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Modeling of River Hydraulic Behavior for Site Selection the Outlets of Surface Water System (Case Study: Rasht City, Iran)

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Abstract: Surface runoff drainage is one of the management problems in Rasht City, Iran. Also, one of the urban flood factors is drainage channel clogging through water level rising. The purpose of present study is to investigate the probability of drainage channels clogging and to select optimum sites for new outlets along Goharrood and Siahrood rivers. So, the rivers bed of Goharrood and Siahrood and their banks terrains were simulated by using HEC-GeoRAS(GIS) extension and digital map(scale:1000). Pick discharges with different return periods were estimated by using stochastic analysis. Then, hydraulic behavior of river were simulated by using HEC-RAS model and the probability of drainage channels clogging was investigated during flood events along Goharrood and Siahrood rivers length. Finally, unsuitable and suitable sites for runoff drainage were identified.

Key words: Hydraulic behavior of river · Surface water · Drainage · Rasht city

INTRODUCTION

Due to some events such as heavy rainfall, The development of impervious surfaces in urban areas, rising water table and the upper watershed flood of city, urban floods occur. Expansion of urban area in all over the world has being increased and it is predicated that it will be increased up to 60% in the year 2030 [1]. Cosmopolitan area growth and population increase have been accompanied by the destroy of forest and range lands which its undesired effects are as follows: reduction of groundwater discharge, increase of surface flow and annual runoff, peak discharge of the watershed, reduction of lag time between beginning rainfall and runoff generation and increase of hydrograph slope [2,3]. Cosmopolitan area development on the surface of the watershed will be included the increase of peak discharge and runoff volume of the watershed [4,5]. For flood studies, terrain geometry is one of the most important factors. Using GIS can provide us higher speed and accuracy in simulating terrain geometry. In the cities of northern Iran, the main drains are rivers which can be clogged in the pick discharges and cause inefficiency of sewerage systems (Figure 2). David and Schmitt [6] studied a hydraulic behavior of river by using HEC-RAS software and their results showed the capability of HEC-RAS in simulating hydraulic behavior of river [7]. David *et al.* [6] studied floods in 5 years period while they provided flood hazard zoning map in United state [4]. Pistocchi and Mazoli [8] carried out rivers study for managing natural hazards by using HEC-RAS and HEC-HMS models. Tate *et al.* [9] presented a new method to providing high accuracy in output analysis of HEC-RAS software in GIS by conforming of field study data, river morphology and ground control points [6]. Carson [10] simulated hydraulic behavior of river and studied flood hazard and bank erosion in United stats [11]. Urban flood and inundated streets are problematic in Rasht City which can be seen in one of streets in Figure 1. Present study has been carried out to design a basic drainage system to control surface runoff and determining the best location to sink surface runoff to Goharrood and Siahrood rivers in Rasht city (northern Iran).

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Fig. 1: Urban flood due to rainfall in Rasht. Flood reasons are river overflowing and the inefficiency of drainage channels of Rasht city

Fig. 2: Outlet channel clogging by rising river level

MATERIALS AND METHODS

Rasht City is located in northern Iran which is capital of Gilan province. For determining the best location to drain surface runoff to Goharrood and Siahrood rivers and identifying the locations where there is possibility of clogging due to rising water level, GIS capabilities, statistical analysis, hydraulic model(HEC-RAS) and field studies were used and two hydraulic models have been presented for simulating hydraulic behavior of Goharrood and Siahrood rivers. At first, the statistic data of maximum instantaneous discharges were analyzed in order to homogeneity, relevancy and adequacy then verified with 5% of confident limit with Run test method. Then, the best statistical distribution was selected by using Smada software (Log Pierson III) and maximum discharges were estimated by using suitable statistical distribution. In this method statistical distribution with the most coverage between calculated and observed data was selected as the best distribution. Hydrometric stations data of Lakan and Siahrood were used. For Siahrood and Goharrood, center flow lines, banks and cross-sections were simulated by using HEC-GeoRAS extension (Arcview-GIS) and digital maps (Scale: 1:1000). With respect to bed condition, considered 134 cross-sections for Goharrood and 63 cross-sections for Siahrood in the way that general condition of the rivers were introduced by those. In next step, Maning coefficient of these cross-sections were determined separately for bed, right and left banks by field studies and river path monitoring and using GPS sets. The simulated bed conditions were brought from GIS to HEC-RAS medium to present model and simulate hydraulic behavior of Goharrood and Siahrood rivers. Flow regime was considered mixed and normal depth was used. At last hydraulic behavior and water level of these rivers in different return periods simulated and proper and improper sections for drainage surface runoff were identified in Rasht city.

