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The Impact of the Tropical Water Project on Darbandikhan Dam and Diyala River Basin

Dana Muhammad Faraj[a] *& Kawa Zaidan*[b]

[a]*MSc. Student, Water Resources Engineering Department, University of Sulaimani, Al- Sulaimaniyiah, 46001, Iraq*
[b]*Assist. Professor, Water Resources Engineering Department, University of Sulaimani, Al- Sulaimaniyiah, 46001, Iraq*

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ABSTRACT

Iran has recently started a well-planned project, called Tropical Water Project (TWP), to build more dams, tunnels, and canals on the main tributaries of the Diyala River (Sirwan and Zmkan) to irrigate agricultural areas inside and outside the Diyala River basin. One task in the TWP project is diverting a large volume of the water flowing through the Sirwan and Zmkan rivers through a series of tunnels. The largest one, called Nowsud water conveyance tunnel, transports water from Hirwa dam to Azgala dam to irrigate millions of hectares of new agricultural areas extending from Kermanshah province in the AL Ahwaz province. This research aims to identify the different features and the size of this project as well as the extent of its impact on the Diyala River and Darbandikhan dam. From the results, it was found that the TWP project consists of 14 dams constructed on Sirwan and Zmkan rivers and their tributaries with a total storage capacity of 1.9 Milliard cubic meters and of about 150 km long tunnels to divert more than one Milliard m^3 of water to another basin. In addition, it has been found that after the full operation of the TWP project, the catchment area of Darbandikhan dam will lose 77% of its original one.

1. Introduction

About three-fifths of water flowing in all rivers is shared by two or more countries—in 263 river basins in 145 countries, where two-fifths of the world's population lives. Many countries are highly dependent on water resources that originate from outside their national territory. For example, 34% of water resources in India and 76% of water resources in Pakistan originate from outside these countries (Levy and Sidel, 2011).

The available freshwater resources around the world are becoming gradually scarce due to increase of population and higher standards of living in different areas, but also in part due to changes in land use and the global warming and global climate change and increase of demands for domestic, water supply, industrial, recreational, and irrigation purpose affect the water deficit in all of the world especially in the middle east (Dubois and others, 2011). So, for that purpose countries tried to construct large water reservoirs on their sides that serve several purposes, such as hydropower generation, irrigation control, flood control, navigation, and other flow regulation objectives and sometimes used for the political purpose as pressure by pursuing a water blockade strategy to force other countries to get involved alongside it.

Construction of a new dam on the upstream side of an old dam on the same river which is between the border of two countries (transboundary river) leads to changes in the catchment area of the old dam and decrease the rate of water inflow into it, the changes cause hydraulic and ecological changes in the rivers flowrate, resulting in a decline in water quality and difficulty in obtaining stable water (Lee et al., 2019) (Williams et al, 1984), (Batalla et al, 2004).

Many dams have been recently constructed on the Sirwan river and its tributaries inside Iran territories which have influenced the inflow rates of the Darbandikhan reservoir. In addition, the water quality of the Darbandikhan reservoir is under threat of the polluted water of the Tanjaro river which is loaded by the municipal and commercial wastewater of Sulaimani city and other towns and villages in the Sulaimani governorate (Ararat et al., 2016).

To the knowledge of the authors, there are no sufficient information about the Iranian water projects across the Diyala River basin inside Iran territories. These projects may negatively affect the water resources in Iraq, especially the Diyala River and Derbandikhan dam. This research aims to collect all the available information and data on these projects in order to help decision makers to understand the extent of the problem and to enable the researchers to study their impacts on the water resources in Iraq.

* *Corresponding author.* Tel.: +9647736989766;
E-mail address:, kawa.abed@univsul.edu.iq

2. Study area

2.1. Darbandikhan Dam (1961)

The Darbandikhan dam is a multi-purpose embankment dam built on the Diyala River. It is located 65 km southeast of Sulaimani city and 230 km North-East of Baghdad, and its boundaries extend from latitude 35° 6'- 35'' N and longitudinal 45°41'- 20'' E (Darbandikhan Dam - Wikipedia, 2018) as shown in Figure (1).

