Lessons learnt from basin management in Iran and the world (case study Helmand, Danube and Colorado basins)

Enseignements tirés de la gestion des bassins en Iran et dans le monde (étude de cas sur les bassins du Helmand, du Danube et du Colorado)

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Abstract. In recent years, river flow into Sistan dam changed because of construction of dams and expansion of irrigation areas in the upper Helmand basin. Planning for construction of more dams and heightening of Kajaki dam in Helmand basin shall intensify the severity of water shortage of Sistan dam and Hamun Lake. Sistan dam located at downstream of Helmand river on Sistan branch of the Helmand river, power shifts in Afghanistan and expansion of irrigation areas in upstream basins and absence of an integrated authority/management in the basin are the major problems. Political nature of international protocols for management of the basin is another problem for water resource management in the region. Above mentioned issues forced the local water authorities to solve the problems using natural and man-made reservoirs and interlink canals, called Chah-Nimeh dams. This study focused on comparison of Helmand, Danube and Colorado river basins to find possible acts in Helmand basin.

Résumé. Ces dernières années, le débit de la rivière dans le barrage de Sistan a changé en raison de la construction de barrages et de l'expansion des zones d'irrigation dans le bassin supérieur du Helmand. La planification de la construction de plus de barrages et de l'élévation du barrage de Kajaki dans le bassin de Helmand intensifiera la gravité de la pénurie d'eau pour le barrage de Sistan et du lac Hamun. Le barrage du Sistan étant situé en aval de la rivière Helmand sur la branche Sistan de la rivière Helmand, les changements de puissance en Afghanistan, l'expansion des zones d'irrigation dans les bassins en amont et l'absence d'une autorité/gestion intégrée dans le bassin est l'un des problèmes majeurs (pour les terres cultivées en aval). La nature politique des protocoles internationaux de gestion du bassin est un autre problème pour la gestion des ressources en eau dans la région. Les

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problèmes mentionnés ci-dessus ont forcé les autorités locales de l'eau à résoudre les problèmes en utilisant des réservoirs naturels et artificiels et des canaux interconnectés, appelés barrages Chah-Nimeh. Cette étude s'est concentrée sur la comparaison des bassins du Helmand, du Danube et du Colorado pour trouver des actions possibles dans le bassin du Helmand.

1 Importance of transboundary basins

Planning and implementation of an integrated water resources management processes is one of important challenges in transboundary basins. There are 263 large transboundary basins covering 45% of continental areas and hundreds of transboundary aquifers around the world (Table 1) [1]. Significant number and percentage of areas covered by transboundary basins show importance of transboundary relations in planning and implementation of IWRM processes. IWRM processes will affect extremely internal and international relations of the neighbouring countries. This paper focuses on international and political relations between countries in three different basins in three continents and effects of political issues between countries on IWRM processes on downstream countries.

Table 1. Transboundary basins in the five continents [1].

Continent	Number of transboundary basins	Percentage of continental area (%)
Africa	59	62
Asia	57	39
Europe	69	54
North America	40	35
South America	38	60
Total	263	45

2 Helmand river basin

Helmand river is one of main rivers in Afghanistan, rises from Hindukush mountains 40 km west of Kabul. Helmand river with 1150 km length is the longest river between Indus and Euphrates. Arghandab river is one of main sources of Helmand river, flowing from Ghazni district and joining Dori river south of Kandahar, then goes west-ward and joins Helmand near Lashkargah city. Afterward Helmand river flows toward west to Rigestan desert (which means sand-field in Persian) and lower Helmand until reaching Iran borders. Near Iran borders it flows north-ward. Some small areas of the river's basin also located in Pakistan will connect from south. Near Kohak village in Iran the Helmand river divided into two branches, first branch known as Sistan river flows into Zabol city and reaches to Hamun-i-Helmand lake. Second branch known as Parian river flows north-ward on Iran-Afghanistan border. After joining Khash, Farah and Hārūt rivers, the Parian river reaches to Hamun-i-Sabori lake, which is connected to Hamun-i-Helmand lake in south. Considering the fact that the Helmand river ends in Sistan area of Iran, the river's basin also is known as Sistan basin

[2]. Area of Helmand river basin (Sistan basin) in Iran, Afghanistan and Pakistan countries is shown in table 2 and Helmand river path and its basin is shown in figure 1.

