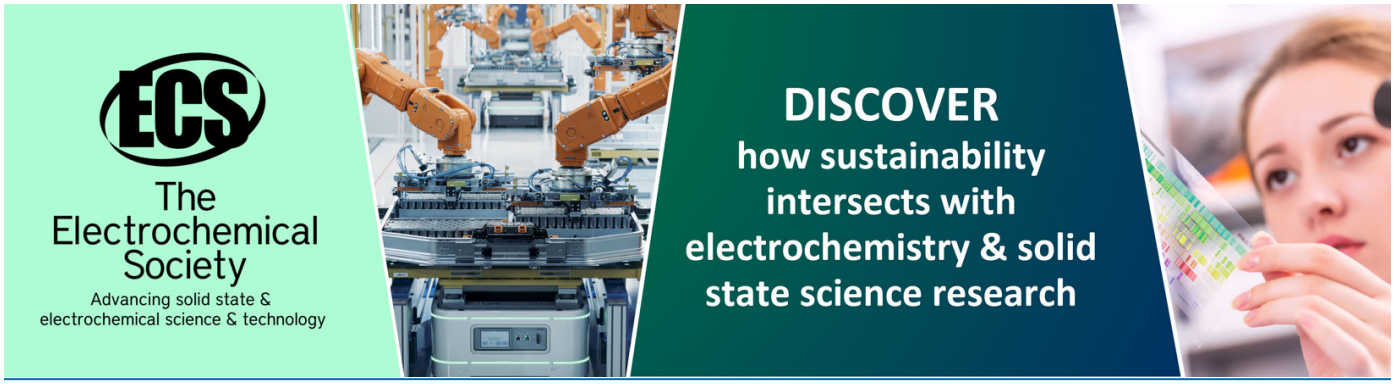
Designing an additional freshwater source infrastructure to ensure the environmental sustainability of coastal areas



IOP Conf. Series: Earth and Environmental Science **395** (2019) 012001 doi:10.1088/1755-1315/395/1/012001

Designing an additional freshwater source infrastructure to ensure the environmental sustainability of coastal areas

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Abstract. The work is based on the search for additional sources of supply of coastal areas with fresh water based on resource-saving technologies and the fundamental rationale for the design and application of the proposed structures in real time. The article identifies potential areas for the placement of aboveground and underground reservoirs of freshwater resources in the coastal areas of the Krasnodar region. The article attempts to develop an innovative project for the seasonal freshwater basin, which allows accumulating the necessary volume during the peak consumption season to meet the needs of the population. The emphasis for placing the pool is made in the mountain gorges, taking into account the geographical features of the landscape of the region. The results of the analytical analysis will subsequently help to optimize constructive solutions, with the aim of further practical implementation of reasonable and proposed measures.

1. Introduction

From the 20th century, the issue of reducing the level of fresh water supplies is considered as a global problem of our time and requires special attention to its solution, which is also extensively reflected in the scholarly literature [5, 6, 7]. This is especially true for border resort areas that need to improve the level of environmental safety. According to official statistics, more than 20% of the total population of the planet lives in an area characterized by a shortage of fresh water [8]. Most of them are in developing countries, and there this problem is based on the underdeveloped infrastructure through which water is taken from aquifers and rivers. All this makes it necessary to design new ways to increase freshwater supplies. For many decades, various ways of solving this problem were developing. This was realized through the creation of a system of aqueducts, canals, and dams, which could satisfy the needs of the population of a given territory. Designing engineering systems for the provision of fresh water allowed to get away from the dependence of the created water bodies on the geographical location of water bodies and move to the development of hard-to-reach areas of our planet. But, given the current trends and intensive population growth, the solutions developed can no longer fully cope with the full provision of fresh water.

Regions of the Krasnodar Territory belong to such problem areas, especially the coastal part with resort towns, in which water demand is particularly felt during the rest seasons. This problem can be solved by involving natural water resources based on natural sediments. At the same time, it is necessary to take into account that the mountain gorges should be chosen to accommodate additional infrastructure to provide water sources. Also, the geographical features of the landscape of the Southern Federal District must be considered.

2. Materials and Methods

The human desire to curb nature has become a conductor to the inexhaustible energy of water. 5000 years ago, unknown engineers attempted to pacify the rivers flowing through the lands of Jordan. Dams were built according to the gravitational principle of operation. They allowed to control the spill and fullness of rivers in the flood season and in the dry season.