It was constructed between 1956 and 1961. Darbandikhan reservoir is a deep and large lake, it is fed by Diyala River which has four main tributaries, the Tanjaro and Zalm rivers, which originate inside Iraq territories and flows from the north/northwest, and the Sirwan and Zmkan rivers, which originate from Iran. Table (1) and Table (2) present some properties of Darbandikhan dam and its reservoir.

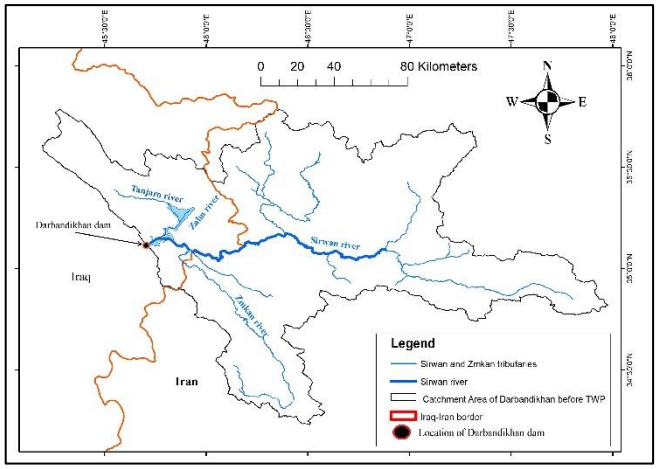

Fig. 1 Darbandikhan dam and its tributaries created using ArcMap 10.4.1.

Table 1 – Darbandikhan Dam and Spillway Properties (Darbandikhan Dam Directorate (DDD)).

Height	128 m
Length	445 m
Elevation at crest	495 m
Width (crest)	17 m
Dam volume	7,100,000 m3
Spillway type	3 control gates
Spillway capacity	11,400 m^3/s

Table 2 – Darbandikhan Reservoir Properties (DDD).

Total capacity	3,000,000,000 m^3
Active capacity	2,500,000,000 m^3
Inactive capacity	500,000,000 m^3
Catchment area	17,850 km^2
Surface area	113 km^2
Normal elevation	485 m
Turbine	3 x 83 MW Francis-type
Installed capacity	249 MW

2.2. Sirwan River

Sirwan river is one of the major tributaries of the Tigris river that originates in Iran then runs mainly through Eastern Iraq. It rises near Hamadan, in the Zagros Mountains of Iran. It then descends through the mountains, where for 32.0 Km it forms the border between the two countries (Chomani and Bijnens, 2016).

According to the official Iranian documents, the annual flow volume of Sirwan river that passes through the Daryan dam site (28.5 km far upstream of Iraq borders), is on average 3.0 milliard m^3/year. However, due to the TWP project, which involves many pumping stations and dams (i.e. Qeshlaq, Gawshan, Java, Ziviyah. Garan, Azad) upstream of the Daryan dam, about 1.20 milliard cubic meters will be deducted. So, only 1.8 milliard cubic meters will enter the reservoir of Daryan dam annually (Khabaronline News Agency, 2015).

2.3. Zmkan River

The Zmkan River is more than 50 kilometers in length originates from the village of Tut Shami in Kermanshah province, which crosses areas of the Thalath- Babajani and eventually flows into the Sirwan River (ISNA News Agency, 2014).

3. Materials and Methods

In order to have a complete idea and to get acquainted with the details of the Iranian water projects that were implemented or planned to be implemented in the Diyala River basin, we have collected relevant information and data from the official documents, interviews with the Iranian engineers and authorities and field visits etc.

3.1. The Tropical Water Project (TWP)

Iran announced plans for the largest Iranian water development project ever, the Tropical Water Project (TWP), which included many dams, hydropower projects, pump stations and diversion tunnels to be constructed inside Iran territories and especially in the Sirwan and Zmkan Rivers basin. According to the Iranian authorities, the tropical water project is one of the most important projects under construction in the western half of Kermanshah and Elam provinces, it is about 450 km long. The project has 150 km long of tunnels in various parts. The project's purpose is to prevent resident's migration, creating employments, and enhancing the region's security, social, economic and cultural indicators (Iran online Agency, 2018). Due to this project, the flow rates in the two main tributaries of the Darbandikhan dam (i.e. Sirwan and Zmkan rivers) are expected to be affected.

