International Journal of Farming and Allied Sciences
Available online at www.ijfas.com
©2013 IJFAS Journal-2013-2-12/343-349
ISSN 2322-4134 ©2013 IJFAS

The study of changes resulting from the construction of spur over the Shoteyt River (Iran) on hydraulic parameters of water level and flow rate using MIKE11 model

Mohammad Heidarnejad[1*], Ebrahim Zalaqi[2] and Mehdi Nadri[1]

1. Department of Irrigation, Science and Research Branch, Islamic Azad University, Khouzestan, Iran
2. Khouzestan Water and Power Manager

Corresponding author Email: m.heidarnejad@khouzestan.srbiau.ac.ir

ABSTRACT: The aim of this research is to study of the hydraulics and evaluate the performance of spurs which are built to protect the Felman wells and to prevent the further destruction of the protected area in the Shoteyt River bank and near the city of Shoushtar (Iran) by MIKE11 model. Since in the area under study the Shoteyt River bank is seriously at the risk of scour, the hydraulic study of constructed spurs is utmost important in order to the effectiveness of them. In the present study, the flow's condition is assumed to be unsteady and the results indicate the efficiency of the spur as well as suitability of the model in simulation of spurs. The results achieved by this software in the studied area show changes in water level and flow rate. Construction of spurs can reduce the flow rate by115 m^3/s over a span of 100 year. The maximum change in water level for this flood has been 47 cm, and the maximum change in flow rate has been 0.558 meters per second. Comparing the results of a flood with a return period of 25 years and a spate with a return period of 100 years, it was noticed that these changes have a direct relation with the increase of return period and the more return period of flood increase, the more changes take place.

***Keywords*:** spur, flow rate, MIKE11, unsteady flow

INTRODUCTION

River area, affected by factors such as geology, topography of river valley, properties of alluvial deposit of flood plain of the river, hydrological characteristics of river basin, the hydraulic conditions of flow and the method of human exploitation, has a natural tendency to achieve dynamic balance. Due to the variable nature of some of these factors, the river is always subject to changes even in the short period and different intervals(Yasi,1988) .Changes and shifts in the direction, alignment and geometry of the river, caused by natural processes and normal or abnormal human expansion, are the logical response of the river system for establishing a new equilibrium. River changes occur as periodic erosion and sedimentation in the basin, destruction and widening of the walls and banks, displacement of spiral pattern and direction of flow, deformation of the river, crosscutting or deflecting of the path(USAE,1980).

So, rivers should be treated with caution and according to the special rules governing this system. Because any change in the structure of the river, even local ones, causes new and in a wider range changes. Therefore, before any operation it is necessary to try to predict the response of the river to it. In other words, the effects of local changes on the river system should be studied.

Spurs are structures with which it is possible to control the erosion of river borders and protect these river banks. Spurs are cross or transverse structures that expand from the river wall toward the flow axis, causing deflection of flow from the borders and leading it toward the central axis of the river. Spurs are created as single or a series of consecutive, on one or both sides of the river.

The main function of a spur is to deflect the flow from sides of river and direct it toward the main channel. The result of flow deflection is the development of a rotatory area with sever turbulence around the spur which appears wider at downstream of the spur. While scouring is a serious threat for spur structure, and thus the river, the phenomenon of sedimentation in downstream of rivers would be a natural solution for stabilization the river wall along the desired direction.

Mathematical modeling allows the study of many river engineering issues. Investigating the capabilities of different models in simulating the hydraulic properties of the flow in a river such as depth, velocity and shear stress at the sides of rivers is one of the basic requirements in river engineering projects. However, form the viewpoint of application, the minimum requirement to field data, the least computational volume and the confidence degree of application should be considered in the mathematical models of rivers(Yasi, and Azizpanah,2006). Studies done in Iran for efficiency assessment of different software in simulation of river structures like spurs are restricted to results of physical models and comparison of them with mathematical models and the field data is less used. Among these, Yasi and Azizpanah (2006) compared the results of the steady flow simulation achieved by known mathematical models with results achieved by a river physical model. For this purpose, the physical model of part of Nazlou River basin was designed and built (Torabizade and Bina, 2009). To simulate the flow, the one-dimensional mathematical model of HEC-RAS, the quasi-two-dimensional model of BRI-STARS and two-dimensional model of surface horizons FAST-2D was selected. The flow parameters of five different flow rates, in three subintervals of the river were compared in initial and boundary conditions. Generally, in the studied interval, these three models respectively were better adapted to the physical model(Yasi, and Azizpanah,2006). Qavasie (2005) studying the hydraulic effect of EPI and dry dam on the flood hydrograph in compound channels came to the conclusion that: first, dry dam (a barrier in the flood plain and main channel for a threshold flow rate) at its best can cause a delay up to 23 percent and a reduction up to 19 percent in flood peak which is almost four times the effect of EPI (a barrier in flood plains) and second, results of one-dimensional model, if calibrated, is more reliable than of two-dimensional model.

