Assessment of Sediment Transport Equations with GSTARS3 model

Fariba Khodabakhshi[1] ,Farzad Hassanpour[2], Mehdi Motallebian[3], Mohammad Dadashi[4]

Abstract—Water and water resource management are one of the main elements in regional and national development Increasing efficiency in water and soil supply usage and procure industrial needs for water and urban drinking water have importance rule in increase economic growth and development indexes. The prediction of sediment load and its variability in rivers is a component of water resources and environmental engineering and management of infrastructures. The Sistan River, located in southeast of the Sistan Plain in Iran and Afghanistan border, branched off the Hirmand River and after passing distance around 72 km, reaches to Lake Hamoon of the Hirmand. In this study, the morphological classification of Sistan River in the distance between Kahak dam and Hirmand Hamoon Lake (with the length of 34 km) was examined. In this paper we have evaluated the software GSTARS3 sediment transport equations. Model GSTARS3 which quasi-two-dimensional model is flow tube was run with three and the best equation to calculate sediment transport equation've got a Toffaleti transport equation.

Index Terms—sediment transport models -,River behavior - Numerical simulation

— — — — — — — — — ◆ — — — — — — — — —

1 INTRODUCTION

THE flow of water is the most important phenomenon in the skin processes of the Earth; and rivers not only have a role in the global feature of the Earth, but they also determine the shape of the life of man on earth. Rivers are major factors in in the morphological change of the Earth . Rivers and channels are completely dynamic systems whose position, shape and morphological characteristics are constantly changing over time [4]. The topic of morphology (or the study of the behavior of rivers) specifies the action and reaction or behavior of river in different situations [2]. In the past one hundred years or so, great progress has been made in river geomorphology. River morphology, focusing on meander and braided river, has been one of the most important parts in river geomorphology. Geometric parameter of modern rivers is a key to palaeohydrologic reconstruction and river evolution ; studies of river morphology also supply geomorphologic basis to protect river landscapes and environment, and to exploit hydraulic resources [3]. Morphological change in river channels primarily consists of adjustments to channel width, depth, local channel slope, and planform. Channel adjustment depends on available stream power-a function of discharge and valley slope the size and volume of bed load[4].

A change in one of the variables disrupts a series of existing balances, and can cause changes in other variables and ultimately change in the course of rivers [5]. In addition to the above cases, human interventions also play a role in changing the course of rivers [6]. Familiarity with the topics of geomorphology and performing these studies are important to identify and analyze the morphology. Lack of attention to the science of geomorphology in the management and organization of river basins will create severe erosion, degradation and destruction of our natural resources [7]. Rivers have been classified from different perspectives, including the classification based on topography, slope, discharge of flow, age of river and the pattern in plan. In this study, the classification system of rivers has been presented from a different and comprehensive perspective, which includes the best features of most previous studies. Therefore, in this sense, it would be possible to predict the behavior of rivers in a more appropriate manner [8]. The study of river morphology using the Mathematical models is necessary to understand the current situations and potential future changes in the river, through which normal behavior of rivers can be predicted with respect to natural changes or actions resulting from the implementation of different projects on river engineering. Sistan River has had many changes in its path in two intervals from 1956 to 2012, and has caused a lot of damage to adjacent lands. In this paper we have evaluated the software GSTARS3 sediment transport equations.

2. LOCATION OF THE STUDY AREA

Sistan plain area is 15000 Km2 and locates in north of Sistan. Climate of region evaluated totally dry. Mean annual precipitation is 52.3 mm and in fully rain years this rate reaches to 120 mm rarely and in dry year there is no precipitation (such as 9 mm for water year 2001-2002). This little precipitation makes impossible any kind of dry farming. Even regional natural vegetations, seldom grow, if do not locate near ground water. In this condition only an external water resource could make alive region and Hirmand Trans Boundary River has such role. Totally could say environment of Sistan is very vulnerable and depends on Hirmand River [9]. Hirmand River is an evident example of a flow of Endorheism from an Endorheic region. After passing a distance of about 1100 km, The river is divided into two main branches ofParyanMoshtarek and Sistan at a place called