The main peak of its development is the artificial hydraulic structures received in the period of the emergence of a new structural material (reinforced concrete) and the newly emerged problem of lack of fresh water for the population. The Hoover Dam, located on the Colorado River, is one of the most prominent structures built in the last century. The Six Companies together with the architect Gordon Kaufman acted as the main developers of the dam. The problem of fresh water also sounded in the XVI-XVII centuries. The approach to the solution laid through desalination. The scientific works of F. Bacon and R. Boyle played an undoubted role in technological developments. Their developments were limited to the study of the model of behavior under the pressure of gases in vacuum. To meet the needs of the population in fresh water, the Rosatom Corporation proposes to produce desalination using the hybrid technology, which includes thermal and membrane methods based on the installation of a nuclear power plant. The United Arab Emirates, Saudi Arabia, and other Eastern countries are the main consumers of this technology.

Each of the technologies presented above is applied depending on the qualitative and quantitative factors of the problem being solved. The algorithm for achieving the goal of designing an additional source of press water is developed by the authors of this paper (Fig. 1).

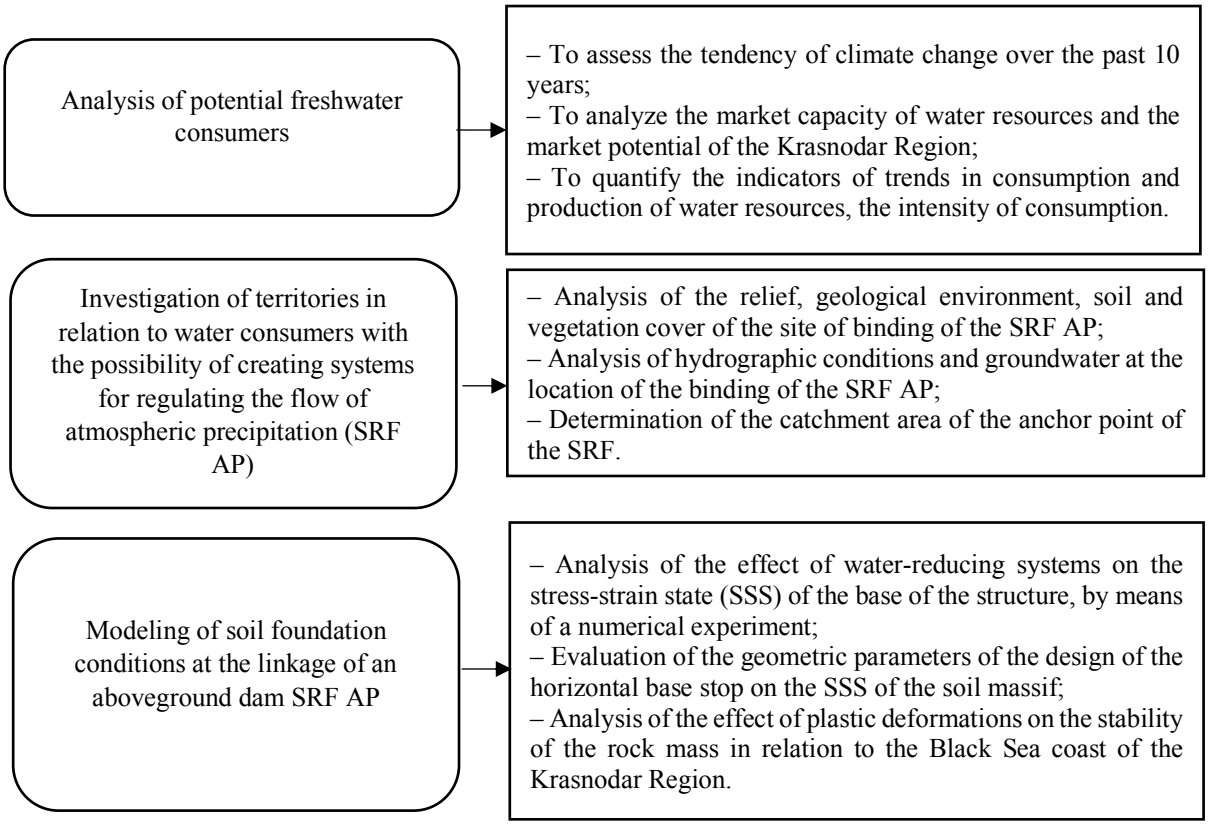


Figure 1. Methodical approaches to designing infrastructure for the supply of fresh water. Source: compiled by authors.