The first part of the project includes the Daryan dam, Nowsud diversion tunnel, Hirwa and Azgala dams (within the Sirwan and Zmkan River basin), and Jamishan, and Sharafshah, (outside of the Sirwan and Zmkan River basin). It is aimed at managing and controlling surface water and preventing floods, providing drinking and agricultural water and meeting the urgent needs of the people in the served provinces by developing the western and the southern provinces of the country (Tasnim News Agency, 2018). The first part of the project has already been finished, it is 50 kilometres long as shown in Figure (2), the water needed to irrigate 18,500

hectares of Kermanshah lands will be provided. With the completion of the project, more than one milliard cubic meters of water will be diverted from the Sirwan basin to the tropical plains annually (Iran online Agency, 2018).

The Second part of TWP project starts at Azgala dam and transport the water of Sirwan and Zmkan rivers to Kermanshah, Elam, and Al Ahwaz provinces through another series of tunnels and canals and finally the extra water will be directed towards the Iraqi's border and discharged into the surface water bodies near Al Amarah city (Pars Today Agency, 2019) as shown in Figure (3).

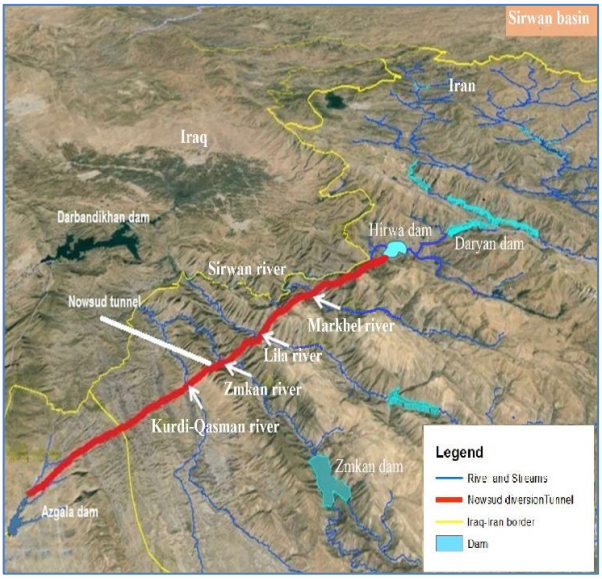

Fig. 2 First part of the tropical water project Hirwa dam to Azgala dam (Hosseini, 2017).

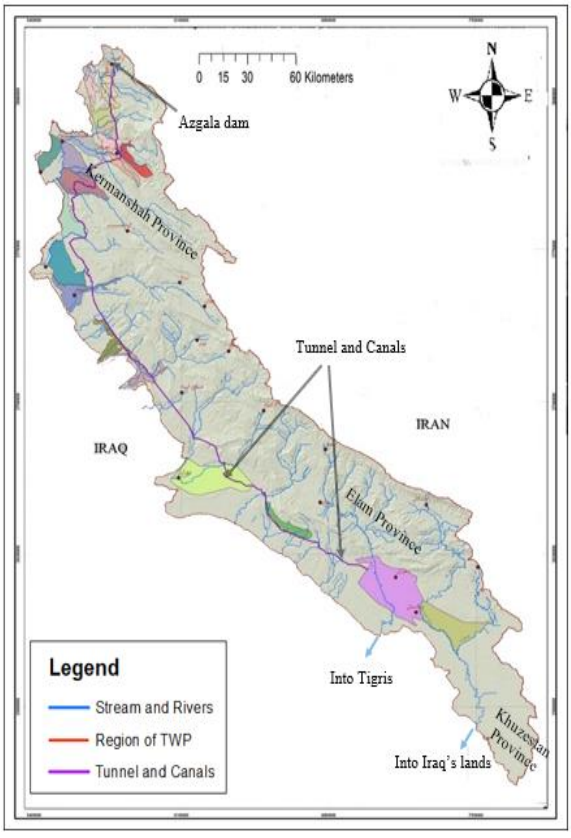

Fig. 3 Second part of the TWP (Parvez, 2017).

In the following paragraphs, the main components of the TWP project constructed on Sirwan and Zmkan rivers and their tributaries will be presented according to their construction dates.

