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Investigation of Check Dam's Effects on Channel Morphology (Case Study: Chehel Cheshme Watershed)

[1]K. Solaimani, [2]E. Omidvar and [2]A. Kelarestaghi
[1]GIS and RS Centre, University of Agricultural and of Natural Resources Sciences of Sari, P.O. Box 737, Sari, Iran
[2]Department of Watershed Management, Faculty of Natural Resources, Sari, Iran

Abstract: This research is focused on morphologic changes of channels resulted from establishing check dam construction in Chehel cheshme watershed located at Fars Province. In this study, five channels with check dams were selected through the study area. Then some morphologic parameters of channels such as width/depth ratio, the maximum depth and cross section area along the channel on which check dam were constructed had been measured. These measurements were made on 6 cross section areas in 10, 50 and 90% distances from check dams at upstream and downstream. The above mentioned parameters were calculated using calculating and graphic soft wares. Then, some analytical methods were used to estimate and compare the average digital numbers of calculated parameters through different channels. The results showed that check dams have definitely influenced on width/depth ratios at their upstream and downstream. These influences are associated with higher width/depth ratios at upstream and lower width/depth ratio at downstream. Furthermore, the maximum depth of channels had significant influenced by check dams. As for cross section areas, no significant difference existed between cross sections through total channels and check dams.

Key words: Check dam, channel, morphology, Chehel cheshme watershed, Iran

INTRODUCTION

Soil erosion is a widespread land degradation problem at the global scale in term of loss of soil fertility and water quality (Lal, 2005; Pimentel, 1997). Soil erosion leads to surface soil decomposition and sedimentation in dams and channels so, river capacities will be reduced, leaving large damages on the country. The undeniable significance of soil in agricultural processes to produce foods as well as the ever-increasing demands of animals and human being for these production, explain the vitality of soil conservation (Khodami, 2005). Mechanical methods are often used for soil and water conservation purposes. One of these mechanical operations to control erosion and conserve soils is to establish check dams on upstream channels of watersheds (Refahi, 2006).

Check dams are small dams constructed across a channel or gully in order to reduce the velocity of intensive flows, monitor and entrap sedimentation, increase infiltration capacity of channels, increase vegetation, reduce the flood peak discharge, increase the concentration and lag time in the studying watershed area and finally to correct the width and length profiles of channel: that's the reason they are called check dams (Gray and Leiser, 1982). There are different geomorphologic influences on upstream and downstream of those constructions. Gradual sedimentation on upstream channels is occurred due to less steep slopes. Thus, These dams are quickly filled with Sediments in Semiarid areas in which the Sedimentation occurs in greater amounts (Poesen and Hooke, 1997). Effects of constructing check dams seem more complicated on down streams. The changes in discharge and sediment loads may lead to some changes in parameters including cross section shape, channel shape and type, slope and particle size of bed materials (Brandt, 2000). This parameters define the channel geometry. The channel geometry is the cross-sectional form of a stream channel (width, depth, cross-sectional area) fashioned over a period of time in response to formative discharges and sediment characteristics (Goude, 2004). As it mentioned earlier, This study is focused on the effects of establishing check dams on the morphology characteristics of channels. To do this, some of these morphologic parameters such as width-depth ratio, maximum depth and Cross section area of channels with check dams on them are evaluated using

Corresponding Author: K. Solaimani, GIS and RS Centre, University of Agricultural and of Natural Resources Sciences of Sari, P.O. Box 737, Sari, Iran Tel: +989111521858