The goal of this research is to study and interpret the impression of constriction caused by the spur construction on changing two hydraulic parameters of water level and flow rate in the spur Headland using MIKE 11 software. Therefore, 12 spurs on Shoteyt River near city of Shoushtar were selected for study.

Theory

Software package of MIKE11 was developed by Danish Hydraulic Institute (DHI) and is able to simulate one-dimensional flow, sediment transport and water quality in unstable rivers, estuaries, and irrigation networks. This program uses the finite difference method for one-dimensional solving of equations governing flow, sediment transport and water quality. In fact, hydrodynamic model is the basic element of the system and a basis for all other models in the program such as scattering, water quality and sediment transport. The water quality model of this software is able to simulate water quality parameters including DO, BOD, phosphorus cycle, animals, vegetation and metals. Despite being one-dimensional in floodplain of rivers, this model is capable of computing quasi-two-dimensional hydraulic parameters(DHI, 2007).

One-dimensional equations governing the river flow are the equations of continuity and momentum (Saint and Nantes equations) which are used in hydrodynamic model calculations in this software(DHI, 2007).

Continuity equation is:

$$\frac{\partial Q}{\partial x}+\frac{\partial A}{\partial t}=q \qquad (1)$$

Momentum equation is

$$\frac{\partial Q}{\partial t}+\frac{\partial(\alpha\frac{Q^2}{A})}{\partial x}+gA\frac{\partial h}{\partial x}+\frac{gQ|Q|}{C^2AR^*}=0 \qquad (2)$$

where Q: flow rate $\frac{m^3}{s}$, A: cross sectional area of flow m^2, q: secondary flow rate $\frac{m^2}{s}$, h: water level relative to a baseline level C, m: Chezy coefficient $\frac{m^{1/2}}{s}$, α: correction coefficient for different rates in section, R*: radius of roughness.

MATERIALS AND METHODS

The modeled area of studied river began from the beginning of City of Shoushtar and at the start of Shoteyt branch at the upstream of eroded area to Arab Hassan station at the downstream of eroded area and along 40 kilometers of Karoun River in the direction of Shoteyt River. The average longitudinal slope of the river bed in the studied area is f about 0.00071.

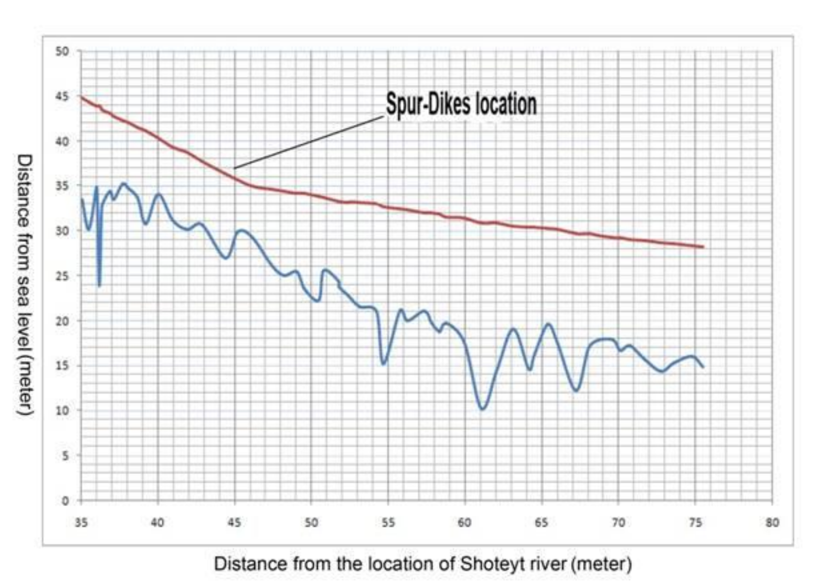

Figure 1. Longitudinal profiles of Shoteyt River for a flood with return period of 100 years (red line is water level – blue line is the digits of river bed).

