World Journal of Science and Technology 2011, 1(7): 01-09
ISSN: 2231 – 2587

ASSESSMENT OF KARKHEH DAM ON ECOHYDROLOGICAL DOWNSTREAM CONDITIONS IN SOUTHWEST OF IRAN

Hossein Madadi

Academic staff Member, Environmental Sciences Department, Faculty of Natural Resources, Behbahan Higher Education Complex, Iran
Corresponding author e-mail: hosein.madadi@gmail.com

Abstract

Dams can change the natural flow of the rivers through influencing the total flow rate, the quality of water, the seasonal scheduling of the flow, continuing the flow, and hydrologic occurrences. Alteration in streamflow regimes may modify many of these attributes and impair ecosystem connectivity. This paper presents assessment of hydrologic alteration at the Payepol streamgauge site to demonstrate the influence of Karkheh Dam on ecohydrological downstream condition using Indicators of Hydrologic Alteration and Range of Variability Approach methods. The results indicate that Karkheh Dam have greatly altered the natural flow regime, range condition and spatial variability. The 31 hydrological indexes have completely changed during 35 years of before constructing of the dam over Karkheh River, particularly in downstream, and regarding the ranges of variability achieved from the period of before constructing the dam . The river ecohydrological targets and minimum ecological and environmental flow requirements for downstream of Karkheh Dam defined by this study can support ecosystem management and restoration plans and provide ecological operations for the Khuzestan Province.

Keywords: Range of Variability Method (RVA), Indicators of Hydrologic Alteration (IHA), Dam, Karkheh, Streamflow regime

Introduction

The goal of ecosystem management is maintaining its consolidation through protecting the domestic species and the ecologic processes that are effective in its creation and maintenance. In confronting with complexities of the natural systems to achieve these goals, structure, function, and the desirable variability of the ecosystem should be analyzed and differences between the existing condition and the desirable one should be delineated (Richter et al., 1996). Dams make exploitation and control of rivers easy and enable water resources manager to change the invariability of the natural flow of the river toward the human necessities (Richter et al., 2006). Dams can change the natural flow of the rivers through influencing the total flow rate, the magnitude of water, the seasonal scheduling of the flow, continuing the flow, and hydrologic occurrences. These changes influence the patterns of migration of fishes and arrange of riparian habitats (Poff and Allan, 1997), and they changes them by bringing alluvia and organic materials to coastal ecosystems (Carmen, 2005). In many cases, these changes can have negative effects on hydrological and ecological services provided by the river ecosystems, and they increase the vulnerability of the people which are dependent on these services. The wide range of changes which takes place in a year or over years are necessary for stability of the function of the ecosystem (Poff et al., 1997; Richter et al., 1996). Discharge of water is a major variable that regulates the ecological unity of the water systems, and confines dispersion and abundance of aquatics and creatures which live near water resources (Poff et al., 1997). Determining the amount of development of water resources which has minimum effects on the

wide range of economic and promenade values and ecological values is considered as one of the main challenges in water resources management (Tejan and Haase, 2008). Thus, the streamflow regime of the river is recognized as a propellant in the river ecosystems (Stanford et al,1996; Poff et al ,1997). The biotic composition, structure, and function of aquatics, ponds, and riverside ecosystems are highly dependent on the streamflow regime (Gorman and Karr, 1978). The changes that occur within a year in hydrological condition are necessary for life cycle of many of aquatics and creatures which live near water and in ponds; these changes often have an important role in mobility of its dependent populations through influencing the birth, the natural dispersion, and the life cycle (Poff and Ward, 1989). The effective fluvial ecosystem management needs that the existing streamflow regime is described by the hydrological parameters, and the degree of changes in regulatory flow regime is specified in comparison to natural streamflow regime. Attempt in the field of ecosystem management should be concentrated on protecting or regenerating the natural streamflow regime of the river with the aim of maintaining the unity (Richter et al., 1998). To do this, it is necessary to determine meaningful and measurable indexes that can provide the need of ecosystem management and its goals (Keddy, 1992). The approach that is used in evaluating the hydrological change is based on the difference in the streamflow regime of the river between two temporal sequences in a streamgauge site (Richter et al., 1996). If the recorded statistic in a streamgauge site is in such a way that it can be divided into two temporal sequences in which one of them is related to a period with a natural flow regime condition and another is related to a changed flow regime condition, the degree of change in the streamflow regime that has occurred between these two sequences can be measured (Richter et al., 1996). Using the Range of Variability Approach (RVA) method provides the ability of determining the range of variability of the flow in the river, and it let the water resources manager determine the directorial and functional goals as a set of administrative instructions or plan of regeneration and reconstruction (Tejan and Haase, 2008). This research has conducted with the goal of quantifying the influence of construction of Karkheh Dam on the streamflow of downstream by using the Range of Variability Approach method (RVA).

