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Investigating of Challenges and Opportunities of an Inter-Basin Water Transfer Project (Case Study: Desalination and Water Transfer from the Oman Sea to the Three Eastern Provinces of the Iran)

Hadi Aghebat-Bekheir[a], Hamid Kardan Moghddam[b], Mohsen Pourreza-Bilondi[c*]

[a]Department of Water Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran.
[b]Water Research Institute, Ministry of Energy Water Research Institute, Tehran, Iran.
[c]Department of Water Engineering, University of Birjand, Birjand, Iran.

[*]Corresponding Author, E-mail address: Mohsen.pourreza@birjand.ac.ir
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Abstract

Water is an important element of the economic and social development of any region, and the availability of safe and clean water is one of the most important issues facing for human. As water consumption increases, the need to extract water sources and use new sources increases. Many problems related to the quantity and quality of water originates from the cities development and the increase in the urban population. On the one hand, successive droughts and the declines of groundwater tables and on the other hand, the increase in water demand have caused other approaches to be used to supply water from other basins. In this research, the opportunities and challenges of transferring water from the Oman Sea and the Persian Gulf to provide drinking water and industrial use in the three eastern provinces of Iran (South Khorasan, Razavi Khorasan, Sistan and Baluchestan) have been investigated. The spatial and temporal non-uniform rainfall in the eastern regions of the country and the increase in population growth has caused hydrological and qualitative problems in the region. There is no permanent river in the study area, and these regions need transboundary water from Afghanistan. Rainfall amount in these provinces is between 75 and 200 mm. Therefore, the majority of water supply in these areas is from groundwater resources. Also, in addition to climate change effects, high evaporation in these provinces (more than 3000 mm) is one of the most challenging issues in these three provinces, which has caused a negative water balance and water deficit and a decrease in the quality of groundwater. In current situation, the amount of extra groundwater pumping of these regions is equal to 856 million cubic meters (MCM) per year. Toward overcoming this problem, and assessing all approaches carefully, it can be said that the justification of water need for industry sectors from an economic point of view can only be achieved in the cities near the origin of the transfer (southern border areas close to the Oman Sea) and therefore, a mega project of water transfer can be redefined in such a way that it only needs to supply industrial uses for the cities close to the source.

Key words: Drought, Groundwater, Hydrological Conditions, Precipitation, Sustainable Development, Water Quantity and Quality.

1. Introduction

Water supply issue in the current situation, which is under various climate tensions, growth and development, along with increasing social welfare, has caused to increase the volume of water resource exploitation and created many problems for water supply and demand (Zhuang, 2016; Zhang et al., 2015). Iran is a country with a dry climate in the Middle East. The non-uniform temporal and spatial distribution of rainfall in the country has caused great pressure on ground water as strategic resources (Safdari et al., 2022). This problem is not only limited to Iran and other countries in the region are also running into this

problem. Climatic changes, decrease in rainfall, significant decrease in ground water level, increasing trend of global warming on the one hand and increasing population, development of new cities and megacities and expansion of water pollution on the other hand aggravate the damage caused by it. This problem has also caused it to be mentioned as one of the most important challenges of mankind. Apart from the cultural insights and the do's and don'ts that oblige man to use God's blessings correctly, there are challenges that have made it very difficult for humans to perform suitable management (e.g., water resources management). High economic and population growth, the increasing migration of rural population to cities, especially in developing countries, has significantly increased the consumption of water. The importance of this issue is greater in the regions of the world including Iran that naturally have a hot and dry climate and lack water. Unbelievable, Iran is the fourth driest country in the world with a rainfall equal to one third of the average rainfall in the world and half of the average rainfall in Asia. The average annual rainfall in the geographical area of Iran has a distribution in the range of less than 100 mm to more than 1000 mm (Beiranvard and et al., 2016).