———————————————

- *Farzad hassanpour Assistant Professor of Irrigation and Drianage Engineering,Dept. of Water Engineering, University of Zabol, Iran E-mail: hassanpourir@gmail.com*
- *Fariba Khodabakhshi masters degree in Water Resources Management engineering in University of Zabol, Iran. E-mail: Fariba.khodabakhshi@Gmail.com*
- *Mahedi Motallebian masters degree in Hydraulic Structures engineering in University of Zabol, Iran. E-mail: m.motallebian@gmail.com*
- *Mohammad Dadashi masters degree in Irrigation Drainage engineering in University of Zabol, Iran. E-mail: mohammaddadashi65@Gmail.com*

Jarikeh bordering Iran and Afghanistan. As one of two main branches of the Hirmand River, Sistan River is the main source of water in Sistan which is responsible for 70 percent of irrigated farmland in Sistan plain. The general slope of the river is about 0.2- to 0.6-thousandt. Important structures such as channel feeder, Kohak dam, Zahak-Niatak flood barrier, Zahak dam, Hedris canal, Sistan dam, Nohoorab Bridge and numerous irrigation channels, several villages and also the city of Zabol are located along the river, each of which has a significant impact on hydraulic process of the river. Sistan River is rare among the world's rivers because concentration of the suspended load of the river's flood flow varies mainly from 10 to 50 grams per liter. Low slope of the Sistan River's bed makes it prone to sedimentation; and on other hand, the negative effects of building Zahak and Kohak dams have sparked and increased the sedimentation. The particles forming the riverbed are very fine, and are mostly in the range of fine sand, clay and silt. The average diameter of particles forming the bed is about 0.02 mm [10]. Figure 1 shows an overview of the position of Sistan and Sistan River.2 Procedure for Paper Submission
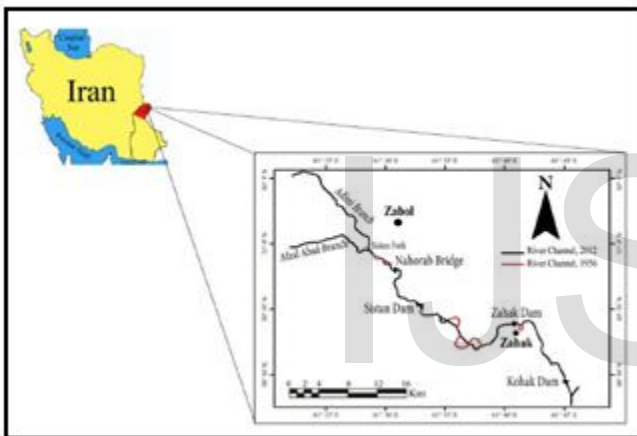

Fig.1.Position of sistan region and plan of sistan River

Review of aerial photographs and satellite images of Sistan River plan show that the meanders of Sistan River have a lot of changes due to the construction of longitudinal and transverse structures, erosion and other similar natural process, and have created several deltas in some cases. These changes also now continue with the relocation, increase or sometimes reduction of sandy islands. For the reasons mentioned above and therefore the reduction of water flow and increase of the amount of sedimentation in the riverbed, these natural and permanent changes have intensified the speed of these developments.

3. MATHEMATICAL MODEL

A fundamental phenomenon of non-equilibrium sediment transport is the continuous adjustment of the sediment transport to the sediment capacity, especially in environments with a predominant suspended load transport. The morphological processes can be simulated sufficiently accurately by 1-D or 2-D horizontal models based on equilibrium sediment

formula. However, commercial mathematical models fail in many cases to simulate exactly the sediment transport in the rivers due to the employed extremely simplified assumptions and lack of calibration and validation processes. On the other hand, the available empirical sediment transport equations as those of ([11], [12], [13], [14]) produce total sediment load that deviates by more than 200% in some cases compared to the actual measured field data. Moreover, the physical models or laboratory experiments to predict the sediment transport are generally very time-consuming, costly and, for many practical problems, impossible [15]. This highlights the importance of developing a mathematical model to solve the sedimentation problems in shallow wide streams as rivers, which is the main aim of the present paper. The developed 2-D sediment transport model can predict the locations of scouring and silting zones along the considered river reach.