Study Area

Karkheh Dam has been constructed on Karkheh River which is 24 kilometers far from the northwest of Andimeshk in Khuzestan Province. This area is located between 47° 51′ 11′′ and 48° 17′ 42′′ eastern longitude, and 31° 56′ 46′′ and 32° 35′ 17′′ northern latitude (Figure 1). Regarding the streamflow, this river is the third big river of Iran after Karun and Dez rivers. Because of the slight slop of the river, the lake of the dam has a considerable extent and volume. The volume of Karkheh reservoir in the exploitation level is 220 meters from the sea level, 5600 million cubic meters with the area of 166 km^2. The average annual temperature and rainfall of the region are 23 C and 240 mm respectively. The climate of that is hot and dry.

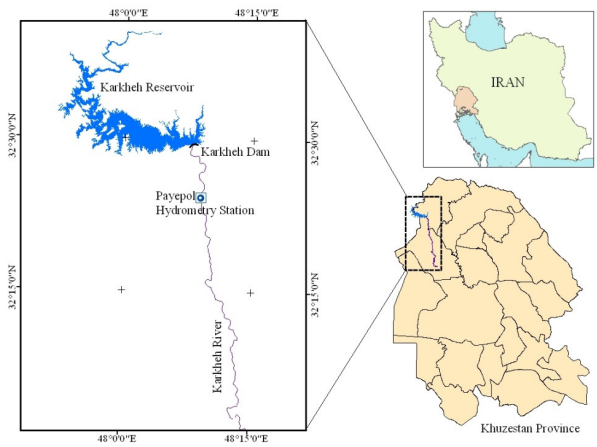

Fig 1. Situation of study area

Methods

From among the existing hydrometric stations on Karkheh River, only the streamgauge which is under in downstream of Karkheh Dam has suitable long-term statistic for investigation. Thus, the Payepol streamgauge station has been chosen as a basis station for investigating the effect of Karkheh Dam. Since each of the components of the streamflow regime of the river has a particular ecological function, it is necessary to recognize parts of the flow of the Karkheh river that have an important role in providing the considered goals. To investigate the components of the streamflow of Karkheh River, the Range of Variability Approach (RVA) method has been used based on the statistic of the Payepol station. In this method that was introduced in 1997 by Richter, 31 hydrological parameters are used as the Indicators of Hydrologic Alteration (IHA) for evaluating the change of the streamflow of the river. These indexes are categorized in five statistical groups: Magnitude of monthly water conditions, Magnitude and duration of annual extreme conditions, Timing of annual extreme water conditions, Frequency and duration of high and low pulses, Rate and frequency of water condition changes (Richter et al.,1996 ; Richter et al., 1998 TNC, 2009). In RVA method, the annual amount of each of IHA parameters is investigated in the natural changes of the long-term streamflow regime in the river. According to the research conducted about analyzing the hydrological regime of river flow, and by considering the statistical period of at least two decade, the continental effects on the hydrological parameters of the flow decrease considerably within a year (Walker et al.,1995; Poff, 1996). According to that this, the daily statistic of flow of Karkheh River in the Payepol streamgauge station from 1962 till 1999 has been considered as the statistic of Pre-Dam data, and from 2000 till 2009 has been considered as the statistic of Post-Dam data. Regarding the fault that exists in the statistic of streamflow data in 1982 and 1983, these two years have not been considered in analyses. Thus, the statistical period that has been used in stage of before the construction of the dam is 35 years, and it is 10 years for after the construction of the dam. In such a way that for investigating the amount of changes of each of IHV indexes in RVA method, the values of plus and minus one of the standard deviation from the mean, or the hundreds of 25 and 75 percentile of each index are considered as the low and the top limits of that index respectively, which are called the acceptable limits of variability or Range targets (TNC,2009; Richter et al.,1997). Considering that the streamflow of Karkheh River has had a natural flow in the temporal area before constructing the dam, so $\pm$ 1 STD values has been used before constructing the dam for determining the range of natural variability of streamflow regime of Karkheh River. In the next step, the percentage of change in each index was specified as the hydrological coefficient of change, can be calculated as

