The problem of Ararat aquifer basin and the ways of solution

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Abstract. The dynamics of water intake for different purposes from the Ararat artesian basin has been studied in connection with the overuse of water by fish farms in Ararat Valley. It has been shown that as a result of those negative processes the surface area of groundwater with positive pressure has decreased by 3 times, 31 communities are partially or completely deprived of water obtained from fountain boreholes for various purposes. As a consequence of the decline in groundwater level irrigation norms of agricultural crops have increased by 25% or about 14 million m³, the physical properties of soils have deteriorated on the area of 7 thousand hectares. It has been proposed to reuse discharge waters from fish-farms for irrigation. Through technical and economic calculations, it has been shown that in case of solar station-pump station-irrigation pipeline construction the cost price of irrigation water per 1 m³ is 8-10 times cheaper than in case of reservoir construction and irrigation water supply systems.

1. Introduction

Agriculture plays a very important role in the economy of Armenia although it depends heavily on irrigation - half the total cultivated area is currently irrigated [1]. The area suitable for agriculture comprises 1.39 million hectares 35% of which is arable agricultural land and highly dependent on irrigation [2]. Currently, the Ararat Valley occupies only 13% of the lands used for agricultural purposes, providing for about 40% of the gross agricultural output of the Republic of Armenia [3]. For years, irrigation water has been supplied from the groundwater basin by mechanical and fountain boreholes for irrigation of Ararat Valley agricultural lands [4]. It is proved that the basin groundwater inflow and outflow balance is maintained in the case of maximum 51.7 m³/sec water abstraction through boreholes (vegetation season), the minimum is 16.4 m³/sec (non-vegetation season), and the average annual water abstraction is 34.7 m³/sec.

As of 1983, total water use from the Ararat Artesian Basin was 34.6 m³/sec, including 12.9 m³/sec was taken from fountain boreholes, and 21.7 m³/sec from deep well pumps, and the groundwater abstraction for fish farming has not been implemented. In 2007, although total water use increased only by 1.8 m³/sec, however water abstraction from fountain boreholes increased sharply to 30 m³/sec or increased by 17.1 m³/sec while pump water intakes reduced sharply up to 6.4 m³/sec, which is a result of electricity tariff increase. 12.7 m³/sec of total abstraction was used for fish farming. In 2013, the process of reduction of water reserves in the Ararat Artesian basin reached its peak when the total abstraction was 55.5 m³/sec, which exceeded the approved water level by 1.6 times - 34.6 m³/sec. Out of that amount the water
abstraction only for fish farming purposes was 35.5 m$^3$/sec, which exceeded the water used for that purpose by 22.8 m$^3$/sec in 2007 [5].

It should be noted that the increase in total water abstraction was made from fountain boreholes, which is used not only for irrigation but also for drinking and domestic purposes.

As a result of the measures taken from 2013 to 2018, although the total water abstraction has reached 36.6 m$^3$/sec in 2018, which allows to stabilize the water inflow and outflow in the Ararat Artesian basin, however its effects have been maintained (Figure 2).

![Figure 2. Water use dynamic in the Ararat Artesian basin.](image)

2. Materials and methods

Ararat valley is located in the north-east of the Armenian Highland. Here is centralized main agricultural production of the country, as well as about 50% of usable groundwater resources.

During the last years the level of Artesian basin groundwater of the Ararat Valley has reduced by 15 m, which has led to a change in the qualitative composition of those waters.

Hundreds of wells have been dug since 2007 due to the unprecedented expansion of the fish farming industry, which has completely disrupted the balance of water and outflow in the Ararat Artesian Basin (Figure 1) [6].

![Figure 1. Fish farm in Ararat Valley [4].](image)
Area of groundwater under positive pressure has been reduced 3 times in Ararat artesian basin – from 32760 hectare (1983) to 10706 hectare (2013). As a result, 31 communities were partially or completely deprived of irrigation, domestic and potable water from fountain boreholes [7]. The 122 wells used for these purposes do not gush. The flow of the Sevjur River, which was 26.1 m³/sec (1983) decreased up to 3.0 m³/sec (2013). As a result of the decrease in groundwater level, crop irrigation norms have increased by 25% or about 14 million m³ on 7 thousand hectares.

The aim of this paper is to identify the main problems of Ararat aquifer basin and offer appropriate ways of solution. 2 main ways of solution have been presented in the paper.

