on the network section \( i \), obtained on the basis of actual and forecast schedules of water consumption; \( x_i \) - the desired flow on a branch of a redundant or transport network; \( \Theta_i, \Theta_i \) - the lower and upper limits on the flux \( x_i \); \( A \) – matrix of connections of nodes and branches of the network; \( q_{cp} \) - vector of average water consumption expenditure, m\(^3\)/s.

To solve this problem, the following method is proposed in this paper [16, 17, 20]. A redundant scheme is being constructed, which is formed on the basis of the overlay of several pre-developed options for the construction of the WSS. The redundant scheme can represent: all possible places for water intakes (from open and underground sources) with local and centralized water treatment facilities, and without them (if the sources have drinking water quality); all possible routes for passing and supplying water to consumers by pressure pipeline sections.

The transport network is built on the basis of the received redundant scheme. To build it, all water-consuming nodes are closed using fictitious branches to a common node \( t \) – flow outlet, and water-source nodes are closed to a common fictitious node \( s \)-flow inlet. at the same time, restrictions on their throughput (upper and lower) are assigned for each section of the transport network. For fictitious stream entry branches, the upper limits correspond to the maximum possible water intake from water sources, and for fictitious stream exit branches, the upper limits correspond to the water needs of localities or subscribers. Restrictions on the flows of projected pipeline sections are not assigned. For existing sections of the network, the upper limit on flows is determined based on the optimal values of water flow rates:

\[ e = V_{opt} \cdot \frac{\pi \cdot d^2}{4} \]  

(15)

For each section of the network, the cost per unit of flow is determined and assigned. For fictitious branches of input streams, this is the cost of intake and water treatment of one m\(^3\) of water, for real pipeline sections of the network, this is the cost of transporting one m\(^3\) of water per 1 km of pipe-water. For fictitious sections of the flow outlet, costs are not assigned, or are accepted as costs for further transportation of one m\(^3\) of water to specific subscribers. For existing sections of the network, the flow unit costs correspond to operating costs.

Taking into account the transport network built in this way the problem of finding the maximum flow of the minimum cost is solved.

3. Results and discussions

As a result of optimization, the location and performance of water intake and treatment facilities, the optimal route of the pipeline system and its parameters are determined. At the same time, there are options for a fully centralized or decentralized water supply system.

Based on the proposed method, optimization calculations were performed and research was performed on the example of the Cheremkhovsk group water pipeline in the Irkutsk region. As possible sources of water supply, the following are considered: a new surface water intake from the
Belaya river (Belsk village), the water in which requires the installation of a de-Ironing, clarification, discoloration and disinfection station; an existing Cheremkhovsk channel-type water intake from the Angara river with water treatment facilities with a capacity of 85 thousand m$^3$/day (Svirsk); a new underground water intake in the village of Rysevo, where the water chemical composition mostly meets the requirements of GOST, but the flow rate of wells is insignificant (about 2.52 m$^3$/h). There is water in each locality at a depth of 80-100 m and it is possible to organize an underground water intake, but with the installation of water softening and de-Ironing stations. Taking into account possible water intakes (in almost every locality), possible pipeline sections that run along existing roads, the redundant scheme presented in picture 3 (number of consumers-33, total network consumption-0.2 m$^3$/s). Taking into account the redundant scheme, the transport scheme is made (see picture 4) and made optimization calculations. The optimal variant is obtained, which is shown in picture 5.

![Redundant scheme of the Cheremkhovsk group water supply system](image3.png)

**Picture 3.** Redundant scheme of the Cheremkhovsk group water supply system
According to picture 5, to the existing water supply system from Cheremkhovsk intake connect two additional localities: D. Camadarie and Hodorogea; he is new in water intake in p. Bielsk connect three settlements: D. Elan, Average Bulay, Keys; from the new water intake in p. Ricevo connects 8 settlements. All other localities must have local water intakes with water treatment facilities. For picture 6 shows the option chosen by the designers based on water intakes from the river. Hangar with water treatment facilities (already built for a capacity of 80 thousand m$^3$/day). For the given costs, the option shown in picture 5 was 21% more economical than the one proposed by the designers.
Picture 5. Optimal scheme of the Cheremkhovsk group water supply system
Conclusions
We propose a new method for optimizing group water pipes, which allows us to solve the following problems in a complex:
- optimize the location and performance of water intake structures from surface and underground water sources;
- to optimize the place of installation, performance and composition of water treatment facilities;
- choose the route of group pipelines and their optimal diameters.

The developed methodology and software package [19] are an effective tool for substantiating promising schemes for the development of district water supply systems and can be useful for both designers and decision-makers on the development of urbanized territories.
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