sampling data in downstream and upstream of these constructions. Although, there are numerous studies on check dam design and its operation (Eisbacher and Clague, 1984; Heierli and Merk, 1985; Chatwin, 1994). Lin *et al.* (2008) researches on the stabilizing effect of ground-sills downstream of check dams on the riverbed through a series of flume model experiments and resulted, although check dams have the ability to control upstream sediment transport, the mass energy produced by the free fall of the overtopping discharge still causes strong local scour downstream of the structure and this scour leads to the instability of the check dam. They conclude ground-sills can effectively protect the streambed from scouring under a suitable equipped condition and the concepts of guiding scour and riverbed inertia were used in the analysis of optimal ground-sill spacing. Catella *et al.* (2005) studied the efficiency of slit-check dams in the mountain region of Versilia basin (Italy). Their results suggested that the design efficiency is affected by the high sediment trapping capacity associated with the relatively minor floods. Also a comparison between the deposit geometry predicted by the theory and the field measurements gathered during a systematic monitoring activity showed good agreement. According to the results of Marston and Dolan (1999) engineering construction to control outgoing sediments from Wyoming (USA) dried watershed were not effective. Boix-Fayos *et al.* (2007) studied the effects of check dams, forestation and land use changes on the morphology of river channels at Rogativa watershed. They found that sediments entrance into channels were reduced due to maintaining sediments behind the check dams furthermore higher conveyance capacity of flows results in more surface erosion at downstream of check dams. The above mentioned corrective operations put significant effects on channel response and sediments dynamic. Castillo *et al.* (2007) assessed the effectiveness and geomorphologic impacts of check dams to control soil erosion at seasonal channels of Mediterranean semiarid areas in Spain. According to their results check dams stop the sediments at upstream and reduced the linear slope. Meantime, entrapped sediment mass at upstream dams are more than the erose materials at downstream , therefore, there is a lower width-depth ratio at shoal which indicate that erosion at downstream was due to high erosive power of water and that the sediments entrapped bay dams. They prevent flood occurrence at downstream. Ran *et al.* (2008) analyzed coarse sediment retention by check dams for five typical catchments in the Hekou-Longmen section of the midstream of the Yellow River. Their results showed that check dams are the most effective to rapidly reduce the amount of coarse sediment entering the Yellow River. If the average percentage of the drainage area with check dams for the five typical catchments reaches 3.0%, the average sediment reduction ratio can reach 60%. Meanwhile, estimating mode is more precise in calculating the balance slopes. The effects of constructing the check dams on concentration time in Roudbar watershed located at Golestan province (Iran) were studied by Kabir (2007). Results of his study showed that the constructed dams had no significant effect on increasing the concentration time and this parameter increased less than 1% in all cases. In recent years, these kind of constructions are commonly used in watershed areas. So it is necessary to study the effects of these dams on channels.

MATERIALS AND METHODS

Study area: Chehel-cheshme watershed with an area of 334.674 km^2 between the longitude of 29° 29′- 29° 58′ and the latitude of 52° 01′- 51° 53′ is one of the subzones of Ghare aghaj river's watershed area in Fars Province and it is located at 45 km distance from west of Shiraz. This area has a mountainous topography. The maximum and minimum height of this area from the free sea level are 3040 and 2020 m, respectively , with and average slope of 40.22%. The area has a very humid climate and its average of annual rainfall is about 1124.4 mm. Geologically, the following formations exist in the study area: Asmari, Gachsaran and quaternaric formations. The estimated sediment delivery ratio is 16.6% and the total produced sediment is 57721.8 tone $year^{-1}$ averages annual discharge is 3.424 m^3 sec^{-1}. Furthermore, about 58.57% of total area is located at average to high erodibility classes. Figure 1 shows the geographic situation of Chehel-cheshme watershed in Fars Province at Iran.

Check dams: Regarding the necessity of corrective operations to prevent the erosion in the study area, many watershed applications such as establishing check dams has been recently conducted in this area.

Table 1 shows the characteristics of sampled check dam volume and the sediments stored behind them was calculated based on channels with rectangular section and using the following equation (May and Gresswell, 2003; Lien, 2003):

Where:
V = ½(Ws Ls H)
V = sediment volume (m^3)
Ls = longitudinal length of the surface area of sedimentation (m)
Ws = The average width of sediment wedge (m)
H = Height of sediments from dam base (m)