Basic requirements of a generalizedmodel for rivers and reservoirs

(1) It should be able to compute hydraulic parametersfor open channels with fixed as well as with movableboundaries;

(2) It should have the capability of computing watersurface profiles in the subcritical, supercritical, andmixed flow regimes, i.e., in combinations of subcriticaland supercritical flows without interruption;

(3) It should be able to simulate and predict thehydraulic and sediment variations both in the longitudinaland in the transverse directions;

(4) It should be able to simulate and predict thechange of alluvial channel profile and cross-sectionalgeometry, regardless of whether the channel width isvariable or fixed;

(5) It should incorporate site specific conditionssuch as channel side stability and erosion limits;

(6) It should be able to simulate and predict sedimenttransport by size fraction so the formation and destructionof armor layer can be determined for long-termsimulation;

(7) Field data requirements are not too extensive ortoo difficult and too expensive to obtain;

(8) The model must be based on sound theories andthe numerical solutions must be stable.[16]

In this research for the analysis of the hydraulic model HEC-RAS4.0 and GSTARS3 used.GSTARS (Generalized Sediment Transport model for Alluvial River Simulation) is a series of computer models developed by the U.S. Bureau of Reclamation for alluvial river and reservoir sedimentation studies. GSTARS stands for Generalized Stream Tube model for Alluvial River Simulation. The first version of GSTARS was released in 1986[17] using Fortran IV for main frame computers. GSTARS2.0 was released in 1998[18] for PC application with most of the programs in the original GSTARS revised, improved, and expanded using Fortran IV/77. GSTARS2.1[19] is an improved and revised GSTARS2.0 with graphical interface to improve the program's user friendliness. The unique feature of all GSTARS models is the conjunctive use of stream tube concept and the minimum stream power theory. The use of stream tube concept enables us to simulate river hydraulics using one-dimensional numerical solutions to obtain a semi-two-dimensional presentation of the hydraulic conditions along and across an alluvial channel. The application of min-

imum stream power theory [20],[21 − 24] allows us to determine the optimum channel geometry with variable channel width and cross-sectional shape. According to the stream tube concept, no water or sediment particles can cross the walls of stream tubs which is valid for most of the natural rivers. At and near a sharp bend, sediment particles may cross the boundaries of stream tubes due to its gravity while water still flows within the stream tube boundaries. GSTARS3 [19] recognizes this phenomenon and further expanded the capabilities of GSTARS2.1 for cohesive and noncohesive sediment transport in rivers and reservoirs. In GSTARS3, bed load sediments are allowed to cross stream tube boundaries.

3.1. GOVERNING EQUATION

3.1.1 Energy Equation

The energy equation can be written as:

$$Z + Y + \alpha \frac{V^2}{2g} = H \tag{1}$$

where z = bed elevation; Y = water depth; V = flow velocity; α = velocity distribution coefficient; H = elevation of the energy line above the datum; and g = gravitational acceleration. Eq. (1) is used for most water profile computations. This equation is valid when the channel's bottom slope is small, i.e., when s0<5%, in which case $\sin(\theta \approx \tan(\theta \approx \theta))$. Hydrostatic pressure distribution is also assumed.

3.1.2 Flow Resistance

a uniform flow formula canbe used to compute the friction losses. This formula is used to compute the total conveyance, K. The total conveyance K is used to determine the friction slope, Sf, for a specified discharge:

$$S_f = \left(\frac{Q}{K}\right)^2 \tag{2}$$

any of the following formulae can be used to compute K:

Manning's formula:

$$Q = KS_f^{1/2} = \left(\frac{1.49}{n} AR^{2/3}\right) S_f^{1/2} \tag{3}$$

Chézy's formula:

$$Q = KS_f^{1/2} = (CAR^{1/2}) S_f^{1/2} \tag{4}$$

or Darcy–Weisbach's formula:

$$Q = KS_f^{1/2} = \left[\left(\frac{8gR}{f}\right)^{1/2} A\right] S_f^{1/2} \tag{5}$$

where n, C, f = roughness coefficients in Manning, Chézy, and Darcy–Weisbach's formulae, respectively; g = acceleration due to gravity; A = cross-sectional area; and R = hydraulic radius.