The methods of economic-statistical modeling, mathematical modeling, heuristic evaluation (survey of expert groups) are used for preliminary evaluation.

When designing, we use modern calculation software packages such as Stark ES and ING +, etc.

Traditional approaches to designing SCB often do not exclude filtration of accumulated water. To solve this issue, we use the advanced development and time-tested technical solutions in the field of construction chemistry of such manufacturers as PLASTFOIL, Techno Nicole, Sika, BASF, Carlisle.

3. Results

A distinctive feature of regions with densely populated areas is the excessive consumption of fresh drinking water [8]. This is especially true for the Krasnodar Region, which is part of the South Federal District. According to official data, the district occupies the last place in the overall ranking of the Russian regions in terms of the density of the river network and the lake territory [9].

Over the past few years, the water quality has dropped significantly. For the centralized sources, the inconsistency indicator for microbiological samples exceeded 10%; it reached the level of 40% for the non-centralized ones. The indicator of water resources availability in the Krasnodar Region is 17,039 thousand m3/year, which is lower than the average Russian values by 14,678 thousand m3/year. This confirms the need to find new sources of fresh water. The lowest level of precipitation is observed in September, the average value of this period remains at around 48 mm. December is characterized by significant precipitation (84 mm). As preliminary studies show, this value is sufficient for the accumulation of wastewater in the projected basin to replenish the freshwater reserves in the region.

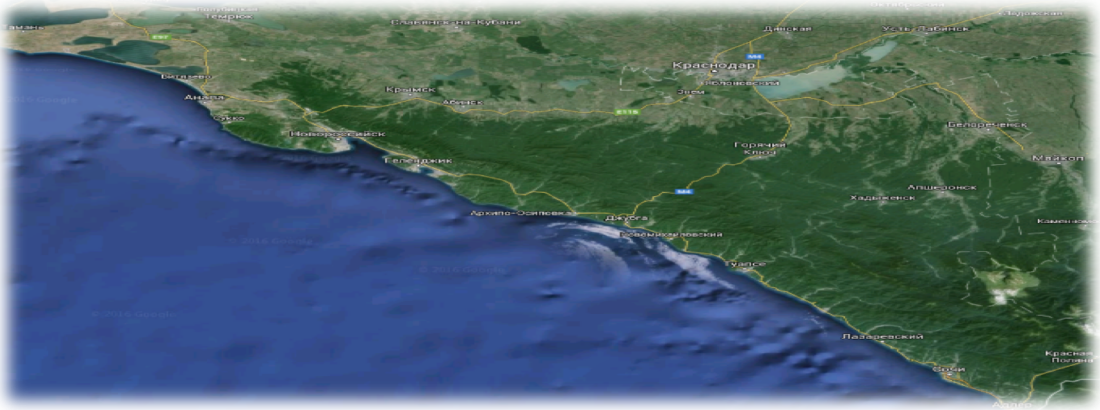


Figure 2. The study area for the design of an additional source of fresh water (Coast of the Krasnodar Region).

At the initial stage, the zone is determined for the design of the basin (Fig. 2), accumulating atmospheric precipitation (AP). Then, the volume of the proposed basin is calculated (Fig. 3).

Figure 3. Estimated Seasonal Control Basin (SCB) of precipitation.

During the next stage, a mathematical modeling of the stress-strain state (SSS) of the base-dam system is used to analyze the joint construction of the dam and foundation, taking into account the different filling levels of the seasonal control basin and the effect of seismic load on the structure (Fig. 4).