1. Application of new water saving technologies [8]
   Among measures aimed to improve groundwater management in the Ararat Valley is the implementation of semi-closed water-saving systems in fish farms, which will reduce water abstraction volume from fountain boreholes and increase water use efficiency.
   Due to the implementation of new technologies, fish farms have two opportunities:
   
   - Keep fish production volumes unchanged and significantly reduce the volume of water used;
   - Leave the amount of water used unchanged and significantly increase fish production.

   Calculations show that capital investment for the implementation of a semi-closed system in fish farms is 3 euros per 1 kg of fish produced, and operating costs - 0.3 euros.
   Thus, in the case of Option 1, the fisherman has to invest large sums of money, but is deprived of the opportunity to recoup those costs. At the same time, production becomes extremely risky: they can lose all output as a result of power outages, so there is a need for additional investment to buy diesel generators. Thus, if such systems are imposed on fish farms, it will lead to the termination of those farms.

   It should be noted that the fish farming sector in the Republic of Armenia is a well-established business, which provided about 16381 tons of product fish in the republic in 2016, 13125 tons of which in the Ararat valley, including 7020 tonnes in Ararat region and 6105 tonnes in Armavir region. Consequently, measures in the fisheries sector should be balanced, allowing to solve environmental problems, at the same time not substantially damaging the fish farming business.

2. "Reusing discharge waters from fish-farms for irrigation [9]
   Water and soil resource use efficiency in the Ararat Valley can be increased by reducing the negative impact of mentioned factors. One of these measures is the reusing of discharge waters from fish-farms as a means of organizing financially accessible irrigation.
   A project was implemented in the Hayanist community of the Masis region with the aim of finding out the possibilities of using irrigation water from fish ponds. It has been shown that water does not have a significant adverse effect on the quality of crop yields. It has been suggested to supply the water removed from fish farms through pumping stations for irrigation of community land [7].

3. Result & discussion
   The following feasibility studies have been carried out to substantiate the effectiveness of irrigation:
   Baseline of data:
   
   - The annual water volume for irrigation is 600 mln m³, which inefficiently flows into the Araks River;
   - Irrigation period 5 months;
   - The maximum amount of irrigation in a month 120 mln m³;
   - The number of seconds per month 30*24*3600 = 2.6 mln. sec;
   - The number of seconds per day 86400 sec;
   - Water outflow in a month will be 120*10⁶ / 2.6*10⁶ = 46 mln. sec.
Output data:

- Pumped outflow 3, 5 and 8 m³/sec;
- Pumping distance 10 km;
- Pumping height 40 m;
- Diameter of pipe 1 m or 1.5 m;
- Material steel or polymer.

Calculations:
The price of 1m diameter steel pipe per meter is about 260 USD, and for the polymer pipe is about 230 USD.

In the case of 10km we’ll have respectively 2.6 mln USD and 2.3 mln USD.
The cost of 1.5m diameter steel pipe per meter is about 370-400 USD: about 4 mln USD for 10km.
Thus, along with transportation and installation costs, it will cost about 5-6 mln USD if we have 1 m diameter pipeline and in the case of 1.5 meters about 8 mln USD:

Pipeline hydraulic calculation:
Assume water outflow $Q= 5m^3/sec$, pipe diameter $d=1m$.
In this case the average velocity of water in the pipe will be:

$$V = \frac{4 \times Q}{\pi \times d^2} = \frac{20}{3.14} = 6.8 \text{ m/sec},$$

which is an unacceptable velocity, as the energy losses will be greatly increased.

If we take two pipelines with a diameter of 1m, the outflow will be split. In this case, the velocity will also be reduced by two times to $V= 3.4$ m/sec, which is again high and not preferable.

It is effective to discharge up to 1.5 m³/sec outflow in case of 1 diameter pipe. In this case, the current speed in the pipeline will not exceed 2 m/s. In both pipelines the total outflow will be 3 m³/sec.

According to the calculations of energy hydraulic losses will be about 30m in the 10km long water line. As we can see, there is a considerable loss in 1m diameter steel pipe even at 1.5 m/sec outflow. Pump pressure should cover this loss as well and raise the water to the required H height.

The same calculation is done for a 1.5 m diameter steel pipe, assuming an outflow 4 m³/sec. (both pipelines will discharge 8 m³/sec outflow). In this case the average velocity in the pipe will be:

$$V = \frac{4 \times Q}{\pi \times d^2} = \frac{16}{7.06} = 2.3 \text{ m/sec}.$$ 

In this case too, the hydraulic losses will be about 30 m.