3.1.3 Sediment Continuity Equation

The basis for sediment routing computations in GSTARS3 is the conservation of sedimentmass. In one-dimensional unsteady flow, the sediment continuity equationcan be written as:

$$\frac{\partial Q_S}{\partial X} + \eta \frac{\partial A_d}{\partial t} + \frac{\partial A_s}{\partial t} - q_{lat} = 0 \tag{6}$$

where η = volume of sediment in a unit bed layer volume (one minus porosity); Ad = volume of bed sediment per unit length; As = volume of sediment in suspension atthe cross section per unit length; Qs = volumetric sediment discharge; and qlat = lateralsediment inflow. A number of assumptions are made to simplify this equation.

Firstly, it is assumed that the change in suspended sediment concentration in across section is much smaller than the change of the river bed, i.e.:

$$\tag{7}$$

$$\frac{\partial A_s}{\partial t} \ll \eta \frac{\partial A_d}{\partial t}$$

Secondly, during a time step, the parameters in the sediment transport function fora cross section are assumed to remain constant:

$$\frac{\partial Q_S}{\partial t} = 0 \ or \quad \frac{\partial Q_S}{\partial x} = \frac{dQ_S}{dx}$$

$$\tag{8}$$

With these assumptions, eq. (6) becomes:

$$\eta \frac{\partial A_d}{\partial t} + \frac{dQ_S}{dx} = q_{lat} \tag{9}$$

which is the governing equation used for routing sediments in riversand streams.

Because of The importance of sediment, the researchers have examined this phenomenon in rivers and reservoirs. Including the research, like Sadek research in 2012 on the Cairo area.The greater Cairo area has many islands formed after the Aswan High Dam construction. Ministry of water resources and irrigation is interested in studying the development and evolution of these islands in order to reflect the esthetic aspects and improvement of the environment surrounding the islands. That study focuses on Shubra El-Khaima Island which is located upstream Delta Barrage in the back water curve region. His research aimed to propose different alternatives for island development. GSTAR3.0 model is the most recent version of a series of numerical models for simulating flow of water and sediment transport and prediction of morphological changes in alluvial rivers. This model was used to simulate and examine different alternatives for Shubra island development on river morphology according to different discharges

scenarios. The optimum alternative was proposed. Also, the future required precautions to mitigate the effects of this development on the stability of watercourse were suggested.[25]

Xiaolangdi Reservoir is located at 40km north of Loyang and 128km downstream of the Sanmenxia Reservoir on the main stem of the Yellow River. Due to high sediment load, Xiaolangdi Reservoir should be operated with yearly draw down flushing to recover reservoir capacity. Near the reservoir delta, 20 ~ 30 m of aggradation occurs in a year due to high sediment input from the upstream Sanmenxia dam and the large amount of deposited sediment in the reservoir are scoured out by a draw down flushing. Deposition and scour pattern occurs periodically in the reservoir. GSTARS3 model has been applied to river and reservoir morphologic change studies and the results were reasonable for most cases. However, due to complexity of Xiaolangdi Reservoir sedimentation and flushing mechanism, some of assumptions made for GSTARS3 original version are no longer valid. Therefore, GSTARS3 model was modified to be applicable to Xiaolangdi Reservoir sedimentation. Non-equilibrium sediment transport equation was used to consider time and spatial delay effects of sediment entrapment and deposition. Unit stream power equation for hyper-concentrated sediment flows was used to compute sediment transport capacity. The simulated results with the modified GSTARS3 model are in good agreement with measured bed profiles, channel geometry, bed material size distribution, and flushed sediment volume.[26]

the simulation of the evolution of river reaches resulting from such catastrophic events is performed by coupling the hydraulic and sediment transport numerical model GSTARS with a developed slope stability model based on the Bishop's simplified method. This is a novel methodology for the delimitation of hazard zones along riverbanks by taking into consideration not only the flood risks but also the possible induced landslides. Indeed, each section of the river reach is subject to changes caused by the river hydraulics and the associated erosion or sediment deposition and also undergoes profile changes caused by possible landslides. The initial hydraulic and geotechnical characteristics are first defined and then used to test the stability of several slopes of representative sections of the river reaches before the dam break. Validation tests are performed on specific reaches of the Outaouais River (Quebec) undergoing a dam break flood.[27]

