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Examining the Effectiveness of Check Structures in reducing Flood Discharge of Kotok Watershed in Khuzestan Province in Iran

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ABSTRACT

Check dams are small structures which are constructed to reduce flow rate and channel slope and to control erosion of waterways. The construction of these dams in watersheds causes changes in time of concentration which has a significant impact on flood control and containment of runoff. Kotok wateshed which is located in Andika County of Khuzestan Province in Iran is one the sub-watersheds of Shahid Abbaspour Dam and Karun River. In this watershed, floods during rainfall seasons cause land erosion in the area and transport plenty of sediments to the downstream. In this research, by studying the area and topographical conditions and conducting protective operations, changes in the flood's concentration time and flow before and after implementation of check structures were compared. In this regard, the following parameters were studied, number and height of dams, soil hydrologic group, channel slope, time of concentration, hydrology of the region, area of watershed and sedimentation volume of structures. With respect to the survey, it can be concluded that the construction of check structures alone cannot have a significant impact on controlling runoff and concurrent implementation of other watershed management operations such as biological and biomechanical operations is essential for achieving the projects' goals.

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INTRODUCTION

Reducing soil erosion and runoff, retaining soil moisture and controlling sedimentation are the most important goals of watershed management projects. Proper implementation of these projects leads to positive and valuable economic, social, etc. effects for watershed residents. In Iran, considerable amounts of money are spent each year for implementation of these projects. Various operations are performed in watershed management programs and activities such as construction of check dams and dry dams. The most important effects of these structures are channel slope stabilization, increasing the time of concentration, reducing flood rates and controlling sediments[5]. Knowledge about the effectiveness of implementation of any project, including watershed management operations, is of crucial importance for their executors[2]. Because with this knowledge, while knowing the level of achievement of primary goals, the relevant advantages and disadvantages are identified and necessary decisions can be made about amendment of flaws or revision in the manner of execution or even the type of executive operation. In this regard, with the development of watershed management projects, this question always stays in minds that really to what extent the objectives of executive operations, which are control of erosion and containment of surface runoff, are met.

Moore (1969) investigated 300 constructed structures and their effects on reducing peak flows in watershed branches in Texas and concluded that there was an inverse relationship between the volume of output runoff and storage runoff and the capacity of flood control structures [4].

ASCE Steering Committee (1998) conducted a comprehensive study on slope control structures. In this research, design, implementation and maintenance principles of various slope control structures such as check dams were studied from the perspective of existing resources in different countries [1].

Yoshikawaa *et al.* (2010) assessed Paddy Field Dam project in Kamihayashi District in Japan. In this study, they examined flow volume reduction and flood damage reduction. The results showed that flood control structures decreased the flow rate by 26%, thus confirming the effectiveness of the structure [6].

The purpose of this study was to evaluate the effectiveness of check structures to control runoff in watersheds. Accordingly, Kotok watershed, in which a series of check structures have been implemented by the

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Department of Natural Resources and Watershed Management of Khuzestan Province, was selected and by field studies, the effectiveness of check structures before and after the implementation of structures was evaluated.

MATERIALS AND METHODS

Kotok watershed is located in the southwest of Iran in Andika County, Khuzestan. The geographic coordinates of this watershed are 359000 to 376000 of eastern longitude and 3586000 to 3606000 of northern latitude. The extent of the study area was 9094 hectares which was divided into 12 parcels (Figure 1). The physiographic characteristics of Kotok watershed are presented in Table 1.

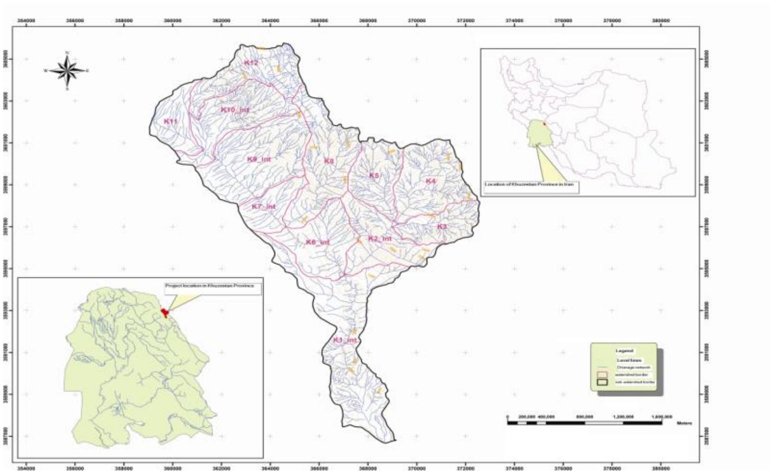

Fig. 1: Parcels and drainage networks of Kotok watershed.