3.1.1. Qeshlaq Dam or Wahdat Dam (1979)

It is located 12 kilometers north of the city of Sanandaj, the center of the Kurdistan province of Iran, which is constructed on Qeshlaq river with a storage capacity of 215 million cubic meters. The main purpose of the dam is to provide 90% of the drinking water of Sanandaj city and to irrigate the downstream agricultural areas (Rahmani, 2017).

3.1.2. Gawshan Dam (2004)

Gawshan dam is an embankment dam constructed to control the Gaveh river with a reservoir volume of 550 million cubic meters. The Gawshan dam has a diversion tunnel of 21 km length and a capacity of 30 m^3/sec to irrigate 31,000 hectares of fertile lands. The major purpose of this dam is to provide 183 million cubic meters per year for irrigation, 63 million cubic meters for the Kermanshah water supply system and for the production of 11 megawatts of hydropower (Talashgaran co., 2015).

3.1.3. Soleyman-Shah Dam (2006)

It is an embankment dam which is located at Sonqor, Kermanshah province, Iran. The total storage volume of Soleyman-Shah reservoir is about 50 million cubic meters and it is constructed on the river of Gaveh. Soleyman-Shah dam provides 5 to 7 million cubic meters of water per year as drinking water for Sonqor and to irrigate 2,600 hectares of agricultural lands (Mehr News-agency, 2018).

3.1.4. Azadi Dam (2012)

Azadi dam is a clay-core earth dam, which is constructed across the Zmkan river with a storage capacity of 70.47 million cubic meters. The main purpose of the dam is to supply water for irrigation of 4,400 hectares of agricultural lands and to provide 14 million cubic meter drinking water to the towns of Tazehabad, Kerend-e Gharb and Eslamabad-e-Gharb, as well as providing three million cubic meters of water to the industrial sector (Qubadi, 2018).

3.1.5. Garan dam (2013)

The Garan dam is an embankment dam constructed on the Garan River, about 15 km northeast of Marivan in Kurdistan Province, Iran. The reservoir has a storage capacity of 110,000,000 m^3. The primary purpose of the dam is to supply irrigation water for 10,450 hectare agricultural areas in Marivan County. In addition, it provides 22 million cubic meters for drinking and industrial purposes in the city of Marivan (Pooyab Consulting Engineering Co., 2018).

3.1.6. Java dam (2013)

Java dam is a concrete dam which was constructed on Sirwan river with a storage capacity of 172 million cubic meters, the dam was built to provide water for industrial uses and to irrigate 17,000 ha agriculture areas in the plains of Qorveh and Dehgolan. The Java dam uses a pipeline and 6 pumping stations to transport water (Wafai, 2013). The project is to

transport an average of 123 million cubic meters of water annually with a maximum capacity of 8 cubic meters per second through a 2000 mm diameter steel pipeline with a length of 32 kilometers (Amini et al., 2017)

3.1.7. Ziviyeh Dam (2013)

Ziviyeh dam is an embankment dam which is located 26 km northwest of Kamyaran city in Kurdistan province on the Shahini river. The total capacity of the reservoir is 17 million cubic meters with a height of 52 m. Ziviyeh dam supplies irrigation water for 2,500 hectares of agricultural areas downstream of the dam (Kurdistan Regional Water Co., 2020).

3.1.8. Azad Dam (2014)

It is an embankment constructed on Gura river (one of the Sirwan tributaries) 40 km west of Sanandaj city with a storage volume of 300 million cubic meters. The purpose of the project is to supply 190 million cubic meters of water annually for drinking, industrial and agricultural needs in the Qorveh-Dehgolan Plains, and producing 10 MW hydroelectric power (Mahabghodss Co., 2014).

3.1.9. Daryan Dam (2015)

Daryan Dam is an embankment Dam constructed on Sirwan river in Paveh County, Kermanshah Province, Iran, it is just 28.5 km away from the Iraqi border. The Construction of the dam began in 2009 and the dam began to fill its reservoir (316 million cubic meters storage capacity) in late November 2015 (Chomani and Bijnens, 2016). The Iranian officials say the dam is being built to produce 210 MW hydroelectric power and to supply water to the 48 km long Nowsud Water Conveyance Tunnel where it will irrigate areas of Southwestern Iran (Barbar, 2016).