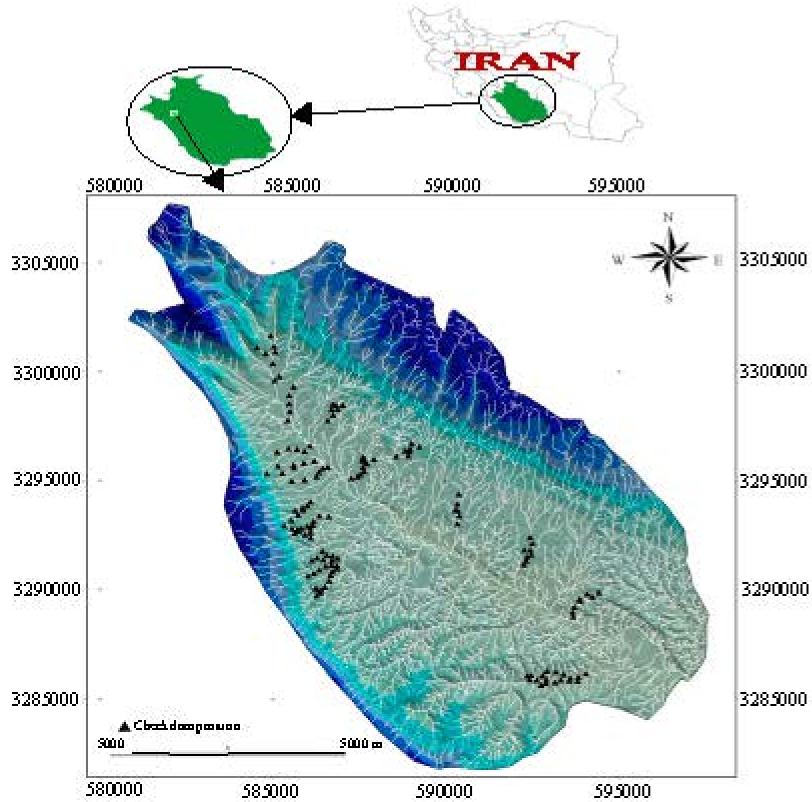

Fig. 1: Location and drainage network of the Chehel-cheshme catchment and the position of the check dams

Table 1: General characteristics of the check dams (*indicates that the capacity of the check dams is filled)

Channel's name	Check dam's No.	Type of check dams	Total height	Effective height	Height of sediments (H)	Width check dam	Average width of sediment wedge (Ws)	Longitudinal length of the surface area of sedimentation (m)(Ls)	Check dam's volume (m³)	Sediment volume (V) (m³)
Najaf abad	1*	Concrete-rock dam	1.90	1.30	1.30*	8.00	7.75	29.00	146.09	146.087
	2*	"	1.95	1.35	1.35*	5.10	5.50	18.00	66.82	66.825
	3*	"	1.90	1.25	1.25*	7.40	5.90	16.50	60.84	60.840
	4	"	1.40	1.00	0.70	6.00	4.60	16.70	38.41	26.890
	5	"	1.50	1.00	0.80	9.50	4.30	14.50	31.18	24.940
Mokhtar abad	1	Loose-rock dam	1.60	1.10	0.60	6.50	4.50	8.50	21.40	11.480
	2*	"	2.10	1.50	1.50*	7.00	5.30	9.50	37.76	37.760
	3*	"	1.70	1.10	1.10*	6.00	5.20	9.00	25.74	25.740
	4	"	1.30	1.00	0.40	7.00	4.30	8.50	18.28	7.310
	5	"	1.50	1.20	0.85	4.00	2.80	10.00	16.80	11.900
Zangane (1)	1*	Concrete-rock dam	0.85	0.50	0.50*	6.00	6.40	22.00	35.20	35.200
	2*	"	1.20	0.70	0.70*	6.50	7.50	19.00	49.87	49.870
	3	"	1.10	0.75	0.50	7.00	7.00	22.00	57.75	38.500
	4	"	1.60	1.10	0.60	7.00	5.90	20.00	64.90	35.400
	5	"	1.80	1.20	1.20	4.70	4.60	19.00	52.44	52.440
Zangane (2)	1*	"	1.30	0.70	0.70*	12.00	11.60	33.00	13.00	133.980
	2*	"	1.80	1.10	1.10*	11.00	12.70	29.00	20.00	202.650
	3*	"	2.00	1.40	1.40*	10.00	9.80	26.00	178.36	178.360
	4	"	2.30	1.60	1.40	15.00	11.30	40.00	361.60	316.400
	5	"	2.50	1.90	1.20	20.50	19.90	48.00	907.44	573.120
Khane zenian	1	"	3.00	1.50	0.50	14.50	18.50	60.00	832.50	277.500
	2	"	3.50	2.00	0.60	15.00	10.50	48.00	504.00	151.200
	3	"	3.70	2.20	0.40	21.00	21.00	13.70	316.47	57.540
	4	"	4.00	2.50	0.70	18.00	13.00	69.00	1121.25	313.950