Water treatment, Use of brackish water and rainwater harvesting systems is categorized as solutions to combat water scarcity. Additionally, inter-basin water transfer is also known as one of the most challenging approaches of water resource management to compensate for the reduction of the deficit of groundwater aquifers. Due to its importance, a number of these plans have been analyzed and investigated in different regions of the world. For many years, the city of Dakar, Senegal, supplies its water mainly from the groundwater tables around it (World Bank Group, 2022). 80% of the city's water was supplied from groundwater sources between Guires and Cabo Verde. The purpose of this project is to build a water channel that can meet the needs of the capital of Senegal. These huge water transfer projects are not in a logical response to a real need for water, but rather in the context of an unreasonable and unnecessary increase in agricultural production and extravagance in dominating nature (World Bank Group, 2022). The vision that now prevails strongly among some officials and people who are not familiar with the long-term negative effects of these plans. A similar plan was prepared for the water supply of the city of Nouakchott. In this plan, the 170-kilometer long open canal between the Senegal River and the capital of Mauritania, should fill a semi-purified water tank with a capacity of 150,000 cubic meters and an underground tank with a capacity of 5,000 cubic meters. In this way, the daily capacity of water production will increase by 3 times until 2020. This project, whose cost is provided jointly by the financial fund for the development of Africa, Kuwait and Saudi Arabia, also intends to build a water treatment plant. But some specialists are afraid that the small size of the canal network will cause water to overflow that can bring very dangerous health consequences (such as the prevalence of cholera) (Babah et al., 2016).

China is rethinking the future of the country's water to carry out engineering feats to transfer water from the highlands of Tibet to the dry Yellow River in the west of the country (Ma et al., 2006). This project is marked on the way to western Tibet, the North-South water. The project will connect to the under-construction Central and Eastern Roads, which will transport water from the Yangtze River to metropolitan Beijing through three 1,100-kilometer routes of canals and pipes at a cost of $300 billion. The first phase of the plan will include the transfer of 4 billion cubic meters of water per year equal to the capacity of the main channel of California. Also, in the future, the capacity of this project will increase to 46 billion cubic meters of water per year. Many plans for water control and transfer are being studied and implemented in this country. Transferring water project from the south to the north of China is one of the biggest projects that are being carried out. Some of the reasons for the water transfer project are listed as: the inappropriate distribution of water and soil resources (the north has susceptible land and the south has suitable water), the lowering of the groundwater table and the increase in pumping and drilling costs, land subsidence, the agriculture crops reduction and the pollution of drinking water in northern China. Among the problems of this transfer, we can mention the adverse effects on the environment (areas of

origin), the high cost of transfer and relocation of residents near the water intake and the route (200 thousand people at the water intake and 50 thousand people along the route) (Long et al., 2017). Russian authorities have prepared for the Chinese plan to build a 300-kilometer irrigation canal and siphon systems in order to collect 450 MCM of water from the Ertis River in the Siberian Plain (shared between the two countries). If this plan is not stopped, more than 2 million Russians will face with water scarcity. There are also rumors that a pipeline is being designed to take water from Russia's famous Lake Baikal to be transported to China and possibly to the Middle East and finally to the United States. Lake Baikal is the largest freshwater lake in the world, which is even larger than the five American lakes. In 2005, for the first time, Russian and Chinese scientists conducted joint environmental studies around the lake and measured its water quality (Lasserre, 2003).