3.1.10. Zmkan Dam (2017)

Zmkan dam, is an embankment dam constructed across the Zmkan river, In Dalahoo County, Kermanshah Province. The total volume of the reservoir is about 23.1 million cubic meters. The main goal of the Zmkan dam construction is to irrigate 531 hectares of cropland gardens and convert 1,694 hectares of drylands in Dalhousie County to green land (ISNA News Agency, 2016).

3.1.11. Hirwa Dam (2018)

Hirwa dam is a concrete diversion dam constructed on the Sirwan river only 3.0 km downstream of Daryan dam at Hirwa village of Paveh county of Kermanshah province. It is 45 m high and has a storage capacity of 12 million cubic meters. The main purpose of the dam is to manage and control the water flowrate in the Sirwan river between the Nowsud tunnel and Iraq. This dam diverts most of the water from the Sirwan river into the 48 km Nowsud diversion tunnel to be used for irrigation of the agricultural lands in the tropical regions of Kermanshah and Elam provinces (Islamic Republic News Agency, 2019).

3.1.12. Nowsud Diversion Tunnel (2018)

The Nowsud Tunnel is one of the largest western water conveyance tunnels in Iran (see Figure (2) and Figure (4)), its capacity is 70 m^3/sec. The main purpose of this tunnel is to divert the water of the rivers of Sirwan, Marakhel, Lila, Zmkan and Kurdi-Qasiman to Azgala dam as shown in Figure (4). According to the TWP plans, more than one Milliard cubic meters of water is to be diverted annually through this tunnel to Kermanshah (Azgala Dam) to provide irrigation and drinking water for the West of Kermanshah and Elam provinces (Lar Consulting Engineers Co., 2019). Table (3) shows the geometric and hydraulic properties of the tunnel.

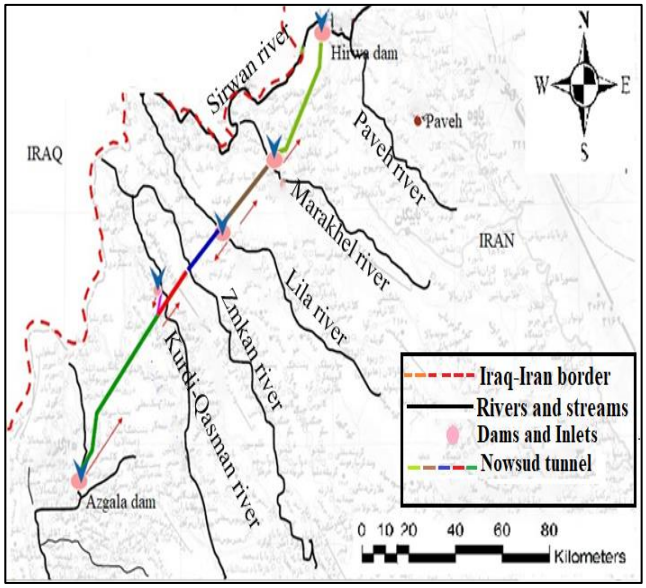

Fig. 4 Nowsud diversion tunnel and its inlets (Rashidi, 2017).

Table 3 – Nowsud diversion tunnel geometry (Rashidi, 2017).

Tunnel length (m)	48,269 m
Transportation capacity (m^3/s)	70
Tunnel cross-section shape	Circular
Excavation diameter (m)	6.12 m
Net tunnel diameter (m)	5.4 m
Slope of the tunnel	0.0008

3.1.13. Azgala Dam (2018)

It is a rock-fill Dam with vertical clay core, it was constructed at Kermanshah province. The Dam is 65 m high and has a reservoir capacity of 30 million cubic meters. With the completion of this dam, the first part of the TWP has been completed. the diverted water from the Hirwa dam through the Nowsud diversion tunnel will eventually reach the Azgala dam and then, subsequently transported to the West of Kermanshah and Elam provinces throught another series of tunnels and canals (Tasnim News Agency, 2018).