2.1 Main dams and uses in Helmand river basin

Main dams in Helmand river basin are shown in table 3. Last important structure on Helmand river located in Iran-Afghanistan border, is an intake to divert river flow to four reservoirs known as Chah-nimeh reservoirs. Three of the reservoirs are natural depressions and the fourth reservoir is formed with a dyke on its north side. The water reserved in Chah-nimeh reservoirs is used for irrigation and urban uses of Zahedan and Zabol cities and suburbans [2].

Table 2. Area of Helmand river in each country.

Country	Area of Helmand river basin (km²)	Percentage of Helmand river basin (%)
Afghanistan	257860	89.2
Iran	25502	8.8
Pakistan	5768	2.0
total	289130	100.0

Fig. 1. Helmand river basin [3].

2.2 Water resources management in Helmand basin

Highest water authority on Helmand river basin in Afghanistan is "Helmand and Arghandab Valley authority (HAVA)". The HAVA is overseen by the Afghan Ministry of Agriculture, Irrigation and Livestock (previously the Ministry of Agriculture and Irrigation).

Water authority on Iran side is divided between Sistan & Baluchestan water authority (SBWA) and Agriculture organization of Sistan & Baluchestan (JASB). Main structures such as dams and main canals are managed by SBWA while distribution canals are controlled by JASB.

Table 3. Dams and reservoirs in Helmand river basin.

Dam	Location	Purpose	Storage (mcm)	Height (m)	Power generation	Year of completion
Kajaki dam	Afghanistan Helmand province	Hydroelectricity, Irrigation	1715	100	52.5 MW	1953
Grishk dam	Afghanistan Helmand province	Hydroelectricity			4.2 MW	1945
Dahla dam	Afghanistan Kandahar province	Irrigation		55		1952
Kamal khan dam	Afghanistan Nimruz province	Hydroelectricity, Irrigation		16	8 MW	1974
Chah-nimeh feeder	Iran - Sistan & Baluchestan province	Irrigation, Urban	1540	3		

2.3 History of Helmand river treaty

First settlement on Helmand river water is Gold Smith 1872 arbitration to solve water distribution between Iran and Afghanistan, which were followed by MacMahon Arbitrary on 10th Apr. 1905. On 1973 an agreement between Afghanistan's and Iran's prime ministers issued to solve the dispute. The agreement is carried out by now.

The Helmand river water have been the cause of disputation since the late 1800s between Afghanistan and Iran. The 1973 agreement founded to supply Iran with an average 22 m^3/s, includes an additional 4 m^3/s for "goodwill and brotherly relations". The treaty also establishes a new Helmand Commission to administer the provisions of the agreement. Monthly flow deliveries are specified in treaty for "normal water years", which is defined as a year with total flows upstream of Kajaki Dam at Dehrawud that are at least 5661 mcm between 1 October and the following 30 September. The Helmand treaty is flexible in that in low flow years, provisions are made to reduce the flow allocated to Iran in proportion to their measured deviation from a normal year for any given month or months.

Also Afghanistan retains all the rights to the balance of the water and may "make such use or disposition of the water as it chooses". This privilege, however, must be balanced with acknowledging the importance of continued flow to the Helmand delta, and indicates that if flow stopped, the Commissioners must develop plans to minimize the problem. What is very clear is that Iran can make "no claim to the water of the Helmand river in excess of the amounts specified in the treaty, even if additional amounts of water may be available in the

Helmand lower delta and may be put to a beneficial use". Consequently, if it is shown that Iran is taking more than 811 mcm/year, it would be in clear breach of the treaty.

Both Iran and Afghanistan have the ability to monitor each other to ensure that they remain in compliance with the treaty. The treaty specifies that during low flow years, the Iranian Commissioner has access to flow measurements at Dehrawud, and is even allowed to observe the flow and take his own measurements. Additionally, both the Afghan and Iranian Commissioners have to jointly measure the delivery of water to Iran. In practice, information from Dehrawud is made available on an ongoing basis, though not consistently, as the Commission does not always meet every year [4].