$$HA\ (\%) = \frac{Observed\ frequency - Expected\ frequency}{Expected\ frequency}$$

The hydrological coefficient of change shows the rate of change in each IHA indexes in the stage of after constructing the dam in comparison to the stage of before that. In this equation, "observed" is the number of years in which the observed value of the hydrologic parameter fell within the targeted range and "expected" is the number of years for which the value is expected to fall within the targeted range. In this regard, the values of change percentage in each index can be positive or negative, in such a way that the positive values show that the frequency of the specific index in the period of after constructing the dam has increased in comparison to that in the period of before constructing the dam, and in contrast, the negative values show the decrease of this frequency (Hu,2008; Richter,1997; TNC,2009).

Results

The results of investigating the changes made in 31 hydrological indexes of Karkheh River in the place of Payepol hydrometric station have been shown in table (1). To investigate the results which are achieved from RVA method better, the values of the change percent in hydrological indexes can be categorized in three classes in such a way that they was divided into the low degree of change (.% - 33%), the medium degree of change (34% - 66%), and the high degree of change (>67%) (TNC, 2009). The negative values shows that the specific hydrological index has been lower than the acceptable minimum amount of the range of variability, and the positive values shows that these values are higher than the acceptable maximum amount. Based on table (1), the rate of average deviation of flow monthly is higher

than the acceptable range in all of the months, except in November and December. Figure (2) shows the average monthly changes of flow in the streamgauge site in the periods of before and after constructing Karkheh Dam.

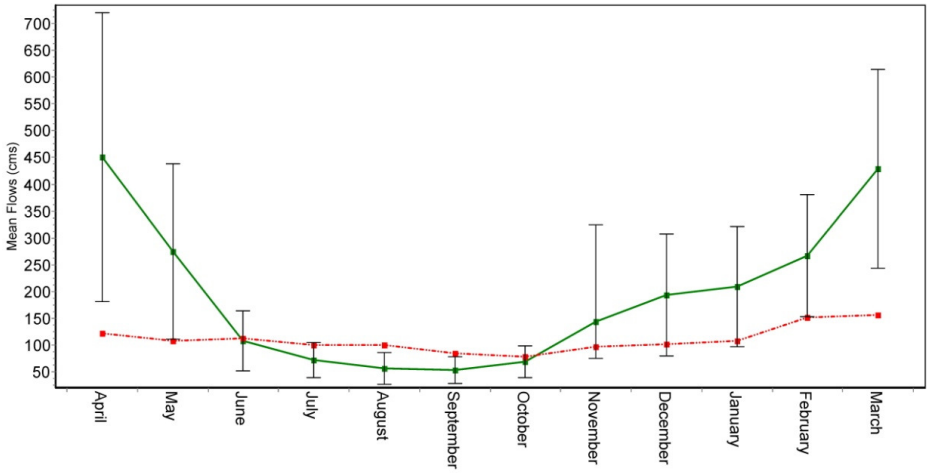

Fig 2. Hydrologic alterations of 12 monthly means flows in the pre- and post-dam period in Payepol station with range of variability