RESULTS

Hydrometric stations data of Lakan (Goharrood River) and Siahrood were applied for estimating maximum instantaneous discharges and by using Smada software were analyzed. According to Figures 3 and 4, Log Pierson Type III distribution is the best for estimating maximum instantaneous discharges in different return periods and the results is shown in Table 1. Also, by using GIS (HEC-GeoRAS extension) and digital maps were simulated physical model of beds and adjacent areas of the rivers as given in Figs. 4-6. After presenting hydraulic model of Siahrood and Goharrood rivers and simulating hydraulic behavior in discharges with different return periods, the possibility of clogging of drainage channels due to water level of the rivers were considered. Some samples of cross-sections and water level in Siahrood and Goharrood in different return periods can be observed in Figures 8 to 11. Sections in river banks which water overflows or will reach to top of the banks in 25 0r 50 years flood (return periods) are not suitable to construct drainage channels and also clogging of outlet channels in such sections while maximum discharge will prevent surface runoff drainage. Finally, all studied cross-sections will be categorized in two categories, proper and improper in terms of drainage which are presented in Table 2.

DISCUSSION

Past studies confirmed the more influence of urban expansion in runoff generation in surface unit [12]. Simulating hydraulic behavior of Siahrood and Goharrood

Table 1: Maximum instantaneous discharges in Siahrood and Lakan-Goharrood stations

Return Period	Siahrood River (m^3/s)	Goharrood River (m^3/s)
7	54.4	35.4
5	72.8	56.7
10	85.3	79.1
75	101.5	121.8
50	113.9	168.4
100	176.5	232.6
700	139.5	321.5

Table 2: River path classification in terms of surface water channel clogging hazard due to rising of water level of rivers

Section(Goharrrod)	X	Y	Drainage Proportion	Section (Siahrood)	X	Y	Drainage Proportion
1	374590	4123606	unsuitable	1	377618	4123628	suitable
2	374568	4123633	unsuitable	2	377602	4123656	suitable
3	374575	4123681	unsuitable	3	377586	4123684	suitable
4	374598	4123712	unsuitable	4	377578	4123734	suitable
5	374616	4123700	unsuitable	5	377541	4123848	suitable
6	374665	4123711	unsuitable	6	377438	4123883	suitable
7	374677	4123738	unsuitable	7	377463	4123951	suitable
8	374672	4123756	unsuitable	8	377454	4124022	suitable
9	374634	4123792	unsuitable	9	377402	4124036	suitable
10	374595	4123821	unsuitable	10	377332	4124067	suitable
11	374630	4123874	unsuitable	11	377316	4124157	suitable
12	374666	4123896	unsuitable	12	377292	4124203	suitable
13	374685	4123914	unsuitable	13	377110	4124330	suitable
14	374707	4123915	unsuitable	14	376846	4124489	suitable
15	374756	4123954	unsuitable	15	376792	4124604	suitable
16	374795	4124007	unsuitable	16	376711	4124659	suitable
17	375022	4124190	suitable	17	376645	4124719	suitable
18	375086	4124249	suitable	18	376572	4124732	suitable
19	375086	4124300	suitable	19	376498	4124834	suitable
20	375098	4124361	suitable	20	376442	4124874	suitable
21	375089	4124414	suitable	21	376254	4125124	suitable
22	375074	412448.	suitable	22	376231	4125205	suitable
23	375102	4124532	suitable	23	376154	4125522	suitable
24	375134	4124648	unsuitable	24	376173	4125619	suitable
25	375160	4124703	unsuitable	25	376429	4125864	unsuitable
26	375197	4124814	unsuitable	26	376567	4126216	unsuitable
27	375212	4124851	unsuitable	27	376367	4126738	unsuitable
28	375227	4124937	unsuitable	28	376214	4126800	unsuitable
29	375224	4124973	unsuitable	29	376029	4126795	suitable
30	375264	4125032	unsuitable	30	375857	4126739	unsuitable
31	375233	4125090	unsuitable	31	375596	4127133	suitable
32	375222	4125144	unsuitable	32	375441	4127736	suitable
33	375092	4125182	unsuitable	33	375131	4128044	unsuitable
34	375050	4125239	unsuitable	34	374743	4127903	suitable
35	375020	4125299	unsuitable	35	374780	4128068	suitable
36	374989	4125311	unsuitable	36	374829	4128502	suitable
37	374946	4125355	suitable	37	374661	4128803	suitable
38	374903	4125406	unsuitable	38	374536	4129143	suitable
39	374851	4125455	unsuitable	39	374496	4129236	suitable
40	374799	4125420	suitable	40	374428	4129318	suitable
41	374739	4125416	unsuitable	41	374251	4129320	suitable
42	374692	4125379	unsuitable	42	374312	4129407	suitable
43	374665	4125373	unsuitable	43	374162	4129535	suitable
44	374614	4125331	unsuitable	44	374120	4129650	suitable
45	374595	4125318	unsuitable	45	373986	4129796	suitable