Thereafter, the treaty has been affected by political status of Afghanistan. Figure 2 shows Helmand river flows near Kohak village, where flow diverts to Sistan river from 1947 to 2014. The flow data shows that in early years before the treaty and construction of great dams in Helmand basin, flow reached up to 80 m^3/s. From 1978 and taking power by People's Democratic Party of Afghanistan (PDPA) and political events and taking over by Red Army of Soviet Union in Dec. 1979, river flow in Kohak is near to its average flow. Which means existence of a moderately powerful government could secure implementation of Helmand river treaty. Also, Until 1992 and fall of president Mohammad Najibullah, the treaty were implemented with no complaints from both sides. In 1994 with taking power by Taliban militia up to 2001, security and implementation of the treaty were doubted. In 2001 the Iranians went to the United Nations to complain that Afghanistan was not releasing water from Kajaki Dam and were in breach of the Treaty. The language used in the complaint demonstrates the Iranians feel the treaty is valid and in force. Decrease in Helmand water flow can be seen figure 2 [5].

In December 2001, after the Taliban government was overthrown, the Afghan Interim Administration under Hamid Karzai was formed. The International Security Assistance Force (ISAF) was established by the UN Security Council to help assist the Karzai administration and provide basic security. During this period the Helmand river flow returned near to values agreed on the treaty.

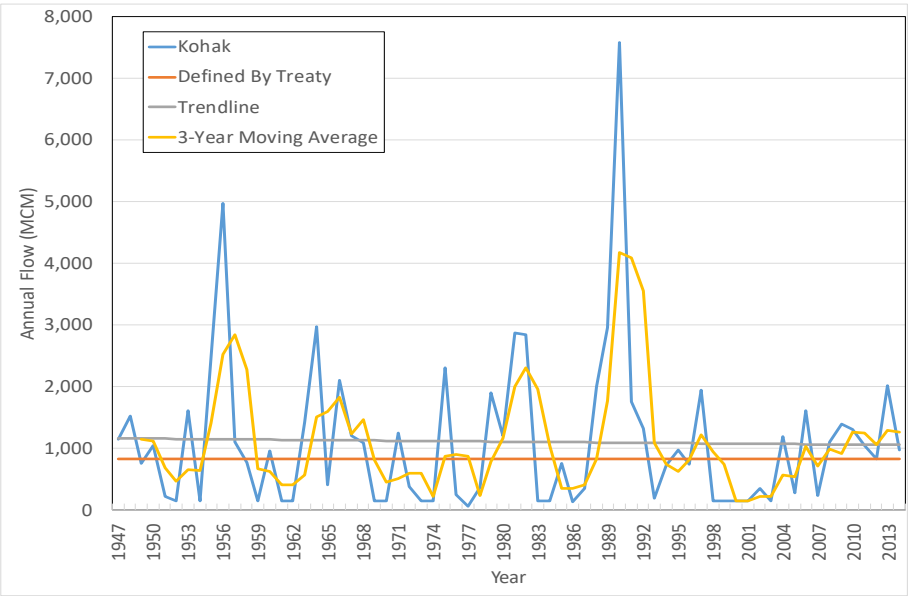

Fig. 2. Helmand river flow near Kohak in Iran-Afghanistan Border (1947-2014) [3].

3 Danube river basin

Danube river basin is Europe's second largest river basin, with a total area of 801,463 km². It starts from Donaueschingen in Black woods in Germany, and after passing about 2730km and through four capitals reaches to Danube delta and the Black Sea. It is the world's most transboundary river basin, covers the territory of nineteen countries. The ecosystems of the Danube river basin are highly valuable in environmental, economic, historical and social terms.

The Danube river basin divided into three sub-regions: the upper basin, the middle basin, and the lower basin (including the Danube delta). The upper basin extends from the source of the Danube in Germany to Bratislava in Slovakia. The middle basin is the largest of the three sub-regions, extending from Bratislava to the dams of the Iron Gate Gorge on the border between Serbia and Romania. The lowlands, plateaus and mountains of Romania and Bulgaria form the lower basin of the Danube river. Finally, the river divides into three main branches, forming the Danube Delta, which covers an area of about 6,750 km².

Area of Danube river basin in different countries is shown in table 4 and its path and the basin are shown in figure 3 [6].

Table 4. Area of Danube river in each country.