In Japan, water has been transferred between regions for the purpose of irrigating rice fields for a long time. But the goal of the new plans is to supply the water needed by big cities. The most important social problem of water transfer projects in Japan is obtaining permission to build reservoirs and getting the consent of people who have to change their place of residence. Except for the big land owners, the rest of the people will suffer economically in this relocation. Another concern of people is the depletion of ground aquifers due to water transfer and reduction of river flow. At the beginning of the 20th century, the population of this city reached 1.1 million people and 50 MCM of water was transferred to this city every year. In 1935, the population increased to 5 million people and the volume of transferred water increased to 300 MCM. In early 1960, the population was 7 million people and one billion cubic meters of water was transferred to the city. In order to meet the growing needs of the city, it was decided to transfer water between basins from the Ton River. Due to the opposition of the farmers trade association, a reservoir dam was built to transfer water downstream of them in such a way that both the needs of the farmers are met and the water needed for transfer is provided (Matsuno et al., 2007). In Africa, there are also experiences regarding water transfer. For example, Libya, where a large part of it is covered by the desert and the high growth of the water demand in its coastal part has reached such a point that the country's limited water resources do not meet the growing needs. Since 1980, Colonel Muammar Gaddafi started the implementation of the largest man-made river to transport water from ancient deep mines in the Sahara. He built a huge underground pipeline with a length of about 5 thousand kilometers and spent 35 billion dollars to beautify the coastal part of Libya (Sternberg, 2016).

In India, a large pipeline is being built from the Tehri Dam (this dam is the fifth largest dam in the world and buries 42 thousand hectares of fertile land) in the Himalayas to use the limited water resources of the important Ganges River for the use of the metropolis of Delhi. This plan is in line with the proposal to connect the rivers of India through the construction of so-called super dams and the implementation of large water transfer projects through canals and pipelines. The cost of implementing this huge plan is 200 times the education cost of the country and 3 times the tax revenues of this country (Das, 2020).

One of the water transfer plans in Iran that has been criticized a lot in recent years is water transfer from the Oman Sea to the eastern provinces of the country to provide water for drinking and industry. The decrease in rainfall in the east of the country due to climate change on the one hand and the drop in groundwater tables in this region on the other hand has added to the water scarcity crisis in this region. Due to the lack of reliable surface flows, this region of the country is highly dependent on groundwater sources. In this research, an attempt has been made to investigate the strengths and weaknesses of water transfer between the aforementioned basins.

1.1.Water transfer from Oman Sea

For the implementation of this project, a total of 3,700 kilometers of pipelines will be laid and the water of the Persian Gulf and the Oman Sea will be transferred to seven provinces including Hormozgan, Kerman, South Khorasan, Razavi Khorasan, Yazd, Isfahan and Sistan and Baluchistan. The water and political conditions governing the supply and demand of water indicate the creation of

critical conditions and the occurrence of major challenge related to this issue. Therefore, the solution to deal directly with these conditions is to save as much as possible, have a look at the salt water resources of the seas and its desalination, and of course, the treatment of wastewater and its reuse. Based on this, the comprehensive study for supply and transfer of drinking water and industry of the provinces located in the eastern parts as well as the central plateau of the country with the aim of population stability, economic, social and industrial development has been investigated for several years. If the three lines of the Persian Gulf water transfer project are completed to the central plateau of Iran, a total of 550 million cubic meters of fresh water will be transferred from the Oman Sea and the Persian Gulf to the central plateau of Iran. In the initial design of the first line, it will transfer Persian Gulf water to Hormozgan, Kerman and Yazd provinces. This project, in phases one, two and three, with a length of 820 km, with 12 pumping stations, will supply the water needed by the industry section in the mentioned provinces. In the second line, the transfer of water from the Persian Gulf to the provinces of Kerman, South Khorasan and Razavi Khorasan is planned. This 1,550 km long project with 18 pumping stations supplies the eastern parts of Kerman province and the provinces of South Khorasan and Razavi. In the third line, Persian Gulf water is transferred to Yazd and Isfahan provinces. This project is 910 km long with 10 pumping stations and supplies the water needed by these provinces. Also, a fourth line is under study, in which the transfer of Oman sea water to Sistan and Baluchistan province is predicted. This 820 km long project with 11 water pumping stations will irrigate the widest province of the country.

The water of the Oman Sea and the Persian Gulf after treatment and desalinating is used for drinking and industrial purposes in eastern provinces of the country. The water requirement of the drinking sector in 2016 and in the horizon of the plan in 2041 in the cities of eastern provinces is presented in Figure 1.