Also, Klump and colleagues in 2005, GSATRS1D to simulate the transfer of unsteady, unsteady flow in stream sediments in the river Pyasjrv California applied.Bed material containing 2% sand, 98% silt and clay.The results showed good agreement with measured results.[28]

Othman and Wang in 2004, GSATRS2.1 software for simulation The process shields Tyqrys River downstream of the Mosul Dam in Iraq were usedAnd showed that GSATRS2.1 software successfully measured and compared with the results of the scour depth can properly simulate and predict changes in sediment particle diameter.[29]

3.2. Data requirement Mathematical models
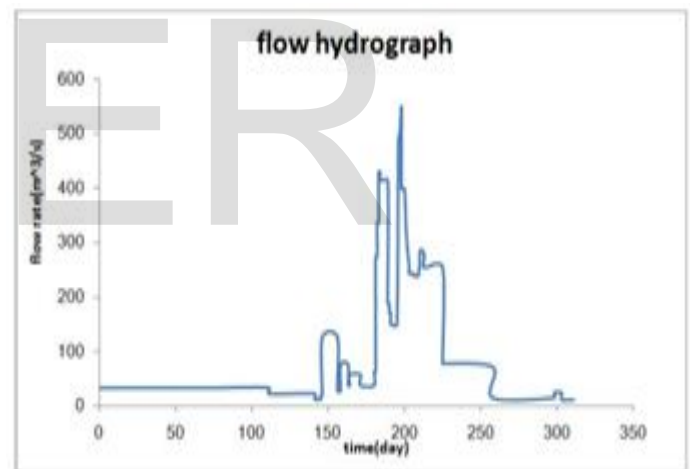
To solve the mathematical equations governing the flow and deposition in rivers and reservoirs, the model boundary conditions must bespecified. In thissituation, thedataflow andsediment intheupper and lowerboundariesandtopographicconditionsorthegeometryof themodel.Inthissection,data areneededonthe part ofthe geometricdata, sedimentdata, hydraulic data, hydrologicaldataare presented.

3.2.1. Geometricdata

The river reach tobe modeled must be described by a finite number of discretized cross sections. Cross section geometry is described by X-Y coordinate pairs, i.e., by coordinate pairs with lateral location and bed elevation. Bed elevations (Y) must be taken using acommon datum for the entire reach and must always be positive. Lateral locations (X) must be given using a reference point for each cross section, and the coordinatepairs must be entered in order of increasing X coordinate, i.e., starting from the lefthandside of the cross section and marching towards the right-hand side (lookingdownstream) InthisstudySegmentallength of about 34km,including 75 cross section Asthecasestudieshave been selected.

3.2.2. Hydraulic data

Daily Discharge in 2006-2007 with 24-hour time step was introduced as the upstream boundary condition to the mod-

els.

Fig2.Time series ofdischarge

Relationship Discharge - stage based on average slope ranges 0.00002 according to the following equation as the

$$H=6.31Q^{2.92}-1.01$$

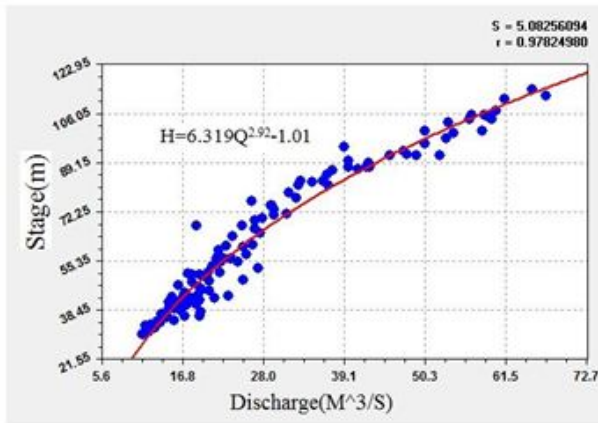downstream boundary condition is considered.