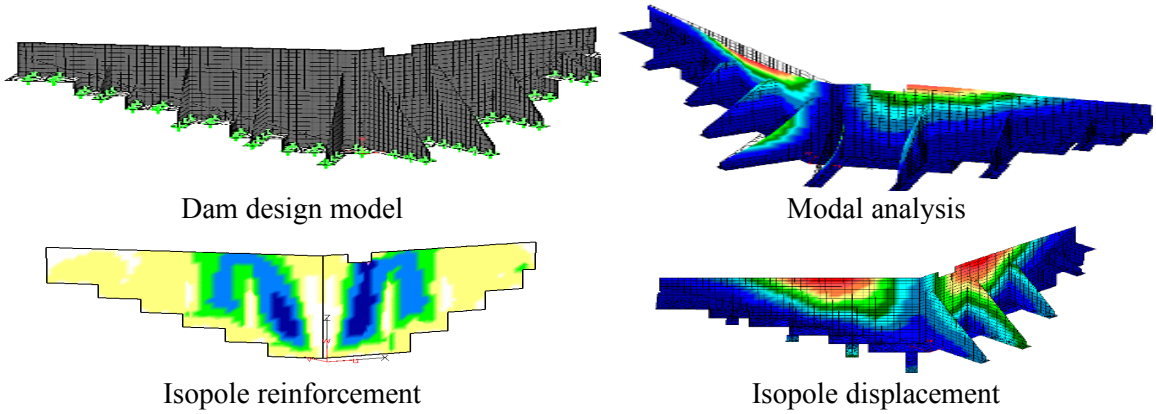


Figure 4. Mathematical modeling of the stress-strain state of the system.

Then, the level of structural and technological regulation is determined (Fig. 5).

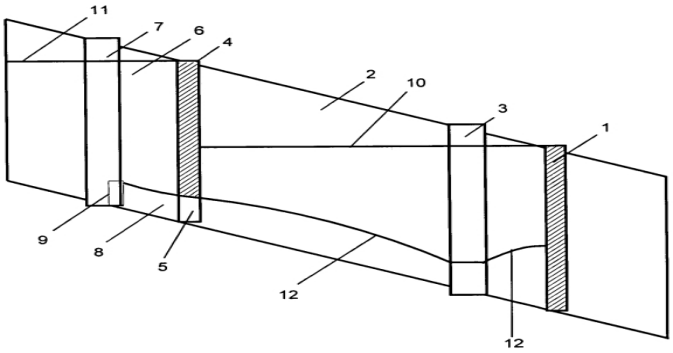
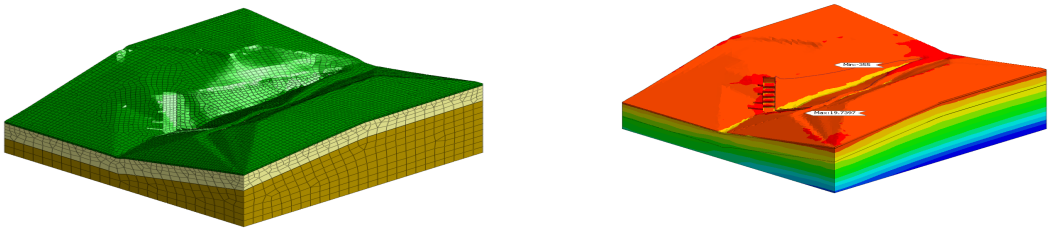


Figure 5. Scheme of constructive and technological level control.

At present, the use of digital technologies allows solving such bold tasks as accumulating precipitation runoff in an integrated way, when the joint work of the underground and above-ground reservoir as well as the ground mass are taken into account. Constructive-technological elements of the system are located on the ground massif, including in the mountainous terrain. As an example, we present the fragments of the element-by-element calculation of the SCB, which is made in the MIDASGTSNX software package. The geotechnical characteristics of the building complex and the topographical survey of the construction site are basic data for the calculation. Based on the data presented, the mathematical model of the soil massif was built in the MIDASGTSNX software package (Fig. 6a). At its base, we can calculate even the main stresses along the axis XX of the structure (Fig. 6b), which is primarily given as an example.



(a) (b)

Figure 6. Mathematical model of the soil massif.

4. Discussion

The device of traditional reservoirs is impossible in the highlands, which represents the Black Sea coast, there is not enough space for the device reservoirs. Also, the device reservoirs in these conditions is very difficult technically and technologically.

Creation of large-scale reservoirs affects the environment, has a strong impact on the landscape, microclimate, flora and fauna. The construction of a reservoir on a large river will lead to changes in its hydrological regime along the course over a hundred thousand meters. The temperature of the water, the ice regime, the flow velocity changes, the height of the wind waves increases. The SCB AP is devoid of all these shortcomings, they are set in mountain gorges. Thus, the creation of a model for the use of natural precipitation sources is of particular interest and requires further development to address the problems of providing the population with water.

5. Conclusion

Analysis of the level of freshwater availability in the region confirms the need to develop its additional sources. Using natural resources by regulating precipitation is one way. Subsequently, the results of the analytical analysis will help optimize design solutions. The achieved purpose was to maximize the economic effect of the introduced resource-saving technologies. This effect was to ensure the environmental sustainability of the territory.

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