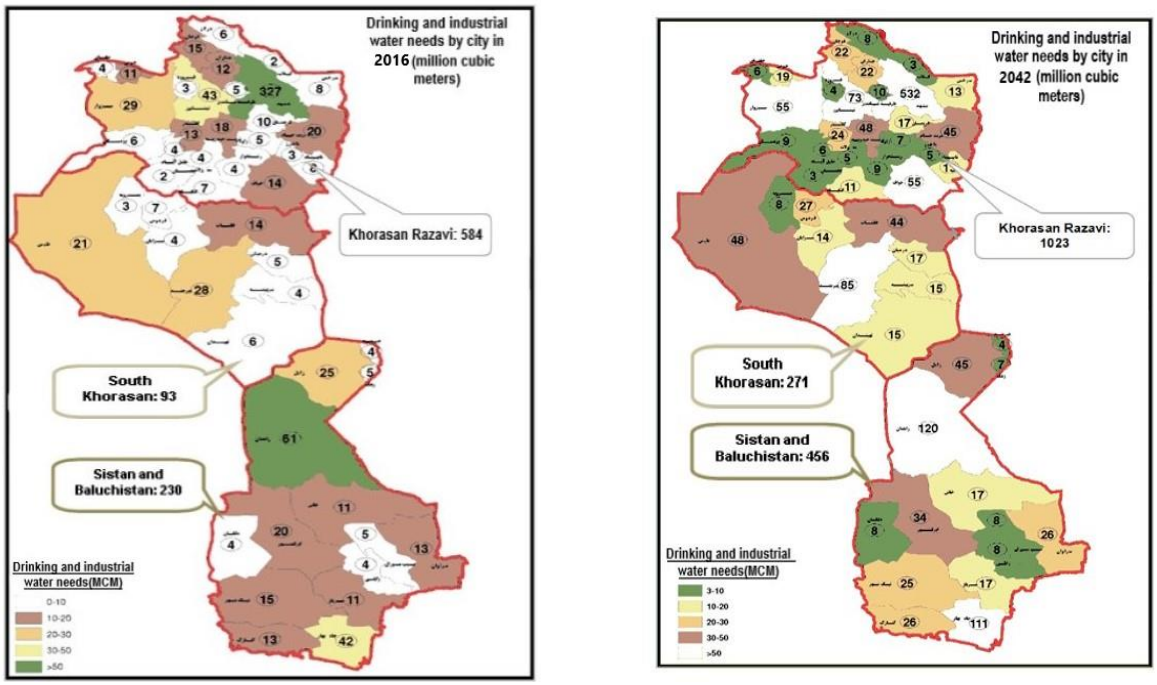

Fig.1. Water requirement of the drinking and industry sectors in the two periods of 2015 and 2040

Examining changes in water demand indicates a sharp increase in water demand in these areas and an increase in water shortages. The studies of this megaproject have been started since 2014 by the Ministry of Energy and it plans to supply water to these areas until the long-term horizon of 2070. The amount of water needed for drinking and industry in the

horizon of 2040 in the studied provinces is estimated to be 1796 million cubic meters, of which the share of Razavi Khorasan is 1068, South Khorasan is 271, and Sistan and Baluchistan is 457 million cubic meters. The water experts believe that one of the most important advantages of this plan is the high depth of the Oman Sea and its connection with the Indian Ocean, which have caused many concerns to be resolved in this area. This plan aims at optimal technical-economical use of capacity, desalination and water transfer in three stages with a capacity of 250 million cubic meters per year, therefore 750 million cubic meters of this shortage is expected to be filled in the horizon of the year 2040 through it to be supplied with water from the Oman Sea. The government authorities believe that this may cause economic prosperity and the development of water-related industries, and will provide the basis for the participation and trust of industrial owners in the private sector. According to the hydraulic calculations of the first section, the water transfer line is 585 km long and 2200 mm in diameter in Sistan and Baluchistan province, and the discharge required for drinking and industry in the medium term of this province until the horizon of 1405 is 70 million cubic meters. Further, after the delivery of drinking and industrial water of Sistan and Baluchistan, the second part of the transfer line with a diameter of 1800 mm and a length of 465 km will be the second route towards South Khorasan to the center of this province, the city of Birjand. So that 70 million cubic meters will be conveyed in Birjand city. The third section of the line, with a diameter of 1600 mm, will construct in a distance of 460 km into the center of Razavi Khorasan province and will supply a volume of 110 million cubic meters for drinking and medium-term industry in Mashhad.