(10)

Where Q= m3/s , H= m.

Fig3.CorrelationbetweenQandH.

3.2.3. Sedimentdata

Sediment data includes bed material size distributions for the reach of study and the sediment inflow hydrograph entering the reach, including its particle size distribution. Data of DistributionShows ParticlesOfthe bed isadhesion. Forsamplesthenumberofbed materialparticle size distribution curveis given in the following figure.To determine the relationship between water flow inputs and sediment discharge (sediment rating curve) data Kahak station is located at 45285.6 Use. The best fit between the data flow and the discharge is related to the data correlation of 83percent.

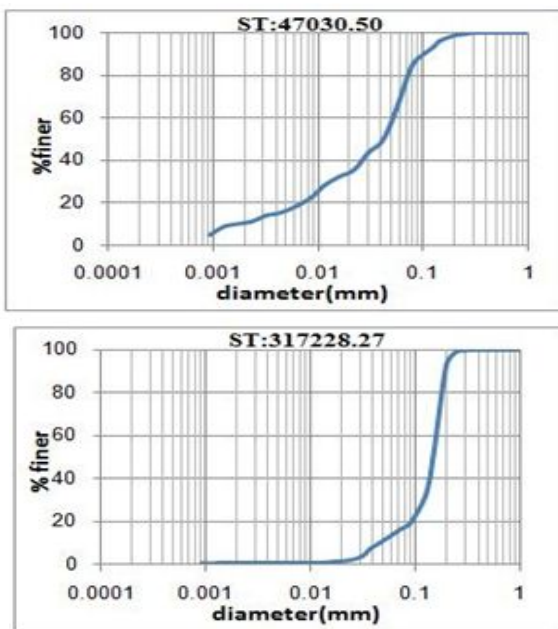$$Q_S = 31.419 Q_W^{1.4646} \tag{11}$$

Where QW=m3/sand QS= ton/day.

Fig4. The bed materialparticle size distribution curveof thenumberofsections.

3.2.4. Hydrologicaldata

One of the required data for the GSTRAS3 model for deposition is river water temperature. Water temperature data, necessary for kinematic viscosity and for water density computations Which directly measured Data are not available. But considering the local meteorological and To note that the main source of the Sistan River is melting snow in the mountains of Afghanistan. After consulting with experts in the region, temperature of Sistan River Flow Table1 is considered.

Table1.temperature ofSistan River Flow

Summer	Spring	Winter	Fall	Temperatures
17	12	7	12	C
26.6	53.6	44.6	53.6	F

3.2.5. Streamlines and Stream Tubes

GSTARS3 routes sediments using stream tubes. Stream tubes are conceptual tubes whose walls are defined by streamlines. The discharge of water is constant along a stream tube because no fluid can cross the stream tube boundaries. Therefore, the variation of the velocity along a stream tube is inversely proportional to the stream tube area. Figure 5 illustrates the basic concept of stream tubes used in GSTARS3.

In GSTARS3, the backwater profiles are computed first. Then, the cross sections are divided into several sections of equal conveyance. These regions of equal conveyance are treated as stream tubes, and the (computed) locations of their boundaries are the defining streamlines, across which no water can pass. The thus defined stream tubes are used as if they were conventional one-dimensional channels with known hydraulic properties, and sediment routing can be carried out within each stream tube almost as if they were independent channels.
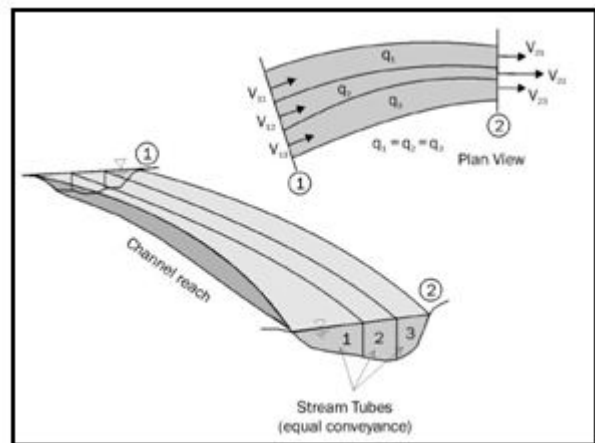