Fig. 2: View of check dams in Chehel cheshme watershed

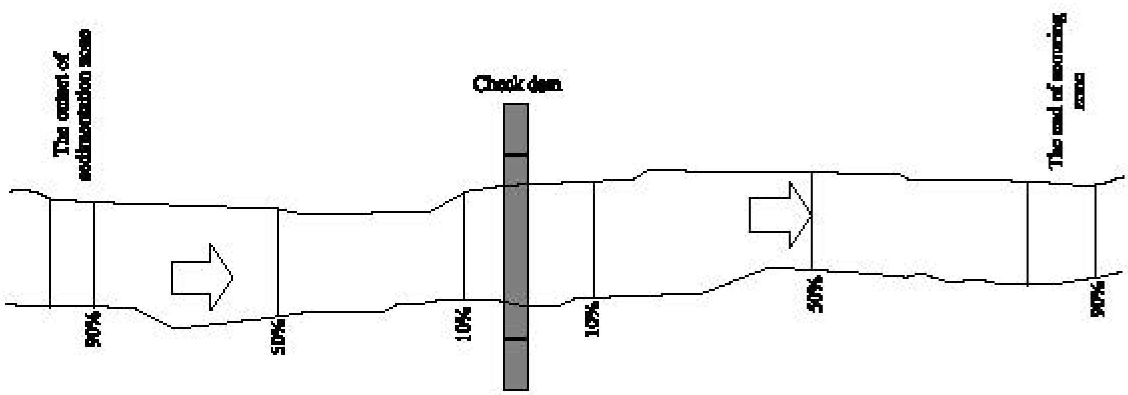

Fig. 3: Layout and subdivision of sampling places for survey

Methodology: At the First step, the areas under the coverage of corrective operations were identified on the maps of corrective operations and potential places for check dams prepared for the area before performing operations. Then, dams with proper distribution keeping enough sediments behind them were selected inside the area. Five different channels including Najaf abad, Mokhtar abad, Khane zenian, Zangane (1) and Zangane (2), were selected in the study area, then, some dams were determined on the upstream channels followed by selecting 24 check dams (Table 1) cross profiles were measured on various parts of upstream and downstream dams (Fig. 2) via field survey methods. The point from which sedimentation processes start on upstream and the point on which this process ends on downstream should be identified in order to determine the sampling sections. The start point of sedimentation process could be identified via sediment grain size, appearing bedrocks vegetation cover changes or linear slope changes. Meanwhile, erosion points of channel starts immediately from upstream check dams and continues to sedimentation start point at the subsequent check dam (Castillo *et al*., 2007). After determining sedimentation and erosion areas, three cross profiles at upstream and three ones at downstream of check dams were determined. These points at sedimentation and erosion areas were located at 10, 50 and 40% distance from check dams (Fig. 3). Channels cross profiles were measured at each filled section. Filled section is defined as a water level just filling the available cross section (Dunne and Leopold, 1978).

Then, some parameters such as cross section area, width-depth ratio and maximum depth were estimated for each cross profile. A one way ANOVA test and a paired t-test ware used to study the effects of check dams on channel morphology. One way ANOVA test was used to compare the averages on various cross sections and different channels, while paired t-test was used to perform a comparison between upstream and downstream cross profiles. To do this, at first, numeral values for above mentioned parameters were averaged separately for upstream and downstream dams. Then, a numeral values for upstream and downstream of each dam were calculated. A statistical test was done on each pair of these numeral values. In order to compare the effects of check dams on the above mentioned parameters, a paired t-test was used for numeral value of 10% in upstream and 10% in downstream, 50% upstream and 50% downstream as well as 90% upstream and 90% downstream in each tripled cross profile separately at upstream and downstream.

RESULTS AND DISCUSSION

Width-depth ratio: The diagram for average width-depth ratio in each section is shown in Fig. 4. Results of the one way variance analysis of this parameter (width-depth ratio) on all check dams of the study area shown a 1% significant difference among 6 section (p = 0.000). Results of comparing the averages via Duncan method showed no significant difference at the level of 1% among 3 profiles of 10, 50 and 90% at upstream. Significantly, there was no significant difference among these averages on downstream, i.e., they are statistically the same. However, a significant difference exists between 2 above mentioned groups of upstream and downstream profiles (Fig. 4). Based on the results of paired t-test to compare the pair correspondence profiles at upstream and downstream showed a 1% significant difference in all tests (Table 2).