Cost of pumping station (building, pumping equipment) will be:

- In case of 1.0 m diameter and 10 km long pair of steel pipelines (pumping outflow 3 m³/sec) 18 mln USD, including VAT,
- In case of 1.5 m diameter and 10 km long pair of steel pipelines (pumping outflow 8 m³/sec) 25 mln USD, including VAT.

These expenses increase each month with the cost of energy and pump maintenance.

For instance, a pump power will be:

$$N = 1.3 \times p \times g \times H \times Q = 1.3 \times 1000 \times 9.8 \times 40 \times 4 = 2100 \text{ kW}$$

This pump will push 4 m³/sec * 86400 sec = 346000 m³ of water in 1 day.
It will be required the construction of 6 pumping stations to push 46 m³/sec of water, with a total cost of 6*25=50 mln USD.
The total power of pumps will be 6*4200 = 25200 kW
Electricity consumption for 1 year will be 25200*24*30*5 = 90720000 kWh, the cost of which will make 90720000 kWh*35 drams = 3175200000 kW or 6.6 mln USD.
To avoid the operating costs, it is possible to build a 30 MW photovoltaic power plant with a cost of 30000 kW * 1500 USD = 45 mln USD.

Thus the total costs, including the power plant, will be 150 mln USD + 45 mln USD = 195 mln USD.

The volume of water pumped annually will be 46 m³/sec * 2.6 mln sec * 5 months = 598 million m³.

The cost of pumping 1 m³ of water will be 195 mln USD / 598 mln m³ = 0.33 USD.

4. Case study
To confirm the accuracy of the technical and economic calculations, the results of the pilot project implemented in fish farm of Samvel Lablajyan in the Hayanist community of Ararat region have been brought.

The project was funded by USAID “Advanced Science & Partnerships for Integrated Resource Development (ASPIRED)” Project, “Reusing discharge waters from fish-farms for irrigation and reclamation of saline soils in Ararat valley” project (funded by the UNDP/GEF Small Groundwater Program in Armenia), Coca-Cola Hellenic Bottling Company Armenia and Hayanist community. Construction began in September 2016 and was completed on May 22, 2017 [8].

The irrigation system consists of two horizontal pumps (one of which is a substitutional) connected to the main water line, by which water pumps into the pipeline system. The technical technical characteristics of the pumps are given in Table 1.

| Pump Power | Maximum volume of water pumped | Cost of pumped water |
|------------|--------------------------------|----------------------|
| 20 KWh     | 70 l/sec or 250 m³/h           | 3.6 AMD/m³           |

On each plot, short pipes are connected to the main water line on both sides, ending with a valve in the manhole. A total of 84 manholes were installed, which provided water to the land user. The system, with a total value of 124.2 thousand USD allows to irrigate up to 40 hectares of land.

Thus, irrigation of 40 hectares of land will require 40 hectares * 7000 m³ / ha = 280000 m³.

For 1 m³ irrigation water has been invested: 124200 USD / 280000 m³ = 0.44 USD / m³. If we add also the cost spent on electricity: 3.6 dram/m³ = 0.007 USD/m³ + 0.44 USD/m³ = 0.447 USD/m³.

The Vedi reservoir is being built for irrigation of the Ararat Valley, the technical parameters of which are.

The amount of water taken annually is 32 mln. m³, irrigated area is 3200 hectares, the cost is about 100 mln USD: 3.1 USD/m³ will be need for accumulating 1 m³ of water. So in case that from 100 mln USD of Vedi reservoir 45 mln USD was invested in the construction of a 30MV solar power plant and the pumping stations would be built with the remaining 55 mln USD, then it would be possible to irrigate at least 8 times more land or 25.6 thousand for the same expenses.

5. Conclusion
Taking into account the last 20 years of experience in the reservoir construction in the Republic of Armenia it should be noted that the cost of 1 m³ of water accumulation in the reservoir makes up 3.0 USD / m³. Thus, the costs are reduced by about 10 times in case of building a pumping station and solar station: 400 mln m³ * 20 Dram/m³ = 8000 mln Dram = 16.7 mln USD. Total costs will be rewarded in 11.7 years.

At the same time the groundwater basin will be renewed annually for 400 million m³, which will be of exceptional environmental importance.

Thus, if the volume of water pushed by deep pumps is reduced, there will be 200 mln m³ of irrigation water, which will allow additional irrigation of 20000 hectares, as well as improve irrigation efficiency throughout the Ararat Valley.
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