Fig 5.Schematic representation illustrating the use of stream tubes by GSTARS3

4.1. Calibration of mathematical models

sedimentcalculationsIninsedimentsimulation models Based on

thehydrodynamicparameters of the flowoccurs. In the modelcalibration should be done In two parts:
1. The hydrodynamic flow
2. The sediment.

4.2. Calibrationofthehydrodynamic:

This section contains roughness equation and roughness co-efficient calibration. To do this in aperiod of Hydrauli-candhydrometricdataare a vailable, the model is calibrated. Thus which per of a certain Discharge, water level calculation is consistent with the observed water level. Otherwise,some parameters need to be changed within a reasonable match between model results caused of natural conditions.

Table2. Calibration of the hydrodynamic

| n	n	n	Q	h	H	RMSE
0.02	0.01	0.02	32	1.188	0.75	0.11619
			61.3	1.351	1.11	
			125.54	1.849	1.4155	
			429.9	2.386	2.55	
0.025	0.01	0.03	32	1.188	0.75	0.10076
			61.3	1.199	1.11	
			125.54	1.831	1.4155	
			429.9	2.375	2.55	
0.02	0.02	0.02	32	0.659	0.75	0.29099
			61.3	0.386	1.11	
			125.54	0.827	1.4155	
			429.9	2.016	2.55	
0.03	0.02	0.03	32	0.659	0.75	0.51538
			61.3	0.123	1.11	
			125.54	0.648	1.4155	
			429.9	1.85	2.55	
0.03	0.03	0.03	32	0.659	0.75	0.51871
			61.3	0.12	1.11	
			125.54	0.645	1.4155	
			429.9	1.848	2.55	
0.04	0.03	0.04	32	0.659	0.75	0.51956
			61.3	0.119	1.11	
			125.54	0.645	1.4155	
			429.9	1.847	2.55	

4.3. Calibrationofthe sediment:

Aftercalibration ofthemodels for Hydraulicsimulation, to run Softwares GSTARS3 inSistanRiver is necessaryThatmodel iscalibratedofthesedimentsimulations, and the bestof thesediment modelaremore compatiblewith theriverareselected. In order to achieve it would required relationship discharge - discharge sediment extracted from the softwares are compared with relationship discharge - discharge to the actual deposition.

Table3. Accumulated results of sediment output from the-model GSTARS3.
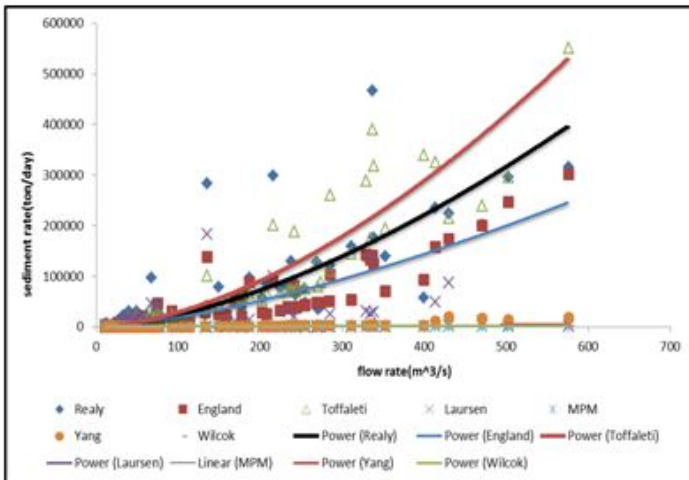
The accumulated sediment (million ton)	Sediment transportequation
107318	Meyer-peterand Muller
75450.82	Laursen
43758.41	Toffaleti
108943.86	Engelund and Hansen
107616	Ackers and White
114894.28	Yang
120775.85	Parker
101843.06	-Revised Acker and White
131253.76	Dubuois
61141.20	Modified Laursen
59629.514	Ashida and Michiue