Table 2: Continued

Section(Goharrrod)	X	Y	Drainage Proportion	Section (Siahrood)	X	Y	Drainage Proportion
46	374570	4125310	unsuitable	46	373789	4129860	suitable
47	374532	4125297	unsuitable	47	373615	4130102	suitable
48	374514	4125304	suitable	48	373549	4130169	unsuitable
49	374462	4125280	unsuitable	49	373548	4130254	unsuitable
50	374397	4125261	suitable	50	373548	4130414	unsuitable
51	374329	4125241	unsuitable	51	373416	4130454	unsuitable
52	374280	4125246	unsuitable	52	373509	4130524	unsuitable
53	374226	4125252	unsuitable	53	373530	4130661	unsuitable
54	374161	4125325	suitable	54	373472	4130695	unsuitable
55	374169	4125375	suitable	55	373424	4130737	unsuitable
56	374148	4125410	suitable	56	373445	4130844	unsuitable
57	374154	4125565	suitable	57	373359	4131066	unsuitable
58	374122	4125614	unsuitable	58	373319	4131138	suitable
59	374070	4125608	unsuitable	59	373279	4131172	suitable
60	374048	4125637	unsuitable	60	373227	4131193	unsuitable
61	374005	4125663	unsuitable	61	373165	4131227	unsuitable
62	373941	4125640	unsuitable	62	373138	4131257	unsuitable
63	373889	4125611	unsuitable	63	373102	4131270	unsuitable
64	373816	4125650	unsuitable	(Goharrood)	X	Y	Drainage Proportion
65	373685	4125693	unsuitable	100	372640	4126512	suitable
66	373623	4125727	unsuitable	101	372657	4126655	unsuitable
67	373560	4125730	unsuitable	102	372656	4126689	unsuitable
68	373540	4125727	unsuitable	103	372593	4126742	unsuitable
69	373464	4125658	unsuitable	104	372580	4126763	unsuitable
70	373426	4125666	unsuitable	105	372562	4126783	unsuitable
71	373375	4125664	suitable	106	372538	4126825	unsuitable
72	373289	4125677	suitable	107	372515	4126844	unsuitable
73	373223	4125690	suitable	108	372451	4126871	unsuitable
74	373143	4125696	suitable	109	372406	4126952	unsuitable
75	373104	4125696	suitable	110	372446	4126981	unsuitable
76	373075	4125692	suitable	111	372473	4126998	unsuitable
77	373010	4125745	suitable	112	372499	4127059	unsuitable
78	372984	4125772	suitable	113	372475	4127093	unsuitable
79	372942	4125783	suitable	114	372472	4127131	unsuitable
80	372908	4125776	suitable	115	372486	4127160	unsuitable
81	372881	4125752	suitable	116	372475	4127194	unsuitable
82	372840	4125726	suitable	117	372445	4127214	unsuitable
83	372789	4125725	unsuitable	118	372424	4127256	unsuitable
84	372762	4125738	unsuitable	119	372421	4127286	unsuitable
85	372738.	4125769	unsuitable	120	372381	4127362	unsuitable
86	372721	4125798	unsuitable	121	372374	4127387	unsuitable
87	372713	4125812	suitable	122	372353	4127414	unsuitable
88	372771	4125867	suitable	123	372330	4127464	unsuitable
89	372823	4125913	suitable	124	372334	4127498	unsuitable
90	372832	4125953	suitable	125	372340	4127533	unsuitable
91	372817	4125974	suitable	126	372333	4127567	unsuitable
92	372795	4125980	suitable	127	372308	4127571	unsuitable
93	372695	4126077	suitable	128	372282	4127591	unsuitable
94	372667	4126112	suitable	129	372311	4127612	unsuitable
95	372663	4126140	suitable	130	372332	4127623	unsuitable
96	372689	4126191	suitable	131	372329	4127639	unsuitable
97	372677	4126321	suitable	132	372350	4127674	unsuitable
98	372678	4126342	suitable	133	372331	4127701	suitable
99	372641	4126436	suitable	134	372293	4127742	suitable