Country	**Area of Danube river basin (km²)**	**Percentage of Danube river basin (%)**	**Country**	**Area of Danube river basin (km²)**	**Percentage of Danube river basin (%)**
Albania (AL)	126	< 0.1	Moldova (MD)	12834	1.6
Austria (AT)	80423	10.0	Montenegro (ME)	7075	0.9
Bosnia and Herzegovina (BA)	36636	4.6	Poland (PL)	430	< 0.1
Bulgaria (BG)	47413	5.9	Romania (RO)	232193	29.0
Coratia (HR)	34965	4.4	Serbia (RS)	81560	10.2
Czech Republic (CZ)	21668	2.7	Solvak Republic (SK)	47084	5.9
Germany (DE)	56184	7.0	Slovenia (SI)	16422	2.0
Hungry (HU)	93030	11.6	Switzerland (CH)	1809	0.2
Italy (IT)	565	< 0.1	Ukraine (UA)	30520	3.8
Macedonia (MK)	109	< 0.1	Total	801046	100.0

Fig. 3. Danube river basin [7].

3.1 Main dams and uses in Danube river basin

More than 1030 dams and main uses are identified in Danube river basin and shown in figure 4. It must be noted that in many cases barriers are not linked to a single purpose due to the multifunctional characteristics of the structure (e.g. hydropower use and navigation; hydropower use and flood protection).

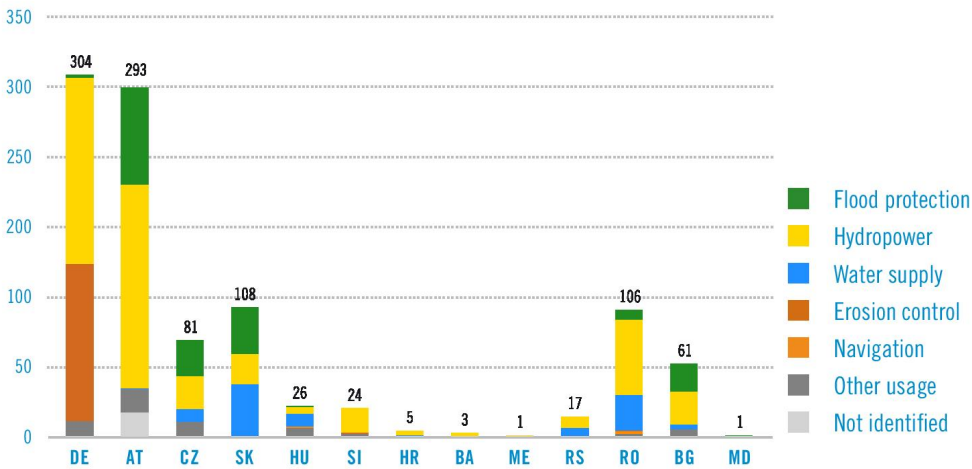

Fig. 4. Main uses in Danube river basin [6].

3.2 Water resources management in Danube basin

The control and operation of the Danube is carrying out by two main directives, "Danube Commission" concerned with the maintenance and improvement of navigation conditions of the Danube river & "International Commission for the Protection of the Danube River

(ICPDR)" concerns with protection of the Danube river and to ensure the sustainable and equitable use of waters in the Danube river basin.

3.2.1 The Danube Commission

The Danube Commission is an international intergovernmental organization established by the Convention regarding the regime of navigation on the Danube signed in Belgrade on 18 August 1948. The main objectives of the Danube Commission's activity are to provide and develop free navigation on the Danube for the commercial vessels, as well as to strengthen and develop economic and cultural relations of the Member States of the Belgrade Conventions among themselves and with the other countries [8].

3.2.2 International Commission for the Protection of the Danube River (ICPDR)

The "International Commission for the Protection of the Danube River (ICPDR)" is an international organization with its permanent secretariat in Vienna. It was established by the Danube river protection convention, signed by the Danube countries in Sofia, Bulgaria, in 1994. The commission focused on water regime and quality regulation in Danube river [9].

3.3 History of the Danube river

The Danube river has been a trade waterway for centuries, but with the rise and fortification of international borders, commerce and shipping has often been affected by political relation between bordering nationals and natural features of the river. Therefore, diplomats over the decades have worked to internationalize the Danube river in an attempt to allow trades to flow as efficiently as possible. Finally in 1856, at the end of the Crimean War, it was decided to establish an international organization for utilization of Danube river for trade routes over Danube. History of the Commissions of the river Danube can be summarised as following [10].