Based on table (1), April and June months have high degree of change and other months, except November and December have medium degree of change. Moreover, the average monthly flow has increased from June till October, and it has decreased from November till May in the period of after constructing the dam. The highest increase has been shown in August, and the highest decrease has been shown in April (Figure 3). These indexes (first group) influence some functions of this region such as the availability and quality of the habitats for the aquatics, availability of the moisture of the soil for plants, and existence of water for the animals which live out of the water.

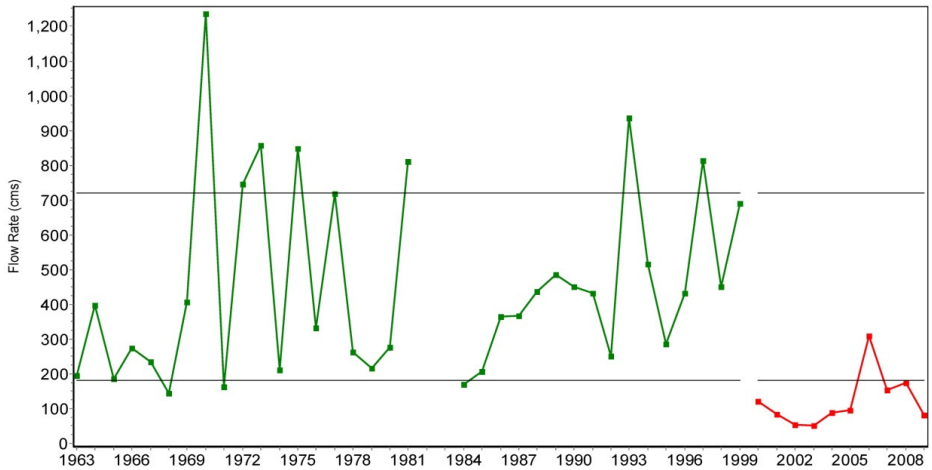

Fig 3. Monthly means for April in pre and post-dam period with RVA targets

Table 1. Results of the Indicators of Hydrologic Alteration analysis for Karkheh River at Payepol Station, Khuzestan, South West of Iran