3.1.14. Amir-Abad and Ramshat Dam (2019)

Both are embankment dams with free overflow spillways, they are located at Mochesh of Kamyaran county of Kurdistan province of Iran with coordinates (35°04'05.7"N 47°15'37.1"E) and (35°04'58.1"N 47°11'51.4"E) respectively. The total storage capacity of both together is 12 million cubic meters, these two dams irrigate 1,200 ha of agricultural lands at their downstream sides (Moradnia, 2019).

3.2. The Catchment Area of Darbandikhan Dam After the TWP Project

The catchment area of the Darbandikhan dam before and after TWP project comes into full operation are determined using Geographical Information Systems (GIS) modelling tools. In order to identify the catchment areas, Raster Data or Digital Elevation Model (DEM) data in ESRI grid format and UTM projection have been used. The DEM data have been downloaded from earthexplorer.usgs.gov website with high-resolution tiles of (SRTM 1 arc) 30m by 30m grid size.

Arc SWAT tool (Arc SWAT is an automatic watershed delineation tool in ArcGIS software) in ArcGIS 10.4.1 has been used to prepare a hydrologically corrected and depression less DEM. Figure (5) shows the catchment area of all the dams which have been constructed on upstream of Darbandikhan dam as well as the catchment area that left for Darbandikhan dam (white-coloured area). Figure (6), shows the catchment area that the Darbandikhan dam will lose after the TWP project comes into full operation (orange-coloured area).

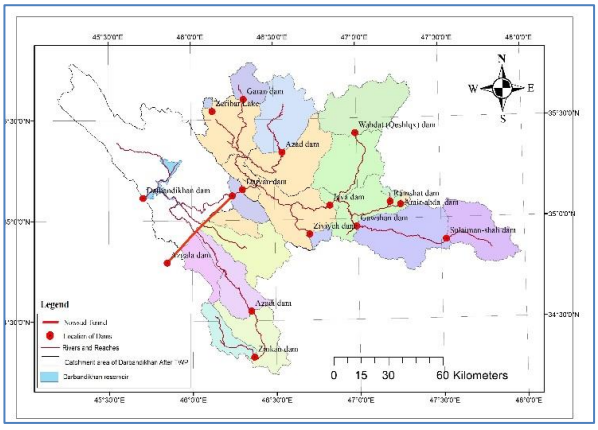

Fig. 5 Catchment area and location of each dam (ArcMap 10.4.1).

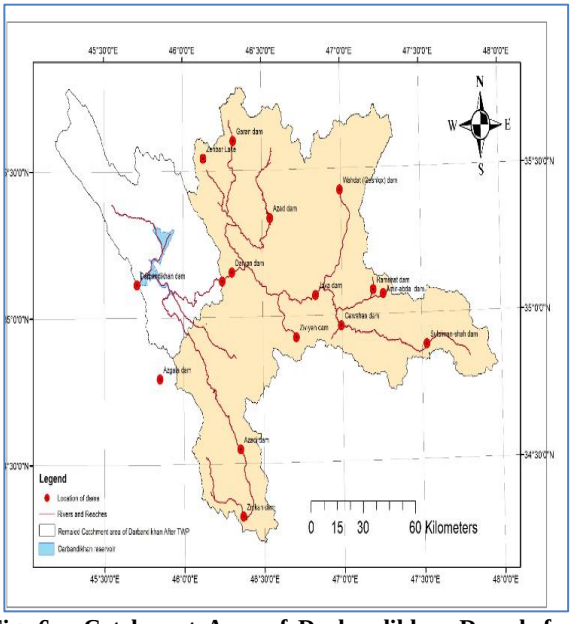

Fig. 6 – Catchment Area of Darbandikhan Dam before and after TWP (ArcMap 10.4.1).

4. RESULT AND DISCUSSION

From the data collected in this study, it's been concluded that the TWP project involves 14 dams and 150 km long diversion tunnels (of different lengths). Table (4) presents a brief summery about the dams built within the TWP project across Sirwan and Zmkan Rivers and their tributaries. The TWP project has been planned to be implemented in two stages, the first stage has already been finished, while the second stage is still under progress.