- 1856 Treaty of Paris: European Commission of the Danube established; Russian boundary withdrawn 20 km north of the Danube
- 1857 Riparian states meet in Vienna to regulate whole river from Ulm to Braila - largely unsuccessful due to the dominance of Austria-Hungary
- 1870 Sulina declared a freeport and cargo could pass up the river without formality
- 1878 Treaty of Berlin: European Commission's rights and privileges extended; lower Danube neutralised; Romania becomes full member of the Commission following her independence; Russia again a Danubian country after war with Turkey in 1877
- 1895-99 Blasting and canal construction along the Iron Gates section of the river somewhat improves navigation
- 1902 Final Sulina arm cut-off completed, shortening the river by 11 nautical miles
- 1919 Treaty of Versailles grants four rivers including the Danube "international" status
- 1921 European Commission of the Danube resumes operations; new International Commission of the Danube set up for the "fluvial" river from Ulm to Braila
- 1939-44/5 Danube under German control
- 1948 Treaty of Belgrade: new Danube Commission is established to regulate whole navigable river, composed only of riparian states

Monthly and annual flow at 8 different flow station were considered. The name and location of these stations is shown in table 5. Annual flow from 1900 to 2016 is shown in figure 5 [11].

Table 5. Location of stations on Danube river used for comparison.

Station Name	Location	Altitude (mASL)	Time series	No. of years
Achleiten	Germany – Austria border	287.7	1900-2015	116
Bratislava	Slovakia downstream of Austrian border	128.0	1900-2016	117
Nagymaros	Hungary downstream of Slovakia border	100.0	1893-1999	107
Bezdan	Croatia-Serbia border downstream of Hungary border	77.0	1931-2003	80
Veliko gradiste	Romania downstream of Serbia border	62.0	1931-1970	40
Bazias	Romania downstream of Serbia border	64.0	1991-2008	18
Novo selo	Bulgaria-Romania border downstream of Serbia border	27.0	1937-1999	63
Ceatal izmail	Romania Upstream of Danube delta	0.6	1921-2010	90

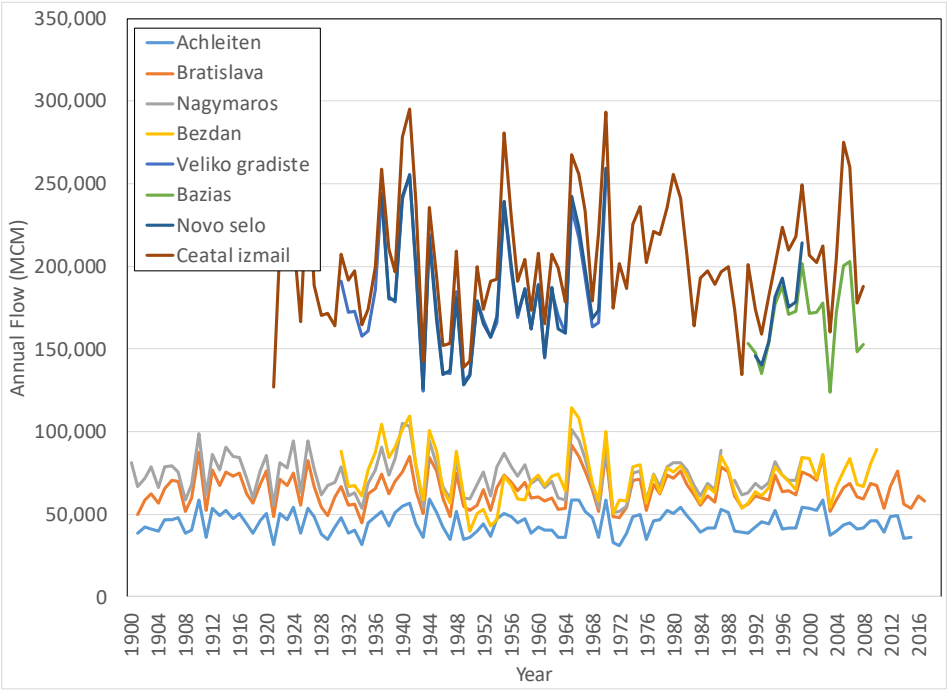

Fig. 5. Danube river flow at selected stations (1900-2016) [11].