Given the abundance of stone materials in this area, check dams are constructed as dry stone and gabion. Reviewing waterway maps, class 1 waterways are dry stone dams and class 2, 3, 4 and 5 waterways are gabion. The conducted survey revealed that all structures designed in the study phase were implemented. Table 2 indicates the number of check structures implemented in each parcel.

Table 1: The physiographic characteristics of Kotok watershed.

Units (parcel)	Area (km^2)	Perimeter (km)	Gravelius coefficient (c)	Main channel length (km)	Maximum height (m)	Minimum height (m)	Weighted average slope of channel (%)
K1	17.05	32.95	2.235	18.314	2131	849	7
K2	7.41	16.17	1.663	5.973	3040	1152	31.61
K3	4.67	10.13	1.312	4.142	3369	1480	45.61
K4	8.89	13.17	1.237	6.007	3354	1516	30.60
K5	5.97	11.22	1.286	4.581	3557	1516	44.55
K6	7.61	12.93	1.313	4.589	2612	1159	31.66
K7	3.97	9.14	1.283	3.426	2619	1517	32.17
K8	10.39	18.41	1.599	8.446	3697	1518	25.8
K9	12.83	15.23	1.191	7.188	3665	1692	27.45
K10	8.5	18.04	1.732	7.031	3710	1780	34.06
K11	4.32	10.34	1.393	10.303	2427	1815	5.94
K12	7.43	16.04	1.649	7.797	3743	1892	23.74

Table 2: Check structures implemented in Kotok watershed.

Name of sub-watershed	No. of dry stone dams	No. of gabion dams
K1	565	11
K2	8	-
K6	133	-
K7	146	2
K8	21	-
K9	153	21
K10	75	14
K11	184	7
K12	4	8

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Fig. 2: Shape of the structures.

American Soil Conservation Service (SCS) method was used to evaluate the impact of check dams on slope of channels and successively changes in concentration time of parcels. And it was selected as the basis for calculations in Kotok watershed.

(1) $$t_{lag} = \frac{L^{0.8}(S+1)^{0.7}}{1900y^{0.5}}$$

(2) $$t_c = 1.67 t_{lag}$$

L: Length of the main channel (feet)
S: Index of water retention within the watershed (inches)
y: Average slope of watershed or mean slope of the main channel (percent)
t_{lag}: Lag time (hr)
t_c: Time of concentration (hr)

According to the studies conducted and by the method provided by American Soil Conservation Service (SCS) and through estimating the weight curve number (CN) under conditions of medium humidity (AMC) of Kotok watershed soil, CN was calculated for each unit and then the coefficient of retention was calculated using equation (3).

(3) $$S = (\frac{1000}{CN} - 10)25.4$$

S: The factor related to water retention on the ground surface (mm)
CN: Index of curve number (dimensionless)

The American Soil Conservation Service (SCS) proposed method is among the common methods in hydrology which is used for watersheds lacking flow rate measurement data. In this method, the height of runoff from rainfall and maximum instantaneous flow rate is calculated by unit hydrograph method through the following equations:

(4) $$Q = \frac{(P-0.2S)^2}{P+0.8S}$$

(5) $$Q_p = \frac{0.208A}{t_p}$$

P: Rainfall height (mm)
S: The factor related to water retention on the ground surface (mm)
t_p: Time to reach the peak discharge (h)
Q_P: Unit hydrograph peak discharge for one millimeter of runoff (cubic meters per second)
A: Watershed area (km^2)

Discussion and Conclusions:

After reviewing and using empirical equations and comparing the results before implementing the check structures, the impact of these structures in reducing flood peak discharge in different return periods was determined. Construction of check structures in Kotok watershed has been performed in 9 parcels out of the total 12 parcels of this watershed. The general slope of the region is above 35% and a significant portion of the watershed lacks access roads for construction of check structures. Because of this issue, no structures have been constructed in K3, K4 and K5 parcels and in some other parcels just a few check structures have been implemented. Therefore, according to the obtained results, executive operations of structures in k1 and K11 parcels were effective on the peak discharge of flood and managed to reduce the peak discharge approximately 23% and 13%, respectively. Furthermore, in other parcels which executive operations were conducted, changes in flood discharge were very low and nearly zero. These results indicate that there are executive constraints for check structures in watersheds with high slopes and construction of these structures alone do not lead to achieving the goals of the project such as reduction of the flow rate and volume of runoff.