In order to determine the geometric characteristics and position of spurs, the area was visited and the location of spurs in UTM system, length, width, height, slope and other characteristics of spurs were measured using surveying camera and GPS. Spurs are straight and with rounded headland. The length of spurs is 40 meters, their height 2.5m, their upper width 10 m and lower width is 3 meters. Spurs are made of rubble. Figure (2) show the location of Shoteyt River and the spurs.

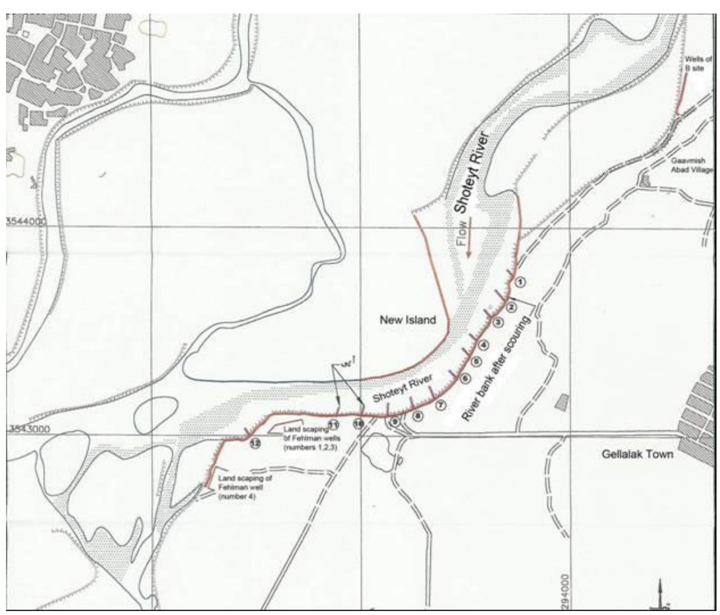

Figure 2. the location of Shoteyt River and the spurs on the river.

Existing spur begins from the kilometer of 44.402 and continues to the kilometer of 45.205 of Shoteyt River. To introduce the modeling interval of these river systems to MIKE 11 model, the topographic map with a scale of 1: 50000 were used.

All sections used in this study are 128 cross-sections of Karoun River in Shoteyt area and with mean distance of about 700 meters. In order to accuracy assessment of Manning roughness coefficients, hydrographs of dated 12.14.1999 to 12.16.1999 were considered simultaneously. The input of the Great Plain and the Gorgor plain was introduced to the model as upstream boundary condition and the flow rate curve in Arab Hassan station as downstream boundary condition(Civil Consulting Engineering Company of Ahvaz Water Resources,2005) and the simultaneous hydrograph of Gotvand station was used for accuracy assessment of Manning roughness coefficients. By running the model many times and changing the parameter *n* in the model and comparison of rate flow predicted by the model and measured values in Gotvand station, the Manning roughness coefficient was obtained. Roughness factor of 0.044 for Shoteyt River made best adaption between calculated hydrograph and observed hydrograph at Gotvand station.