Long-term flow in Danube river shows no significant changes and stable flow along Danube river. Significant river flow rate comparing water demands and absence of new development plans are the main reasons for the stability of the flow in the Danube river.

4 Colorado river basin

The Colorado river is one of the principal rivers in the South-west of United States and northern Mexico. The Colorado river is 2,330 km long and drains an expansive, arid watershed that covers parts of seven U.S. states and two Mexican states. The Colorado river starts in the central Rocky mountains of Colorado, flows generally southwest across the Colorado plateau and through the Grand canyon before reaching lake Mead on the Arizona–Nevada border, then it turns south toward the Mexican border. After entering Mexico, the Colorado approaches the mostly dry Colorado river delta at the tip of the gulf of California between Baja California and Sonora. Area of Colorado river basin in each US states and Mexico is shown in table 6 and Colorado river path and its basin is shown in figure 6.

4.1 Dams and uses in Colorado river basin

More than 45 dams or diversion dams is built on Colorado river basin, 14 of them on main stem of Colorado river, 20 on upper Colorado basin and 11 on lower Colorado basin, which 30 of them has a reservoir larger than 100 MCM (million cubic meter). Total volume of reservoirs on Colorado basin reaches up to 95,461 MCM, with about 4,538 MW hydropower capacity [13].

Table 6. Area of Colorado river in each state/country.

Country / State	Area of Colorado river basin (km^2)	Percentage of Colorado river basin (%)
USA / Arizona	269542	43.8
USA / California	9817	1.6
USA / Colorado	100038	16.2
USA / Nevada	30573	5.0
USA / New Mexico	53575	8.7
USA / Utah	105351	17.1
USA / Wyoming	44304	7.2
Mexico	2480	0.4
total	615680	100.0

Fig. 6. Colorado river basin [12].

4.2 Water resources management in Colorado basin

The Bureau of Reclamation (part of the Department of the Interior) manages much of the basin's water supplies. Colorado River water is used primarily for agricultural irrigation and municipal and industrial (M&I) uses, but it also is important for power production, fish and wildlife, and recreational uses. In recent years, consumptive uses of Colorado river water have exceeded natural flows, causing an imbalance in the basin's available supplies and competing demands.

4.3 History of Colorado river treaty

Main events in the Colorado river basin can be summarized as following:

- In 1922 the river was divided at Lee's Ferry, Ariz., into the lower compact states - Arizona, Nevada, and California - and the upper compact states - Wyoming, Utah, Colorado, and New Mexico; the total annual flow of the Colorado river was estimated to be 21,000 MCM (17 Maf) at Lee's Ferry, of which about 18,500 MCM (15 Maf) were equally, yet somewhat ambiguously, divided between the lower and the upper compact states
- In 1928, Congress passed the Boulder canyon project act. The act authorized the construction of Boulder (now Hoover) dam which completed in 1936.

- In 1944, a treaty allocated 1,850 MCM (1.5 Maf) of water per year to Mexico. It was later discovered that the initial estimate of Colorado river supplies was based upon an abnormally wet period and that substantially less water was available than the amounts specified in the agreements.
- In 1945, the Colorado - Big Thompson project, the first federal inter basin water-diversion project in the U.S., was completed.
- In 1963, a decision of the U.S. supreme court made explicit the amount of water apportioned among the lower-basin states, as well as the amounts that had been implicitly "reserved" for Indian tribes and federal public lands.
- In 1966, Glen canyon dam was completed
- In 1972, Controversy between the United States and Mexico over the salinity of water delivered to Mexico was addressed in an international agreement, which led to desalinization experiments in the lower basin and irrigation management and projects for the disposal of saline water in the upper basin.
- Since the late 1990s the U.S. Department of the Interior has been experimenting with flow modification at the large Colorado river dams. Large flows are released from the dams during spring, so as to mimic the spring floods that naturally occurred on the river. More-aggressive attempts to improve the river's flow are under consideration, including removal of the dams [14].

Monthly and annual flow at 8 different flow station were considered. The name and location of these stations is shown in table 7. Annual flow from 1912 to 2019 is shown in figure 7 [11].