2. Case study

Razavi Khorasan, South Khorasan and Sistan and Baluchistan are the eastern provinces of the Iran country, which have a hot and dry climate. The cities of Mashhad, Zahedan, Neishabur, Birjand, Zabul, Chabahar, and Sabzevar are among the important cities of this region. The issue of water and supply of water resources in Iran has become so important and challenging that it has doubled the need for very serious and strategic attention. On the other hand, the implementation of development plans in the eastern provinces of the country will only be practical if there is access to acceptable and sustainable water resources. Due to the lack of new and extractable water sources on such a scale in the region and even the adjacent internal basins, the prospect of providing this vital substance in the future is predicted to be much more ambiguous than the current situation. Finding the source of environmental problems also shows that most of these problems are directly or indirectly related to the exploitation and increase of over-mining of water resources. The drop in the groundwater level, the drying of springs and Qanat, the decline in the quality of water resources, land subsidence and the occurrence of cracks and sinkholes and salt water intrusion are among the problems that the east of the country is facing with. For example, the declining of the groundwater in the Mashhad-Chenaran plain has caused one of the highest Land Subsidence records not only in Iran but also in the world to occur in this aquifer. One of the consequences of the water and environmental crises in the east of the country is the increase in population growth, especially in Sistan and Baluchistan, the phenomenon of evacuation of villages, migration and mainly marginalization in big cities, especially Mashhad metropolis. Figure 2 shows the location of the eastern part and its characteristics. About a quarter of the urban population of Mashhad are marginal residents who have taken refuge in this city in the last 2 decades and have settled in 13% of the area of the city and its suburbs. Meanwhile, the average marginalization of the country's metropolises is one-seventh of the population. Thus, with the concentration of population in big cities, the eastern border strip of the country is depopulating. The forecast of the needs of drinking water and industry in the east of the country in the horizon of 2040 shows that, taking into account the existing resources and small scattered projects that are coming into operation up to the horizon of the plan, the three eastern provinces of the country will face with about 900 million cubic meters of drinking water supply shortage and

industry. Table 1 shows the analysis of the state of water needs in the drinking and industrial sectors in the eastern part of the country.

Fig. 2. Map of Oman Sea water transfer plan to the eastern strip provinces

Table 1. The amount of drinking water and industry needs of the eastern provinces of Iran (MCM/year)

Province	2041	2036	2031	2026	2021	2016	Requirement
Khorasan Razavi	749	698	646	593	540	496	Requirements drinking water
	273	243	211	180	128	88	Requirements industry water
	1022	941	858	773	668	584	Total water requirement
Southern Khorasan	83	74	66	59	52	45	Requirements drinking water
	188	160	132	104	75	47	Requirements industry water
	271	234	198	163	127	92	Total water requirement
Sistan and Baluchestan	271	244	217	199	181	163	Requirements drinking water
	186	163	140	116	92	67	Requirements industry water
	457	407	357	315	273	230	Total water requirement
Total	1103	1016	929	851	773	703	Requirements drinking water
	647	566	484	399	295	202	Requirements industry water
	1750	1582	1413	1250	1068	906	Total water requirement

2.1. Opportunities and challenges

Many challenges that have arisen in the field of water resources, especially groundwater, have caused the project of transferring water from the Oman Sea to the three eastern provinces be considered. In this plan, several sub-projects and tasks are defined. The completion of these actions requires investment and the creation of appropriate cultural and social infrastructures. In this case, the cost of physical measures can be reduced and also the participation of the community in these measures can be provided. Finally, by organizing people's

groups in general and users in particular, the stability of the balance of these resources is guaranteed in the long term. Figure 2 shows the view of the water transfer plan from the Oman Sea in the eastern part of the country.