IHA parameter group	Annual pre-impact 1963 - 1999			Annual post-impact 2000 - 2009			Annual mean value difference between pre-post impact %	RVA targets		Deviation % (degree)
	Mean	Min	Max	Mean	Min	Max		Low	High	
Group 1: Magnitude of monthly water conditions										
October	67.94	32.94	169	78.33	33.01	143.9	10.39/15.29	38.41	97.48	- 43.55
November	143.4	53.88	1145	96.41	62.34	139.4	-32.77	75.84	324.4	- 5.80
December	193	57.13	599.4	102	60.25	129	-91/-47.15	79.63	306.4	3.70
January	209.4	68.39	590.7	108.1	61.23	175.5	-48.38	96.65	322.2	- 46.15
February	266.6	112.6	562.8	151.8	61.45	320.7	-43.06	153.2	380.1	- 39.13
March	508	137.6	1780	154.7	69.32	468.8	-353.3/-69.5	158.3	857.7	- 59.62
April	451.5	143	1236	121.1	52.1	308.6	-73.18	182.2	720.7	- 86
May	274.6	79.1	652.1	107.9	35.79	279.4	-60.71	110.5	438.7	- 41.67
June	107.5	29.05	251.4	111.5	33.07	240	4/3.72	50.71	164.3	- 70.83
July	71.14	28.32	169	99.85	29.64	191.7	28.71/40.36	37.78	1.4.5	- 35.19
August	55.55	0	169	100.1	26.51	164.8	44.55/80.2	26.37	84.74	- 37.5
September	53.65	25.2	169	83.5	35.63	160.4	29.85/55.64	29.15	78.15	- 66.13
Group 2: Magnitude and duration of annual extreme conditions										
1-day minimum	23.64	0	67.6	31.39	0	62.8	7.75/32.78	3.413	43.86	28.95
3-day minimum	41.12	0	169	39.91	24.6	70.27	-1.21/-2.94	15.39	66.84	1.61
7-day minimum	41.92	0	169	43.35	25.17	72.87	1.43/3.41	16.23	67.61	- 9.68
30-day minimum	44.77	0	169	51.55	26.2	93.16	6.78/15.14	19.33	70.22	- 23.44
90-day minimum	51.9	27.73	169	65.72	28.1	112.7	13.82/26.63	27.91	75.89	- 34.38
1-day maximum	1694	219	5203	407.3	142	909	-1286/-75.98	584.6	2803	- 86.54
3-day maximum	1239	206.7	3696	352.3	118.3	704.7	-71.57	506.4	1972	- 75
7-day maximum	938.6	194.4	2697	295.8	111.9	505.4	-68.48	389.9	1487	- 50
30-day maximum	591.1	145.6	1322	225.4	87.56	437	-61.87	271.9	910.4	- 39.13
90-day maximum	373.9	122.4	824.7	160	71.14	262	-57.21	190.6	557.2	- 56.25
Group 3: Timing of annual extreme water conditions										
Julian date of annual maximum	201.6	80	292	157.5	26	306	-44.1/-21.88	119.8	283.4	- 27.08
Julian date of annual minimum	54.77	8	365	106.3	6	346	51.53/94.08	57	105.7	- 53.33
Group 4: Frequency and duration of high and low pulses										
Low pulse count	2.143	0	6	8	0	18	5.86/283.31	0.8113	3.474	- 75.86
Low pulse duration	53.46	1	149	15.4	1	48	-38/-71.19	15.02	91.9	- 59.62
High pulse count	4.571	0	12	2	0	10	-2.57/-56.25	1.792	7.35	- 74.07

High pulse duration	7.704	1.6	26.75	1.933	1	3.2	-5.77/-74.91	3	14.27	- 82.5
Group 5: Rate and frequency of water condition changes										
Rise rate	60.71	12.18	152.9	20.63	5.27	40.63	-40/-66	23.21	98.21	- 54.35
Fall rate	- 26.25	- 67.63	- 5.847	- 18.89	- 4.74	- 5.05	7.36/-28.04	- 40.03	- 12.46	- 16
Reversals count	70.11	11	112	167.3	96	227	97.19/138.63	50.17	90.06	- 100

The second group of hydrological indexes shows that the annual of 1, 3, 7, 30, and 90- day minimums have no considerable differences before and after period of constructing the dam, and only the 3-day minimum has decreased and others have increased. Moreover, the 7, 30, and 90- day minimums have been lower than the acceptable range. In contrast, the annual above-mentioned maximums have been highly changed in such a way that the 1 and 3-day maximums show high rate of deviation, and the 7, 30, and 90-day maximums show the average rate of deviation from the range of variability (Figure 4). These indexes determine the rate of tensions that create by the extraordinary water condition such as flood and drought.