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Table 3: Changes in concentration time before and after the construction of check structures.

Units (parcel)	Area (km^2)	Proportion of parcel area to the total watershed area	CN	The concentration time before construction (hr)	The concentration time after construction (hr)	Changes in the concentration time (hr)
K1	17.05	17.22	76	5.99	9.37	3.38
K2	7.41	7.48	78	1.08	1.09	0.01
K3	4.67	4.72	79	0.65	0.65	0
K4	8.89	8.98	77	1.14	1.14	0
K5	5.97	6.03	77	0.76	0.76	0
K6	7.61	7.68	77	0.90	0.96	0.06
K7	3.97	4.01	75	0.75	0.83	0.08
K8	10.39	10.49	79	1.54	1.55	0.01
K9	12.83	12.95	77	1.39	1.49	0.1
K10	8.5	8.58	78	1.33	1.38	0.05
K11	4.32	4.36	71	4.73	6.18	1.46
K12	7.43	7.50	79	1.5	1.51	0.01
The entire watershed	99.04	100				

Table 4: The flood peak discharge at different return periods before and after the construction of check structures.

The flood peak discharge at different return periods before the construction of check structures							
Unit	Return period (years)						
	2	5	10	20	25	50	100
K1	2.99	6.16	8.50	10.92	11.71	14.23	16.88
K2	2.27	4.71	6.47	8.29	8.87	10.72	12.63
K6	3.42	6.54	8.80	11.15	11.92	14.35	16.91
K7	1.64	3.22	4.41	5.64	6.05	7.33	8.7
K8	6.86	11.86	15.43	19.08	20.29	24.07	28.09
K9	6.58	12.05	16.05	20.10	21.48	25.76	30.30
K10	5.16	9.14	12.01	14.93	15.89	18.95	22.20
K11	0.73	1.6	2.27	2.97	3.21	3.97	4.79
K12	5.49	9.32	12.05	14.84	15.76	18.67	21.77
The flood peak discharge at different return periods after the construction of check structures							
Unit	Return period (years)						
	2	5	10	20	25	50	100
K1	2.28	4.71	6.5	8.35	8.95	10.88	12.91
K2	2.26	4.7	6.46	8.28	8.85	10.70	12.61
K6	3.39	6.48	8.71	11.04	11.80	14.20	16.74
K7	1.62	3.18	4.35	5.56	5.96	7.23	8.58
K8	6.85	11.84	15.40	19.05	20.26	24.03	28.05
K9	6.48	11.87	15.81	19.79	21.15	25.36	29.84
K10	5.12	9.06	11.91	14.81	15.76	18.80	22.03
K11	0.64	1.39	1.97	2.59	2.79	3.46	4.17
K12	5.48	9.30	12.03	14.82	15.74	18.65	21.74
Percentage of flood discharge reduction							
Unit	Return period (years)						
	2	5	10	20	25	50	100
K1	23.75	23.54	23.53	23.53	23.53	23.53	23.51
K2	0.44	0.21	0.15	0.12	0.2	0.18	0.16
K6	0.88	0.92	1.03	0.99	1.01	1.04	1.01
K7	1.2	1.24	1.36	1.42	1.49	1.36	1.38
K8	0.15	0.17	0.19	0.15	0.15	0.16	0.14
K9	1.52	1.49	1.49	1.54	1.54	1.55	1.52
K10	0.77	0.88	0.83	0.80	0.82	0.79	0.77
K11	12.33	13.12	13.21	12.79	13.08	12.84	12.94
K12	0.1	0.21	0.17	0.13	0.13	0.11	0.13

Suggestions:

1- When designing check structures for any watershed, it is necessary to calculate the level of flood control and reduction of flood peak discharge that is achieved from the implementation of the structure, so that the performance of implementation of the project is specified and it can enter the implementation phase only in case of having economic justification. This will prevent implementation of projects without an acceptable efficiency.

2- Implementation of biomechanical activities such as terracing and plowing in the direction perpendicular to the slope along with the mechanical activities have a significant impact in controlling floods and reducing soil erosion.

3- Implementation of biological operations along with the mechanical activities and development of vegetation are important factors in preventing the flow of runoff. Particularly in parcels where there are less possibility of constructing check structures due to high slopes, implementation of biological operations and vegetation evelopment have a significant impact in enhancing the permeability of the soil and reduction of runoff.

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