Comparison of annual flows show that from early years of the twentieth century up to about 1965 although the Hoover dam (with about 37% of reservation volume in Colorado river basin) was built, the river flow has an uncontrolled nature. But after about 1965 and completion of Glen canyon dam (with about 34% of reservation volume in Colorado river basin) and decision of U.S. supreme court in 1963 the river flow became controlled and flow peaks reduced. On another view only four large dams with more than 100 MCM storage (McPhee, Ridges basin, Rodgway and New Waddell dams) were been built in last four decade, and water in the Colorado river basin controlled by authorities acting under laws and rules.

Table 7. Location of stations on Colorado river used for comparison.

Station Name	Location	Altitude (mASL)	Time series	No. of years
Below Yuma Main Canal WW at Yuma	Arizona State	31.1	1963-2019	57
Below Hoover Dam	Arizona-Nevada border	205.9	1943-2017	84
Above Little Colorado R Nr Desert View	Arizona State	818.9	1985-2002	18
Lees Ferry	Arizona State	946.7	1911-2019	109
Near Cisco	Utah State	1246.6	1913-2019	107

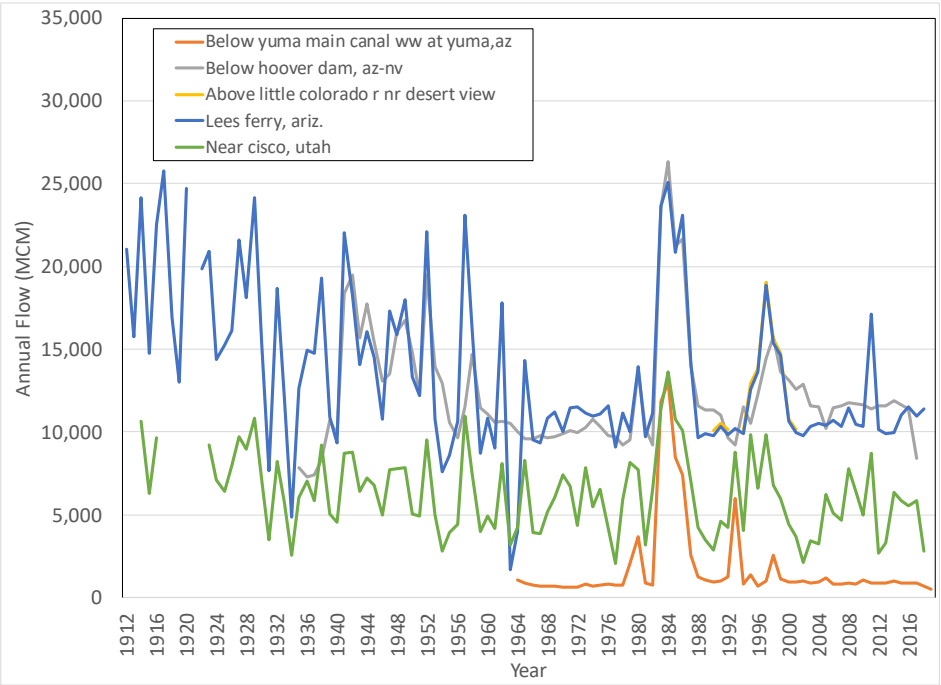

Fig. 7. Colorado river flow at selected stations (1912-2019) [3].

5 Comparison and conclusion

Comparing the above mentioned basins and their management systems shows the following points:

- An integrated water resources management plan applies in at catchment level and it requires cooperation between all neighbouring parties in the catchment area. This cooperation may be achieved by a common mutual understating based on common benefits (like Danube basin) or drawn by a well implemented laws (like Colorado basin). Without an understanding, downstream parties will be affected severely (like Helmand basin).
- Lack of cooperation may affect reliability and robustness of an international treaty. To achieve a good cooperation, parties must participate in planning and implementation of the IWRM plan. A common goal can be a very good purpose for cooperation, like navigation in Danube river.
- Implementation of a great infrastructure programme (such as construction of large dams) requires a considerably time and budget, can be granted under a long-term treaty. Therefore, a long-term agreement which is planned and implemented correctly, shall be beneficiary for all neighbouring parties and profiting construction of large dams in transboundary basins.

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