Two indexes that shows the number of minimum and maximum days of 1- day flow from the third group has been related to birth and death of the species, so they influence the mobility of population. Regarding that in this method of investigation, the days of a year have been numbered from 1 to 365, so results show that the number of the minimum day of occurrence in 1-day flow in the period of after constructing the dam happens sooner than the previous period, and the day number of maximum occurrence of 1-day flow happens later that the difference of 1-day minimum occurrence has been low, but the difference of 1-day maximum occurrence has been high in the period of after constructing the dam. In the fourth group of the hydrological indexes, the rate and direction of the number of the annual low and high pulses deviation from the acceptable range of variability have been equal in the period of after constructing the dam, based on what had happened before constructing the dam, and both of them with high deviation degree locate lower than the range of variability

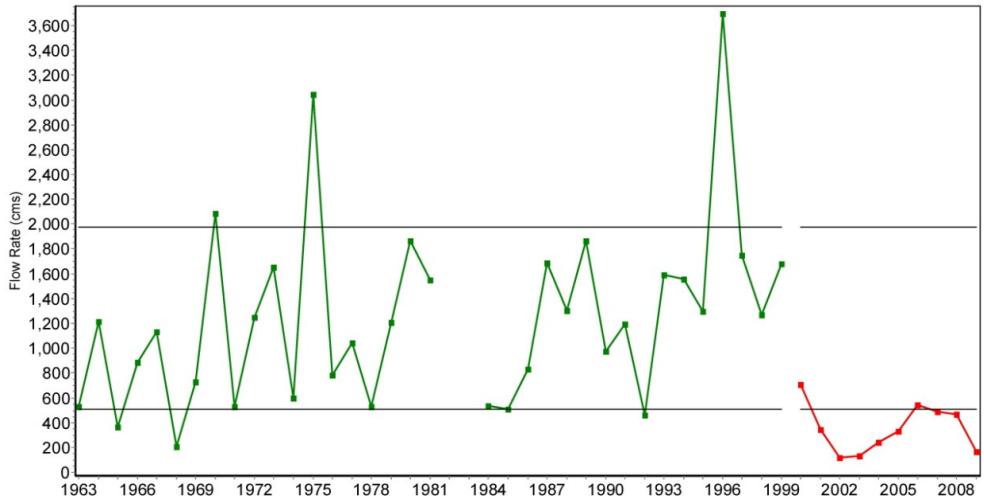

Fig 4. Annual maximum 3-day magnitudes in pre and post-dam period with RVA targets

But these two indexes are completely different considering the percentage of difference, in such a way that the number of the annual minimum pulses has increased 283%, and the number of the annual maximum pulses has decreased 56%. Moreover, the continuance of minimum and maximum pulses has decreased almost equally in the period of after constructing the dam. These indexes influence the alternation and the rate of the moisture of the soil that create tension on plants. Furthermore, they influence the availability of habitats for the aquatics in floodplains, exchange of organic materials and alimental substances between the river and floodplains, and existence of the mineral materials of the soil. In the fifth groups, the rate of decrease and increase has had descending procedure. In such a way that both of them have decreased 28% and 66% respectively in the period of after constructing Karkheh Dam (Figure 5).