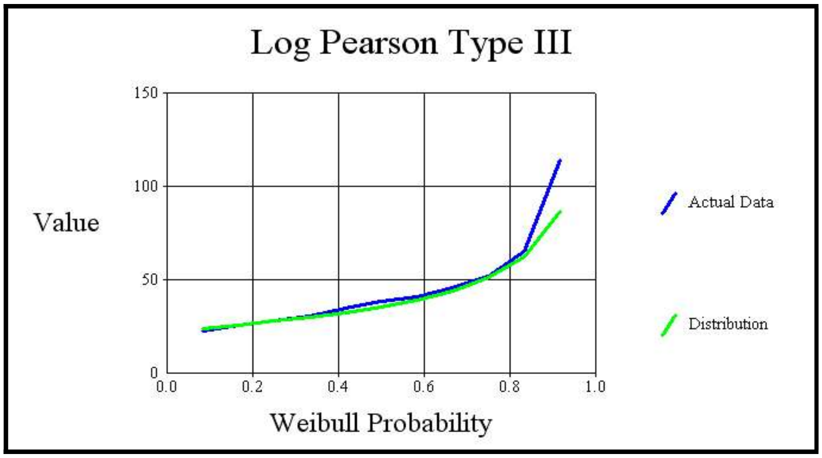

Fig. 3: The comparison between observed and estimated values by using Log Person type III distribution (Lakan – Goharrood station)

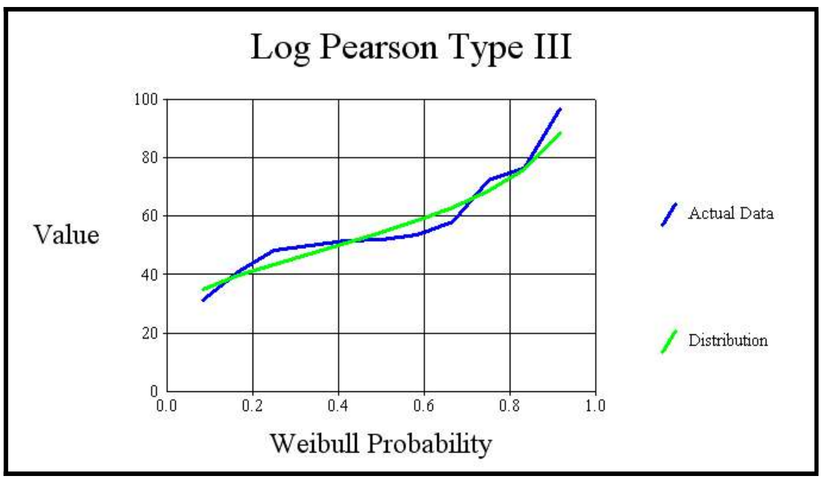

Fig. 4: The comparison between observed and estimated values c by using Log Person type III distribution (Siahrood Station)