According to the results of one way ANOVA test for width-depth ratio related to each discrete channel, there was a significant difference at the level of 1% between the measured sections of Najaf abad and Mokhtar abad channels, while a significant difference at the level of 5% existed between Zangane (2) channels. However, no significant difference was observed between the averages of different profiles at Zangane (1) and Khane zenian channels (Fig. 4-9).

Maximum depth: The diagram for average maximum depth in each section is shown in Fig. 4. One way ANOVA test was used for max depth of all dams. Results of this test showed no significant difference between max depth of sample sections (p = 0.075) (Fig. 4). To compare this parameter between upstream and downstream, the one way ANOVA test was applied for each separate channel according to the results of this comparison. There is a significant difference at the level of 1% between the measured profiles of Najaf abad, Mokhtar abad and α 5% significant difference in Zangane (2) channels, however, no significant difference between the averages at different profiles of Zangane 1 and Khane zenian (Fig. 4-9).

Results of paired t-tests indicated that a significant difference at the level of 1% existed between the profiles with 10% distance from dams in downstream and upstream and a significant difference at the level of 5% between profiles with 50% distance from dams and among

Table 2: Results of paired t-test to compare the pair correspondence profiles at upstream and downstream

Paired cross section	Average	SD	df	t-value	Sig
10% upstream	19.94	10.57	23	5.348**	000.0
10% downstream	10.29	3.75			
50% upstream	25.05	15.39	23	3.990**	001.0
50% downstream	11.85	5.00			
90% upstream	19.44	10.96	23	3.795**	001.0
90% downstream	10.80	4.69			
Upstream average	21.48	9.91	23	6.025**	000.0
Downstream average	10.98	3.23			

**p<0.01

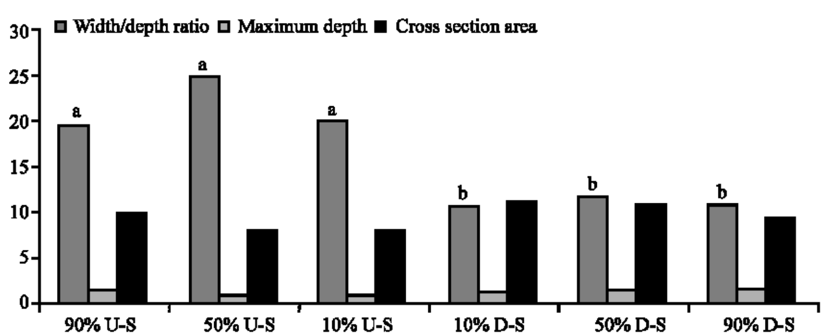

Fig. 4: Results of one way ANOVA test for width-depth ratio, maximum depth and cross section area related to total of check dams

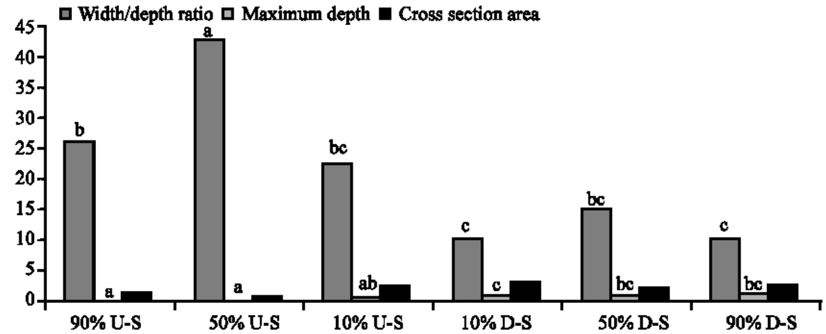

Fig. 5: Results of one way ANOVA test for width-depth ratio, maximum depth and cross section area for Najaf abad channel's check dam