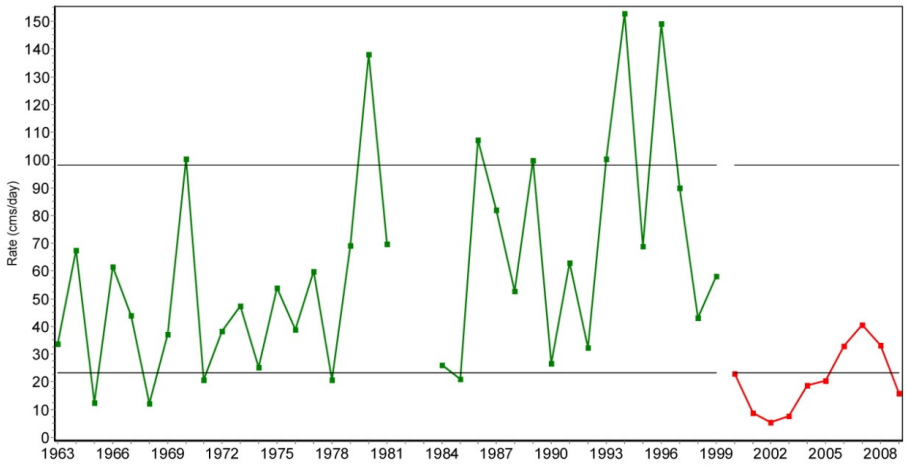

Fig 5. Annual mean rise rates in pre and post-dam period with RVA targets

In these two indexes, the deviation in the rate of increase of the flow has been more than the acceptable range, and this deviation has an average degree. The index of the number of flow's returns in this group is equal to the number of times that flow changes from the period of increase of the flow into the period of its decrease or vice versa. Result shows 139% of increase in the number of returns of the flow in the period of after constructing the dam and the degree of variability in the period of before constructing of the dam is high. These indexes influence the tensions resulted from the shallowness on plants in the period of decrease of the flow, and trap and confine the animals in the period of decrease of the flow.

Conclusions

The importance of protecting from the environment and imposing the environmental criteria has been regarded gradually and with an increasing procedure. Today, this topic that the economic developmental policies should be in accordance with the environmental objectives is accepted by all the people. In the 18th chapter of the twenty firth program of the Environment and Development Committee of UN (NNCED), regarding maintaining quality and providing the fresh water, protecting from the environment and natural resources has been emphasized as a basis of water resources development for developing agriculture and rural uses. Regarding the complexities of natural ecosystems and interactions that exist between their elements, any kinds of interferences and changes in the natural ecosystems has a lot of effects. Based on the Theory of Complexity that introduced in 60 decade, complexity can be defined as an ability of self-organizing and achieving an optimal limit for interaction and answering to the condition of the

environment (Loehle, 2004). The ecological indexes have important roles in simplifying these complexities, and through these indexes, we can find the way of interaction and response of the environment to development. In this research, hydrological indexes of change are used for simplifying the complexities that rules over the ecosystem of Karkheh River. The hydrological indexes showed that with constructing Karkheh Dam over this river, the hydrological indexes have completely changed during 35 years of before constructing of the dam (according to the existing information) over Karkheh River, particularly in downstream, and regarding the ranges of variability achieved from the period of before constructing the dam, all of the indexes have been influenced. Considering that in 83% of months in a year, the rate of inaccessibility to the hydrological condition of the period of before constructing the dam has the average and high degree of change, so it has a direct effect on the level of availability of the soil moisture for the plant that exist in the border of the river (Richter et al., 1996), in such a way that in the period of after constructing the dam. The hydrological indexes showed that constructing Karkheh Dam can properly control the existing hydrological tensions in the ecosystem of Karkheh River in downstream and moderate them. One of the different types of existing hydrological tensions in this ecosystem is the occurrence of innumerous flood that the maximum 1 and 3-day indexes show these kinds of intensions. Based on the maximum 1 and 3-day results they have had a considerable decrease with the high degree of change in the period of after constructing that can demonstrates a success in controlling the floodwaters of this river. On the other hand the 1-day minimums that can be an index for shallowness of the river has decreased in the period of after constructing the dam, and it shows regulation of the flow of the river in this period. By decreasing the number and continuance of the annual maximum and minimum pulses in the period of after constructing the dam, the level and continuance of the soil moisture have influenced in the border of the river and the exchange of organic materials and alimental substances between the river and floodwater plains and existence of the mineral materials of the soil, and it has led to decrease of the mass of the plant covering in the border of the river. The indexes of the rate of increase and decrease of the flow shows the establishment of the regulatory flow in the period of after constructing the dam, in such a way that by natural decrease of the streamflow regime of the river, the flow increase and by natural increase of that, the flow of the river decrease (Poff et al., 1997; Richter et al., 1996). Generally, regarding the change of the hydrological condition in the downstream of Karkheh River by constructing the dam and the effect of this change of the regime in the structure of the appearance of the region in the border of the river, it can be said that the hydrological regime and structural patterns of the appearance of the region in the border of this river have had mutual action in the ecosystem of the river and have had a direct relation with each other. Controlling floods that had an important role in feeding and providing the ecological condition of the floodplains in the period of after constructing the dam has led to emerging the phenomenon of decomposing in the pattern of woodland covering in the border of the river (Naiman et al., 1997; Nilsson et al., 2000). Thus, regarding that the positive results of constructing the dam is in the field of providing the water for agriculture and water supply and preventing from the damages of innumerous floods, to maintaining the ecological condition in downstream of Karkheh River especially in the valuable ecological regions (the protected region and the wildlife refuge of Karkheh), the management and planning of water resources for exploiting should be done in such a way that the annual values of each of the hydrological indexes of Karkheh River occur in the range of natural changes in the period of before the constructing the dam.