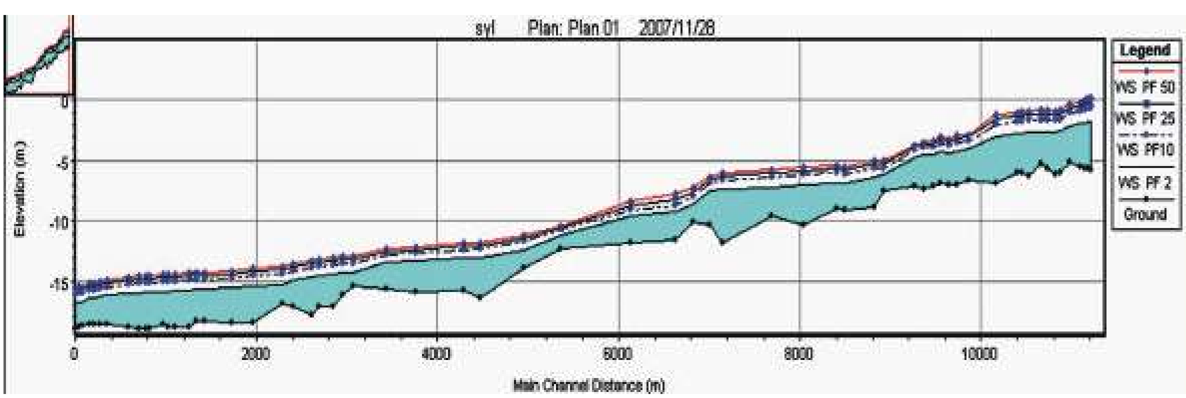

Fig. 5: Length-section of Siahrood and water level in different return periods

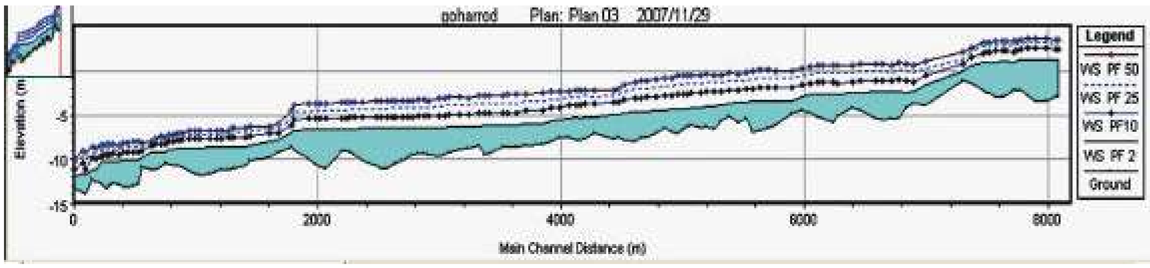

Fig. 6: Length-section of Goharrood and water level in different return periods

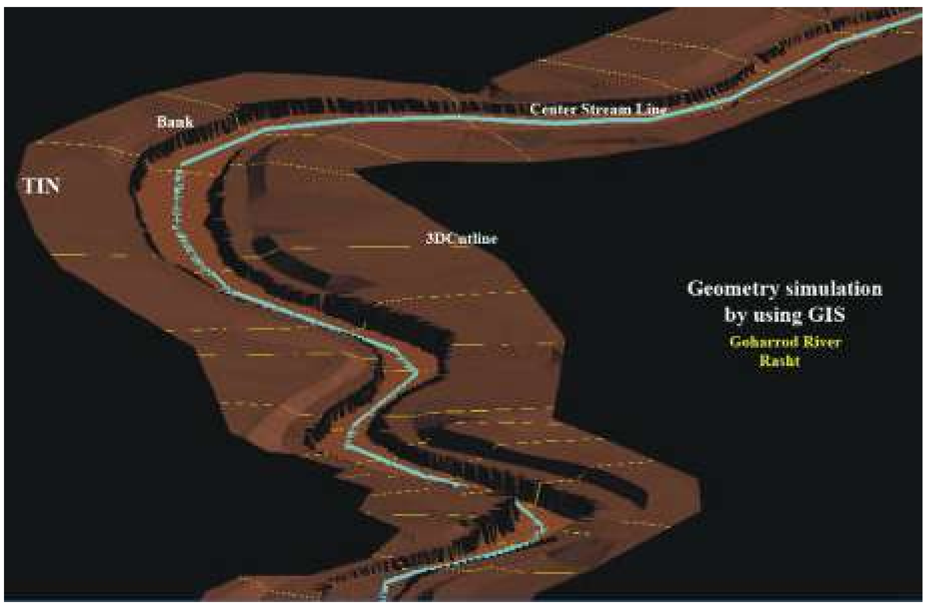

Fig. 7: 3D model (TIN), Center Stream line, Banks and 3Dcutlines in a part of studied path, Goharrood river