The total capacity of all the dams together is about 1.9 Milliard m^3 of which 1.806 Milliard m^3 will be stored in the dams built across Sirwan river and its tributaries and the left will be held by the dams built across Zmkan river. In addition, Nowsud diversion tunnel of a maximum capacity of 70 m^3/sec will be utilized to divert more than 1.0 Milliard m^3 of water annually from Sirwan and Zmkan rivers to Kermanshah and Elam Provinces (outside of the Diyala basin).

Accordingly, Darbandikhan dam will suffer from the loss of a significant amount of water. The first loss will be due to the water that will be diverted from its original basin to Nowsud Conveyance Tunnel, which exceeds a Milliard cubic meter. while the second loss, will be due to the dams built in Iran, as in addition to the evaporation losses from the surface of their reservoirs, large quantities will be used for irrigation and drinking purposes. So, the negative impact of the TWP project will appear soon when the project comes into full operation. This drawback of the TWP project is expected to be worse in the dry years.

Table 4 The TWP Dams properties.

Dam	Completion Date	Dam height (m)	Storage capacity (Million m^3)	Catchment area (Km^2)	Longitude and Latitude
Azadi dam	2012	64	70.47	722	34°32'55.6"N 46°21'12.3"E
Gawshan dam	2004	123	550	1,245	34°57'49.0"N 46°59'38.5"E
Daryan dam	2018	146	316.3	3,135.85	35°09'08.3"N 46°18'25.3"E
Soleyman-Shah dam	2006	36	50	859.53	34°53'32.4"N 47°31'51.6"E
Zmkan dam	2017	65	23	367	34°19'10.7"N 46°22'04.0"E
Azgala dam	2018	65	30	----	34°47'30.1"N 45°50'57.2"E
Wahdat (Qeshlq) dam	1979	89	215	1,077.7	35°25'34.4"N 46°59'34.1"E
Garan dam	2013	62	110	307.07	35°36'03.6"N 46°19'10.1"E
Hirwa dam	2018	45	12	261.6	35°07'19.8"N 46°14'43.3"E
Java dam	2013	86	172	1,751.7	35°04'09.0"N 46°50'01.2"E
Azad dam	2014	125	300	984.5	35°20'08.6"N 46°32'58.5"E
Ziviyeh dam	2013	54	17	83.6	34°55'38" N 46°42'36.9" E
Amir-abad dam	2019	30	6	35	35°04'05.7"N 47°15'37.1"E
Ramshat dam	2019	35	6	36.3	35°04'58.1"N 47°11'51.4"E
Darbandikhan dam before TWP	1957	128	3,000	16,685	35°06'47.2"N 45°42'24.6"E
Darbandikhan dam After TWP	1957	128	3,000	3,837	35°06'47.2"N 45°42'24.6"E

In addition, based on the GIS modelling results, the catchment area of Darbandikhan dam before the TWP project is 16,685 km^2, while after the TWP project completion it will be reduced to 3,837 km^2 (see Figure (6)). Accordingly, Darbandikhan dam will lose about 77% of its original catchment area by the completion of the TWP project. It should be noted that according to the original design documents available at Darbandikhan dam directorate, the catchment area of Darbandikhan dam is 17,850 km^2 as shown previously in Table (2).

5. CONCLUSION

Iran has recently announced a big water project called the Tropical Water Project (TWP) which involves building a series of dams and diversion tunnels on the Sirwan and the Zmkan rivers. According to the gathered information, the TWP project includes 14 dams, many hydropower projects, many pump stations, and diversion tunnels which are constructed or planned to be constructed on Sirwan and Zmkan rivers and their tributaries inside Iran territories. The total storage capacity of the 14 dams involved in the TWP project is about 1.9 Milliard m3 of water. In addition, the diversion tunnels are designed to divert more than 1000 Mm3/year of water to areas located outside the Diyala river basin. The flowrates of the Diyala river and its tributaries will be influenced by the TWP projects and the inflow of the Darbandikhan dam will then be reduced significantly. According to the GIS model results, when the TWP project is completed and fully operated, about 77% of the original catchment area of the Darbandikhan dam will be lost. This drawback of the TWP project is expected to be worse in the dry years. So, in order to mitigate the adverse effects of the TWP project on the water resources inside Iraq, the Iraqi decision-makers should start negotiating with the Iranian officials concerning the downstream rights in order to achieve an appropriate coordination regarding the operation of the TWP project.

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