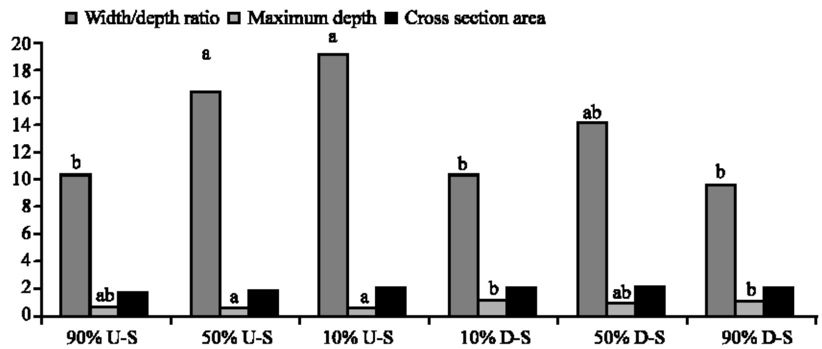

Fig. 6: Results of one way ANOVA test for width-depth ratio, maximum depth and cross section area for Mokhtar abad channel's check dam

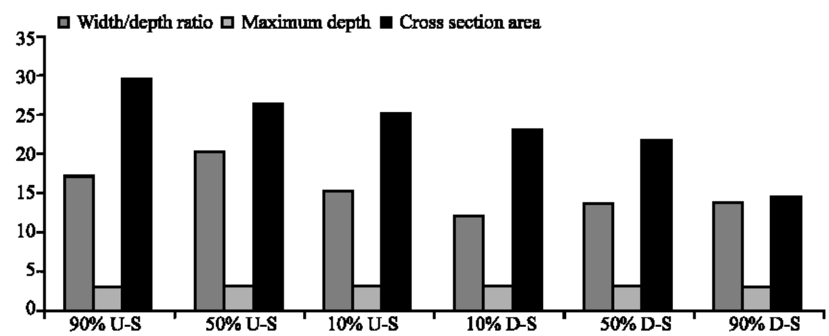

Fig. 7: Results of one way ANOVA test for width-depth ratio, maximum depth and cross section area for Khane zenian channel's check dam

Table 3: Results of paired t-test to compare for max depth at upstream and downstream

Paired cross section	Average	Standard division	df	t-value	Sig
10% upstream	0.876	0.672	23	-4.108**	0.000
10% downstream	1.385	0.798			
50% upstream	0.889	0.811	23	-2.652*	0.014
50% downstream	1.478	0.973			
90% upstream	1.157	1.216	23	-1.309^{ns}	0.310
90% downstream	1.444	1.041			
Upstream Average	0.974	0.844	23	-2.472*	0.021
Downstream Average	1.436	0.870			

*p<0.05, **p<0.01, ns: non-significant

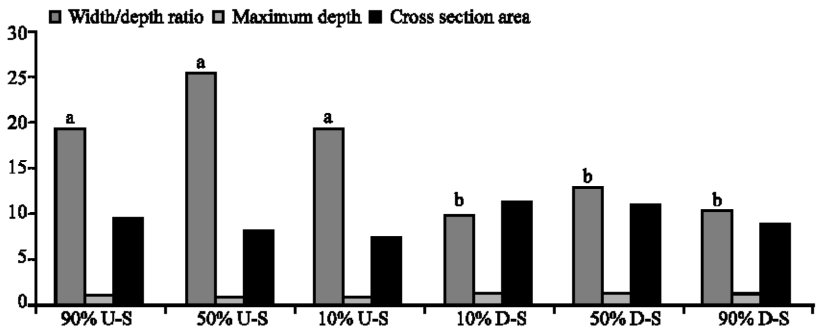

Fig. 8: Results of one way ANOVA test for width-depth ratio, maximum depth and cross section area for Zangane (1) channel's check dam

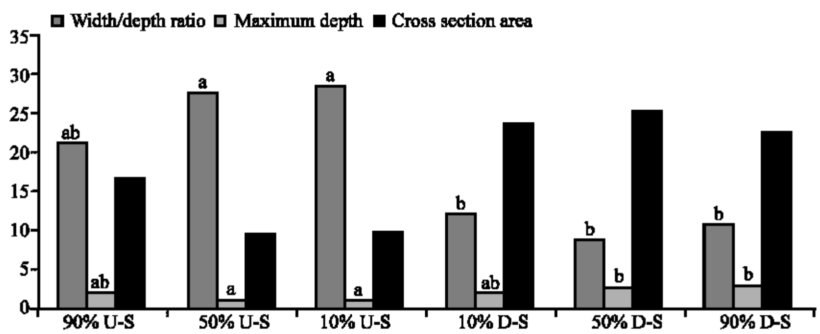

Fig. 9: Results of one way ANOVA test for width-depth ratio, maximum depth and cross section area for Zangane (2) channel's check dam