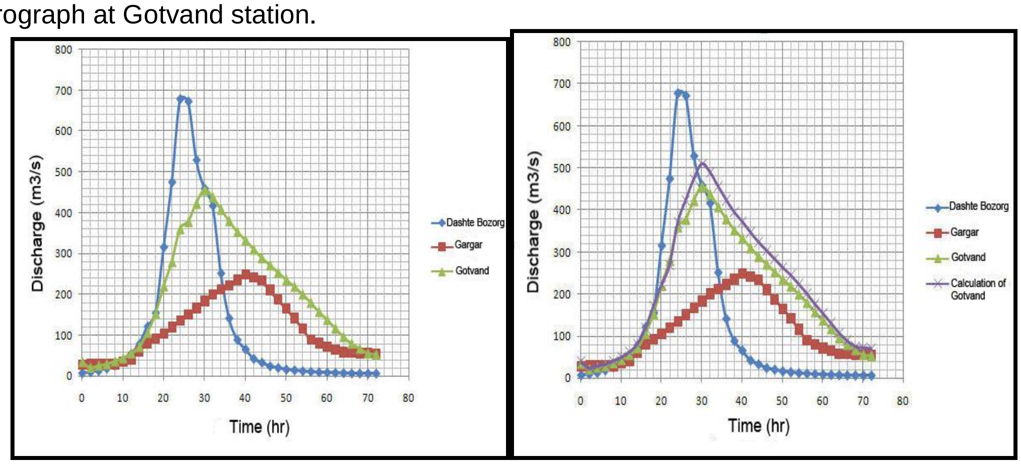

Figure 3. Comparison of simultaneous observed and computed hydrographs in Gotvand station for accuracy assessment in 12.14.1999.

In hydrological studies, the flood hydrographs for different return periods at the initial formation of Shoteyt branch is estimated by combination of flood hydrographs of Gotvand station (Karoun River basin), Great Plain (Shour River), Shoushtar station (Gorgor River) and floods of intermediate area between Gotvand and Shoushtar. Estimated hydrographs were in the regulatory state (after operation of Shahid Abbaspour Dam). So at present design, the regulate hydrographs were introduced to mathematical model of MIKE11 as upstream boundary condition of Shoteyt River. To provide the downstream boundary condition for the model, the cross sections of the river to Arab Hassan station on the Shoteyt River is selected. Using statistics, the flow rate- scale equations at the downstream were estimated and s introduced to the mathematical model. Note that for removing the possibility of relative error in estimating flow - scale equation, the location of estimation and introduction of abovementioned equation is selected in the distance of about 30 km of downstream of the eroded area and neutralizing and removing of probable errors in this interval will be done in the hydraulic calculations.

After the data needed to run this program, such as geometric data (river path, cross sections, roughness coefficient and boundary conditions) were entered into the software, the model was run in two modes. The software was run in the first mode without and in the second mode with consideration of spurs to observe the effect of spur in comparison with the first mode.

Because the MIKE11 model is one-dimensional, to investigate the effect of spurs, the border line introduced to the model coincides with the headland of spur. Then, the average hydraulic Characteristics of flow deflected to the main river bed can be calculated(Bina et al,2007).

RESULTS AND DISCUSSION

The maximum flow rate at the location of spurs for a flood with return period of 25-year is 5871 cubic meters per second and for a flood with return period of 100-year is 7621 cubic meters per second. Base flow rate in the river is 626 cubic meters per second. In Figure (4), two hydrographs for before and after the location of spur with the return period of 100-year are compared. As it is shown, the flood hydrograph after, compared to the flood hydrograph before, the location of the spur has a drop of 115 cubic meters per second.

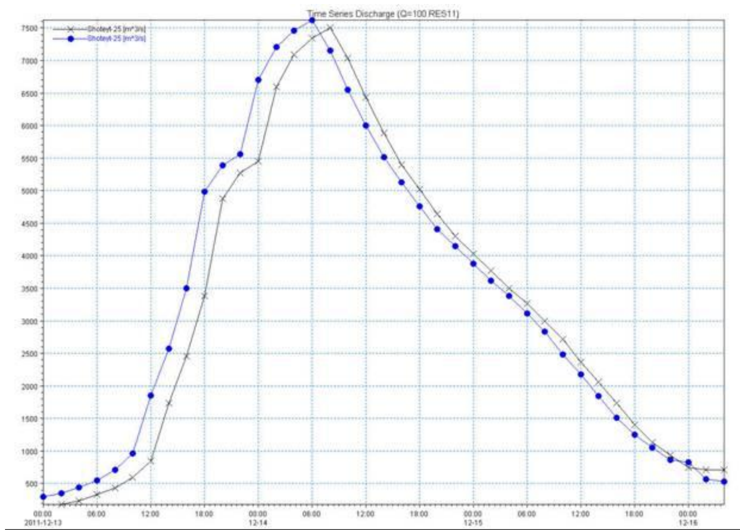

Figure 4. Comparison of the flood hydrograph with 100-year return period in Shoteyt River considering the spurs (blue and black lines are before and after flood hydrograph in before and after the spur location, respectively)

Figures (5) and (6) show (for example) the variation graph of water level and flow rate for a 25-year-old flood at the location of spur No. 3. As shown in Fig (5), the maximum water level for 25-year- old flood in spur No. 3 with considering the spur is 35.34 meter and without considering is 35.55 meters. This means that the presence of spurs in the location of third spur increases the water level about 21 cm.