Currently, an important part of the large agricultural production centers of the country are located in the critical plains, whose aquifers do not have hydrological balance. In these areas, which cover about one third of the country's plains, in order to deal with over- extraction, it is possible to issue new extraction permits for non-agricultural purposes and greenhouse uses only in a limited way and in case of implementation of special projects. It is very difficult to manage the implementation of development plans in this way, and in most cases, it has not been able to respond to the developing needs and remediate the groundwater table.

According to what is said, the following can be listed as the main advantages for desalination of sea water and its transfer to the studied areas in the eastern of the country:

A stable water source without quantitative restrictions

Not being of legal and international issues

Minimal environmental and defense problems

The possibility of meeting the needs of consumers who are located in the transition path

Of course, regarding the last case, if it is not implemented properly, it will appear as a problem and challenge. The protests of the people of the cities and villages around the transfer pipeline, which sometimes cause damage to the project and increase the cost of each cubic meter of desalinated water transferred (the experience of transferring water to Yazd, which led to the breaking of these lines for several times.)

But on the other hand, there is another important issue called the high subsidy of energy consumption, which is indirectly but very effectively related to the issue of water transfer. Iran offers the highest amount of energy subsidies in the world. Currently, the government has made a very good profit margin for industrial sector by granting high energy subsidies (natural gas used by steel and petrochemical industries). Cheap energy is the Achilles heel of the country's steel industry. The amount of this subsidy is so much that if only the price of their energy becomes 30% of world prices, they will no longer be profitable. For example, the average price per kilowatt-hour of electricity among the 37 top steel producing countries in the world is 15 euro cents, while the average price of electricity consumed in Iran's industry in 2019 is about 120 Tomans (0.4 cent of Euro) per kilowatt-hour. Regarding natural gas, its average price in 2019 among the above 37 countries was 18 euro cents, while in Iran, this number was about 2 euro cents per cubic meter of natural gas. So, if economic surgery and the process of removing subsidies (once written in the 2022 budget but not implemented for some reasons) is on the government's agenda, it can be said that it will cause problems for steelmakers from two perspectives, one is water transfer costs from thousands of kilometers and another increase in the cost per ton of steel due to the increase in natural gas rates. As a result, the problem has changed and the current need of the industry in the east of the country to transfer water at once will be significantly reduced because the economic justification of industries uses the most water such as steel is diminished.

3. Results and discussion

Iran is among the top 20 countries in the world in terms of water and energy consumption in the agricultural sector, so there must be an enormous change in the water consumption situation of our country, especially in the agricultural sector. The experience of most countries has shown that the lack of knowledge about the status of groundwater resources both at the level of users and at the level of policy makers is the missing link in the failure of governments in water scarcity adaptation programs. Most of the information about groundwater resources is technical information, but political and social information is not available in this field. The water reservoirs of the eastern provinces of Iran, which are mostly located in the eastern basin and Qara Qom, have been depleted in a severe trend in recent years, and by current trend, these provinces have

experienced a crisis in water supply. Therefore, it is necessary to pay attention to other solutions such as the use of runoff from rains and the rainwater harvesting system and increasing the productivity of agricultural water.