Table 4: Results of paired t-test to compare for cross section area at upstream and downstream

Paired cross section	Average	Standard division	df	t-value	Sig
10% upstream	9.90	19.47	23	-0.276 ns	0.785
10% downstream	10.89	12.80			
50% upstream	7.90	14.28	23	-0.887 ns	0.384
50% downstream	11.08	12.83			
90% upstream	7.69	11.37	23	-0.644 ns	0.526
90% downstream	9.33	11.10			
Upstream average	8.50	14.62	23	-0.626 ns	0.538
Downstream average	10.43	11.84			
	8.50	15.22	71	-1.035 ns	0.304
	10.44	12.12			

ns: non significant

the averages of max depth of 3 upstream profiles and the average max depth at 3 downstream profiles. While, no significant difference existed between profiles with 40% distance from dams (Table 3).

Cross section area: The above mentioned statistical tests were applied to total check dams, as well as: each discrete channel. According to results of both t-test and ANOVA test, no significant difference existed between cross sections at different sections (Fig. 4-9, Table 4).

CONCLUSION

Based on the results of this study about the width/depth ratios in t-test and ANOVA tests, this parameter are definitely affected by check dams both in upstream and downstream, so that, this ratio increases at upstream and decreases at downstream. These findings are in accordance with the results of Castillo *et al.* (2007). Results of assessing (Fig. 4-9) for maximum depth parameter showed a significant difference in 10 and 50% as well as between the total average of upstream and downstream profiles; therefore, it can be induced that check dams had significant effects on maximum depth of channels; water flows conveying sediment from upstream are associated with a dramatic increase in sediment conveyance capacity, this factor as well as falls from spillway result in surface erosion in downstream, thus, the maximum depth is related to 10 and 50% distant from check dam; as the result, a significant difference existed between these distant at downstream and their correspondent distances at upstream of this check dam. These results are in concordance with Castillo *et al.* (2007).

The reasons of lacking a significant difference between profiles with 90% distance from the check dam in upstream and downstream could be explained as follows due to further distances between this section and check dams, less erosion and sedimentation occurs on these points, thus, no significant difference existed between their maximum depth at upstream and downstream. This could be due to the fact that channel depth is reduced by sedimentation processes in upstream sections. However the width is increased a these places. In downstream, the channel width is decreased due to the higher depth erosion.

Since, a direct relationship exists between the cross section area and channel's depth and width; therefore, no significant difference exist between the cross section areas in upstream and downstream of check dams. The retail changes in different sections could be related to other parameters such as roughness coefficient, slope and plow speed.

Results of variance analysis on 3 parameters of width-depth ratio, max depth and cross section area in each channel could be explained as follows:

- In Najaf abad and Mokhtar abad channels, the average width-depth ratio and average max depth didn't show different effects of check dams on up streams and down streams. However, establishing check dams may cause a significant difference at the level of 1% between these averages. These channels are from type 1 channels which are rocky and their slopes and flow speed are significantly changing therefore, there is a turbulent flows in that various sections and the expected systematic order in terms of averages in up streams and downstream.
- As for Khane zenian and Zangane (1), any of 3 studying parameters didn't show a significant difference. Khane zenian had very deep and wide channels. Since 2 factors of depth and width are directly related to dams storage volume (Lien, 2003; May and Gresswell, 2003), check dams were highly potential to collect sedimentations therefore, 3 years after establishing check dams, still a great part of them are empty, i.e., the real effects of check dams on these
- Tests showed no significant difference at Zangane 1 channels. This channel is located at a part of Chehel cheshme watershed under the land use of dry farming with no vegetation during a long period of the year. This area is classified as average to high erosion class. Check dams in these channels are so much filled with sediments that instead of erosion sediments are kept in downstream. In addition, sediments are also entered from banks to these channels and filled it. Thus, there are similar conditions in upstream of check dams and no significant difference exists between them
- Result of variance analysis in Zangane (2) channel showed no significant difference between maximum depth and width/depth ratio in upstream and downstream of this channel indicating the effects of check dams on the characteristics of this channel

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