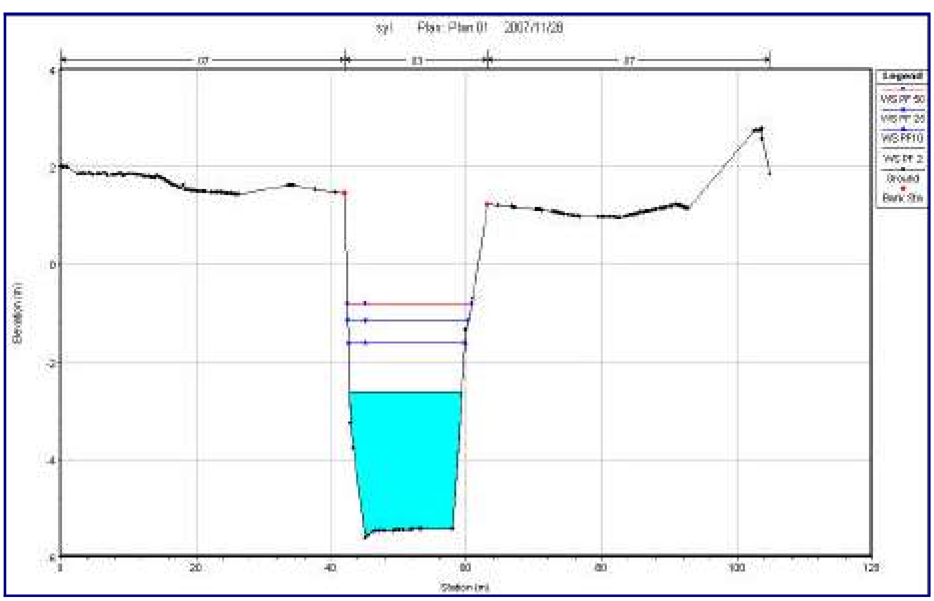

Fig. 8: Cross-section number 8 in Siahrood river and water level in return periods 2,10,25,50 years (cross-sections coordinate was given in table 2)

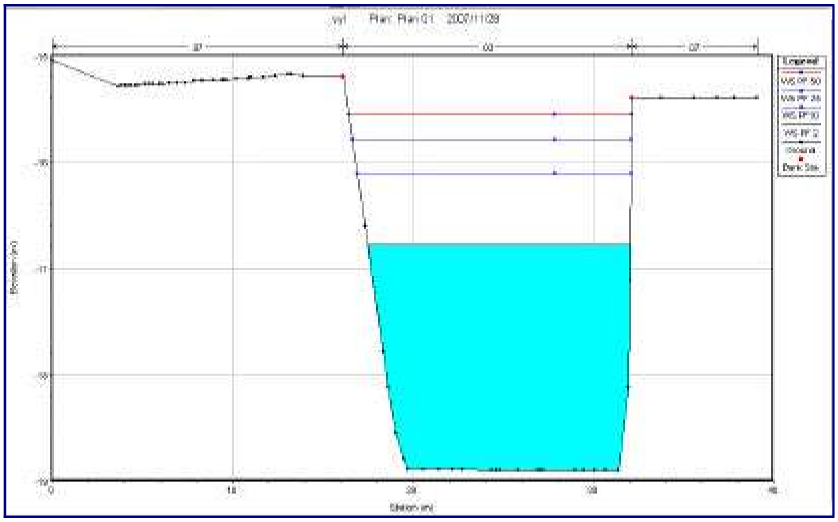

Fig. 9: Cross-section number 63 in Siahrood river and water level in return periods 2,10,25,50 years (cross-sections coordinate was given in table 2)