For example, up to now, 70% of the water needed in Mashhad metropolis was supplied through the storage of Doosti Reservoir Dam, but now, due to various reasons, including climate change and human interference outside the borders, this dam cannot be counted on anymore. Also, the drying up of the Hirmand river due to climate changes and the construction of dams in Afghanistan and the lack of proper water diplomacy has caused the drying up of the Hirmand lake and the emergence of social, environmental and economic challenges in the Sistan region. These issues caused a large deficit in the water balance of the eastern region of the country, and according to figure 3, it has shown the current situation and lack of water in the eastern provinces. Considering the continuation of the drought in the southeast and east of Iran, the increase in water demand due to population growth, land subsidence in the mentioned plains and the decrease in the level of groundwater and its effects on environmental and social issues, caused to transferring desalinated water from Oman sea to the three eastern provinces of the country for drinking water and industry sector is the most important suggestion in order to solve the problem.

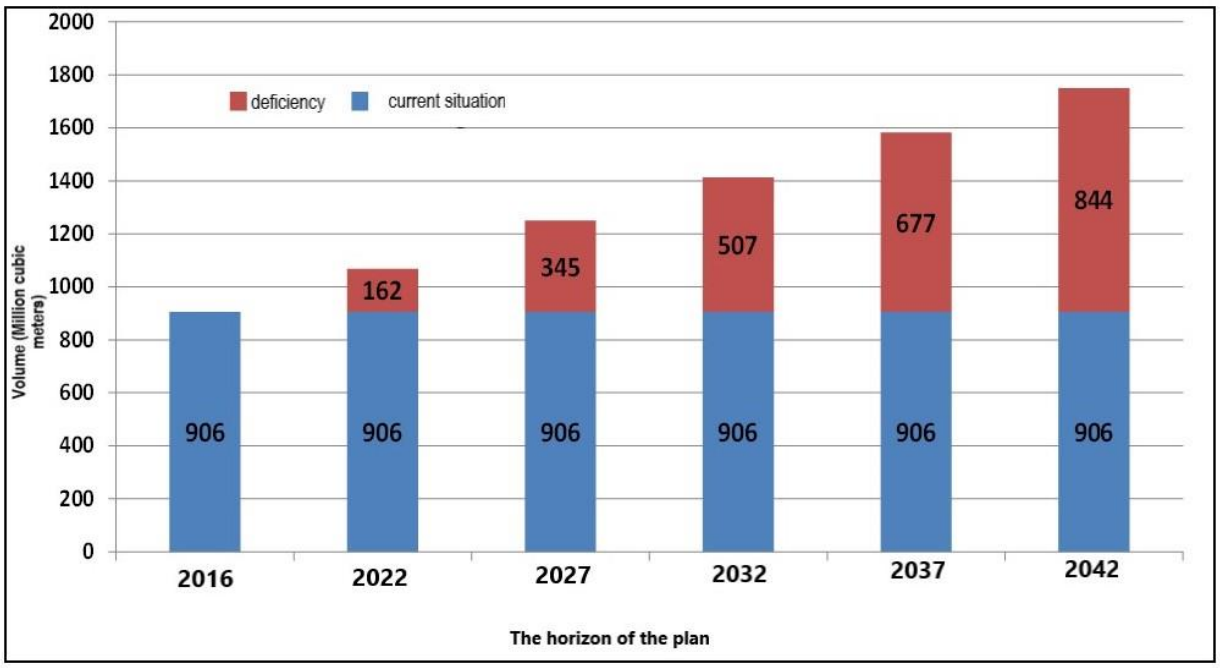

Fig. 3. Deficit in meeting the drinking and industrial needs of the eastern provinces up to the project horizon (million cubic meters)

In order to balance the groundwater resources in the eastern regions of the country, a maximum reduction of 30% of agricultural use can be scheduled. According to the growth of water demand (based on consumption in the horizon of 2040) and the need of the cities (Figure 4), about 1 billion cubic meters of water is needed for the guaranteed supply of water in these sectors. It also should be noted that this value is with considering high energy subsidies.