References

Carmen, R., (2005). Developing indicators of ecosystem condition using geographic information systems and remote sensing. Reg. Environ. Change, 5: 205–214.

Gorman, G.T., I.R., Karr.(1978). Habitat Structure and structure and fish communities. Ecology, 59: 507-515.

Hu, W.W., G., Wang, W., Deng, S., Li. (2008). The influence of dams on ecohydrological conditions in the Huaihe River basin, China .Ecological Engineering, 33, 233-241.

Keddy, P.A.(1992). Assembly and response rules: two goals for predictive community ecology. Journal of Vegetation Science, 3: 157-164.

Loehle, C., (2004). Challenge of Ecological Complexity. Vol.1. USA: Illinoise.

Naiman, R. J., and H. Decamps. (1997). The ecology of interfaces: riparian zones. Annual Review of Ecology and Systematics, 28: 621–658.

Nilsson, C. and K. Berggren.(2000). Alterations of Riparian Ecosystems Caused by River Regulation. BioScience. Vol. 50 No. 9: 783-792.

Poff, N.L. and J.V. Ward. (1989). Implications of streamflow variability and predictability for lotic community structure: a regional analysis fo streamflow patterns. Canadian Journal of Fisheries and Aquatic Sciences, 46: 1805-1818.

Poff, N.L., (1996). A hydrogeoghraphy of unregulated streams in United States and an examination of scale-dependance in some hydrological discriptors. Freshwater Biology, 36: 71-91.

Poff, N.L., Allan, J.D., Bain, M.B., Kar, J.R. (1997). The natural flow regime: a paradigm for river conservation and restoration. BioScience, 47: 769–784.

Richter, B.D., J.V. Baumgartner, J. Powell, D.P. Braun. (1996). A method for assessing hydrologic alteration within ecosystems. Conservation Biology, 10: 1163-1174.

Richter, B.D, J.V. Baumgartner, R. Wigington, and D.P. Braun. (1997). How much water does a river need? Freshwater Biology, 37: 231-249.

Richter, B.D., J.V. Baumgartner, D.P. Braun , and J. Powell, (1998), A Spatial Assessment of Hydrologic Alteration Within a River Network. Regul. Rivers: Res. Mgmt, 14: 329-340.

Richter, B.D., Andrew, T., Warner, J.L., Meyer, K. (2006). A Collaborative and adaptive process for developing environmental flow recommendations. River Res. Appl., 22: 297–318.

Stanford, J.A., Ward, J.V., Liss, W.J., Frissell, e.A., Williams, R.N., Lichatowich, J.A., and Coutant, e.e. (1996). A general protocol for restoration of regulated rivers, Regul. Rivers: Res. Mgmt, 12: 391-413.

Tejan, E.C. and Haase, C.S. (2008). Indicators of hydrological alteration (IHA) analysis of selected streams on the Arbuckle-Simpson aquifer, South Central Oklahoma. Oklahoma Cooperative Fish and Wildlife Research Unit.

TNC, (The Nature Conservancy) (2009). Indicators of Hydrologic Alteration User's Manual.

Walker K.F., F. Sheldon , J.T. Puckrid. (1995). A prespective on dryland river ecosystems. Regulated Rivers, 11: 85-104.