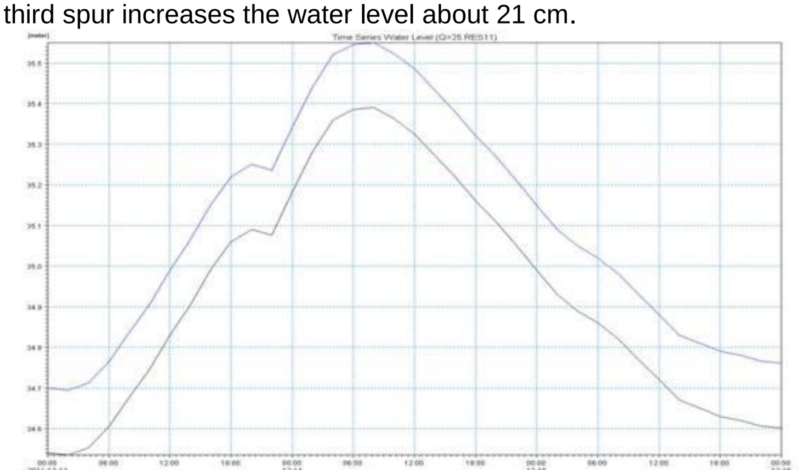

Figure 5. Changes in water level for 25-year-old flood at location of spur No. 3 (Blue line is with spur – Black line is without spur)

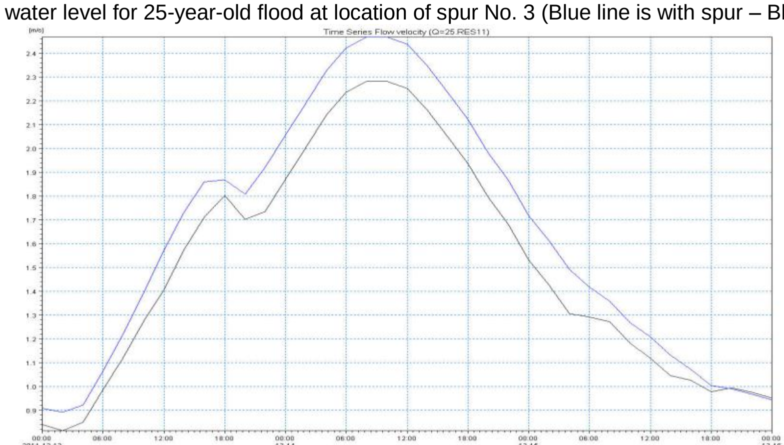

Figure 6. Changes in flow rate for 25-year-old flood at location of spur No. 3 (Blue line is with spur – Black line is without spur)

As it can be seen from Figure (6), the maximum flow rate for 25-year-old in the location of spur No.3 without considering the spur is 2.281meters per second, and with considering it, is 2.467 meters per second. This means that the presence of the spur increases the flood velocity 0.186 m/s.

Table 1. Comparison of the maximum water level at the spur with and without spur in 25-year-old flood (meter)

No. of spur	location	Water level with 25-year return period		variation
		With spur	Without spur	
1	SHOTEYT 5557.36	35.590	35.380	0.21
2	SHOTEYT 6451.28	35.570	35.703	0.200
3	SHOTEYT 7438.14	35.550	35.345	0.205
4	SHOTEYT 8062.96	35.50	35.415	0.085
5	SHOTEYT 8112.64	35.490	35.454	0.036
6	SHOTEYT 8187.05	35.480	35.279	0.201
7	SHOTEYT 8252.89	35.460	35.350	0.110
8	SHOTEYT 8353.29	35.440	35.310	0.130
9	SHOTEYT 8393.29	35.410	35.394	0.016
10	SHOTEYT 8476.69	35.400	35.280	0.120
11	SHOTEYT 8570.66	35.380	35.299	0.081
12	SHOTEYT 8642.64	35.360	35.268	0.092