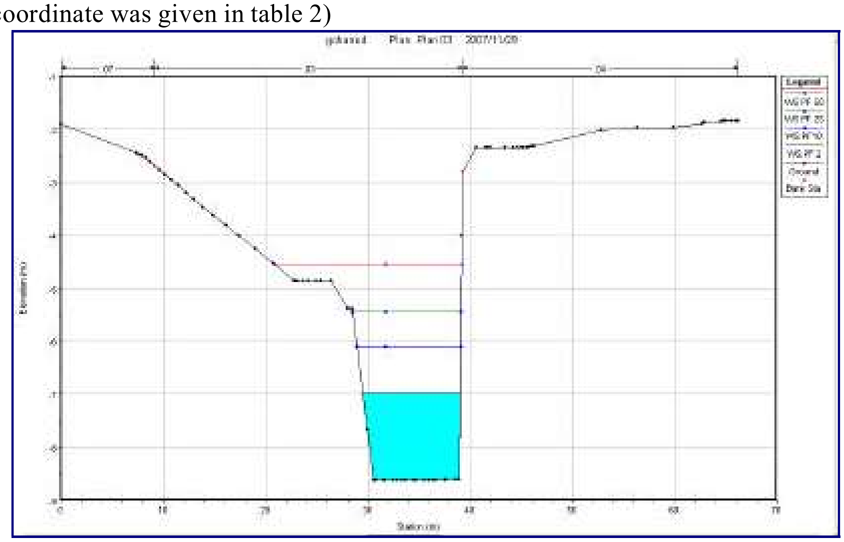

Fig. 10: Cross-section number 98 in Goharrood river and water level in return periods 2,10,25,50 years (cross-sections coordinate was given in table 2)

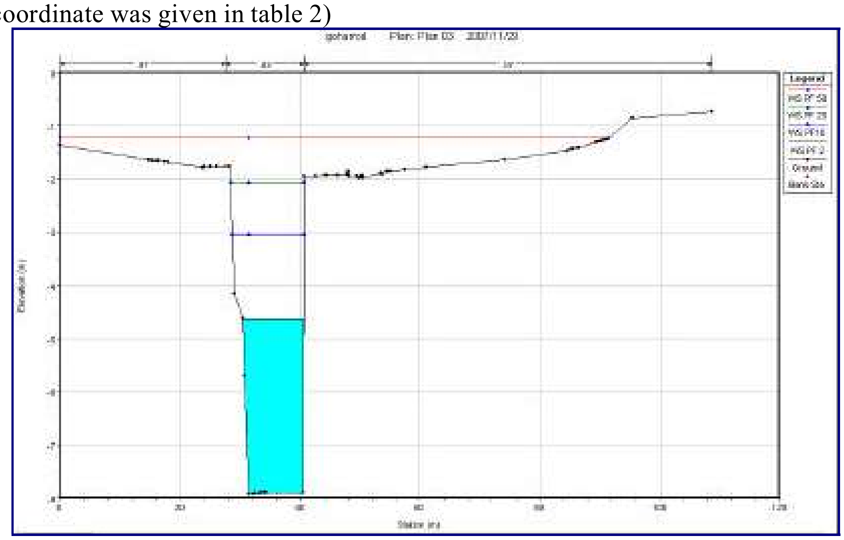

Fig. 11: Cross-section number 53 in Goharrood river and water level in return periods 2,10,25,50 years (cross-sections coordinate was given in table 2)

rivers was carried out by using GIS and HEC-RAS hydraulic model. According to past investigations using capabilities of GIS will cause acceptable results in simulating river conditions and adjacent areas [2,3,13]. Also, this method lead to higher efficiency and lower expenses [5,8]. In present study, rivers bed and adjacent areas geometry were simulated with using GIS capabilities and simulating hydraulic behavior by using HEC-RAS in higher accuracy and shorter time. In Siahrood river with 50 years return period there will be no danger on river banks adjacent areas but in some locations water flow can reach to the banks or overflow. So, it is essential to manage the location which has limited discharge capacity such as under bridges, by organizing rivers and preventing sedimentation and crossing trunk of trees we can prevent overflowing rivers. But, this study is aimed to consider clogging possibility of sinking channels outlet of Rasht city urban flood in different return periods which will be clear with comparing the channel elevation from bed or upland road to water level in target cross-section. Clogging possibility of channels outlet during heavy rainfall and flood by river body while overflowing along rivers path in Goharrood river will be much more than Siahrood river in Rasht city. According to presented results in Table 2, unsuitable sections for drains outlet in Goharrood river path is more than Siahrood river. It is essential to point out that numerical water level is different in left and right banks and that has been evaluated with respect to water level in the both of banks. So, according to present results proper locations for sinking and drainage urban runoff were determined and tactful measurements should be carried out to prevent drainage channels clogging which are located in improper places. Finally, it is suggested to investigate the effect of urban development in runoff generation and flash floods occurrence in northern Iran.

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