The result of this research shows that the economic and technical justification of inter-basin water transfer projects is one of the important elements in such projects, so that the economic situation should be evaluated from two aspects of the national economy and the regional economy. The social and environmental costs by the source basin are also very important. The advantages and disadvantages resulting from the implementation of the project in both the

source and destination basins should be fairly evaluated and analyzed.

It should also be noted that changing the ecological conditions of a region should not be more than its self-purification capacity. Caring of social and environmental rights is also one of the other fundamentals in inter-basin water transfer projects and can be effective as a criterion for examining the negative effects of these projects in reducing their social effects. In most cases, the lack of proper information about the reasons and achievements of implementing water transfer projects and the lack of clarity of their purpose has been the main reason for protests or even people's approval of such projects. Because most of the people in these areas consider the reasons for the water transfer plans to be political and not because of the existing shortages.

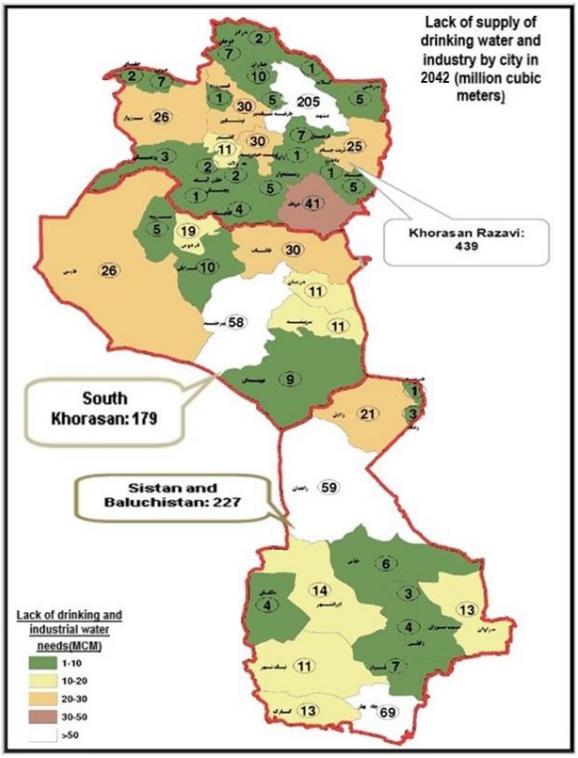

Fig. 4. Deficit in meeting the drinking and industrial needs of the eastern provinces up to the horizon of the project by city (million cubic meters)

4. Conclusion

With all the problems and challenges facing this plan, it is possible to conclude the necessity of implementing parts of the plan as follows:

The most important strength of the water transfer plan is to supply the drinking water needs of the cities of the eastern provinces of the country due to the crisis in the central and eastern aquifers of the country and the occurrence of drought. Assuming that all measures are taken to reduce urban water consumption, as well as a 30% reduction in agricultural use, due to the growth in demand for water, about one billion cubic meters is needed for reliable water supply in these sectors. By studying the distribution of this required amount of water, it is clear that most of it belongs to Razavi Khorasan province, which has the farthest distance from the source. Also, the presence of water industries in the eastern provinces is also known as the most important consumer and the biggest factor of this amount of shortage, so with the revised prices after energy subsidy removal, this amount of shortage can be highly adjusted and then actual need will reduce significantly. Therefore, it can be said that the justification of these water industries from an economic point of view can only be achieved in the cities near the origin of the transfer (southern border areas close to the Oman Sea) and therefore, the mega project of water transfer can be redefined in such a way that it

only needs to supply industrial uses for the cities close to the source. So that, the water industries in the cities further away due to the lack of economic justification (and of course environmental and social issues) should be completely out of priority. In this solution, other provinces will also be able to meet drinking water needs from different places, such as optimization in the management of agricultural consumption, water recycling methods, rain water harvesting, or flood management.

5. Disclosure statement

No potential conflict of interest was reported by the authors

6. References

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