Table 2. Comparison of the maximum flow rate at the spur with and without spur in 25-year-old flood (meter/second)

No. of spur	location	Flood rate with 25-year return period		variation
		With spur	Without spur	
1	SHOTEYT 5557.36	3.090	2.967	0.123
2	SHOTEYT 6451.28	3.120	3.007	0.113
3	SHOTEYT 7438.14	2.467	2.281	0.186
4	SHOTEYT 8062.96	2.950	2.760	0.190
5	SHOTEYT 8112.64	2.920	2.564	0.356
6	SHOTEYT 8187.05	2.530	2.519	0.011
7	SHOTEYT 8252.89	2.890	2.573	0.137
8	SHOTEYT 8353.29	2.910	2.793	0.117
9	SHOTEYT 8393.29	2.900	2.497	0.403
10	SHOTEYT 8476.69	2.460	2.027	0.433
11	SHOTEYT 8570.66	2.530	2.429	0.101
12	SHOTEYT 8642.64	2.570	2.461	0.109

As the table numbers (1) and (2) implies, the maximum increase in water level after construction of spur has occurred at the location of spur No.1 and the maximum increase in flood rate after construction of spur has occurred at the location of spur No.10.

CONCLUSION

Construction of a spur causes constriction of the channel and reduction of river width and because of this the depth of the river and the flow rate is increased. In this study, the maximum increase in water level for a flood with a return period of 25 years was 21 cm which occurred at the spur No.1. Also, the maximum flow rate was 0.433 meters per second and occurred at the spur N0. 10. After the location of spurs, the flood hydrograph has a 115m^3/s – drop in flow rate compared to the flood hydrograph in before the location of spurs and moves downstream with a time lag. But its shape does not change. Thus, although there is a time lag, if the purpose of this design id to delay time of flood, it is better to use more appropriate structure for delaying the flood hydrograph. Return of water to the upstream is due to the reduction of flow width in the interval (the interval in which the spurs have been constructed). Considering that the spurs were built to protect the left border and in some sections the talweg of the river is near the right border of the river, in floods with shorter return period, the amount of water reached to the spurs is less than that for floods with longer return period. Therefore, the effect of spurs is more in floods with longer return period. Because the river is wide at the location of spurs, considering spurs, the water level change is not significant. So, construction of the spur in this area is not a risk for agricultural land and residential areas around, but the process lead to the beach creation.

In unstable conditions, MIKE11 model modeled spurs well and provided acceptable solutions.

Figure 7. The spur built on Shoteyt River

REFERENCES

Bina, M., Javan, M., Taleb Bidakhti, N., Yasi, M. 2007. "Guide to the design, construction, and maintenance of river spurs", Journal of Water Engineering Standards No. 311 - A, Standards of water Engineering Office, Department of Energy.

Civil Consulting Engineering Company of Ahvaz Water Resources. 2005. Study of Phase I of Karoun River Bank Protection Project in the countryside of Shoushtar

DHI. 2007. Water & Environment, MIKE11, User Manual, Hydrodynamic reference “A Modeling System for River and Channels”,DHI Software.

Torabizade, A., Bina, M, 2009. " Hydraulic assessment of spurs and their effects on Zohre river using MIKE11 model", Eighth International Seminar on River Engineering, Ahvaz, Shahid Chamran University.

USA.E. 1980., “Detailed Project Report for Flood control and Environmental Assessment Sespe Greek at Fillmore” Ventura Country, California, U.S. Army Corps of Engineers Los Angles District.

Yasi, M. 1988. "correcting the path and protecting the walls of the river using natural –building methods" Master thesis of Irrigation, Shiraz University, Shiraz.

Yasi, M., Azizpanah, B. 2006. "Comparison of the properties of flood in physicals and results of one-dimensional, quasi-two-dimensional and two-dimensional mathematical model, in an interval of a river", Iranian Journal of Water Resources Research, Second Year , No. 3, Pages 78-89.