5.1.Results from the model output.
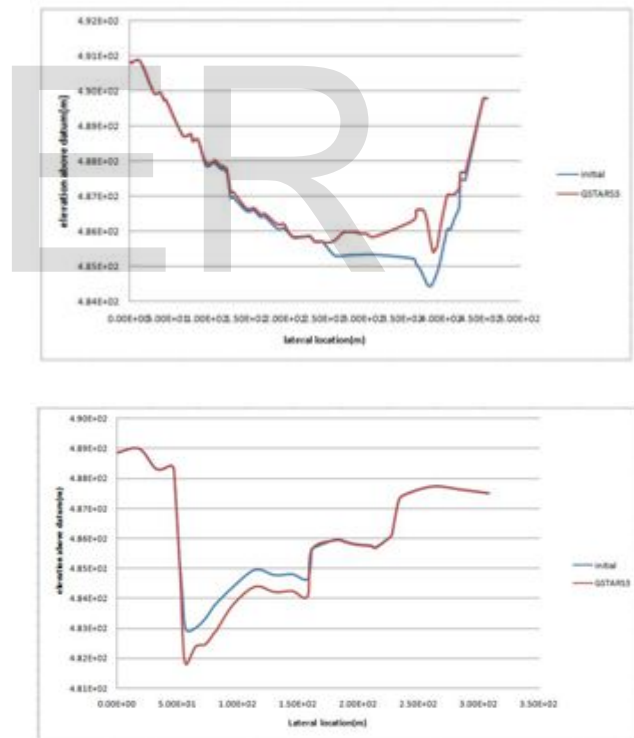
Fig6. Comparison between initial data and of results produced by GSTARS3 and HEC-RAS at station 33659 and 18449.

Fig7. Comparison between the measured and simulated re-

lationship discharge - discharge sediment in GSTARS3 model.

6. CONCLUSIONS

The advantage of using stream tubes is to reduce the intensive data and computational requirements of the more sophisticated truly 2-D and 3-D models. In addition, it can handle irregular cross sections regardless of whether single channel or multiple channels separated by small islands or sand bars. Hydraulic parameters and sediment routing are computed for each stream tube, thereby providing a transverse variation in the cross section in a semi-two dimensional manner. Backwater computations are carried out using the standard step method based on the conjunctive use of the energy and momentum equations.

The review of this paper was to model GSTARS3.0 and model We reached the following conclusions:

1.   Select a method to determine the sedimen to fthemodelis important. Quasi-two-dimensional model of a one-dimensional model to simulate the phenomenon of sediment transportand deposition volume estimate is more accurate. Although The GSTARS3 is a quasi-two-dimensional model

2.   Whatever number of sediment dynamics during a time step is greater   better predict sediment distribution with in the river but does not affect the estimated total volume of sediment.

3.   From Figures 6 we see that Toffaleti transport equation in model GSTARS Transport equations are best.

REFERENCES

[1]   Rangzan K, Salehi B and Salahshouri P (2008) Changes in the downstream of Karkheh dam after dam construction (using temporal images Landsat). Proceedings of Conference of Geomatics, National Cartographic Center, Tehran, Iran, pp:1-13.

[2]   Talebi l, Bayazidi S (2008) A Study on morphological changes of river using the Rosgen classification (case study: Sabzekooh River). Proceedings of 7th Iranian Hydraulic Conference, University of Power and Water Industry (ShahidAbbaspour), Iran, pp:1-10.

[3]   Yang, C, T. Applications of GSTARS Computer Models for SolvingnRiver and Reservoir Sedimentation Problems. Trans. Tianjin Univ. 2008, 14:235-247.

[4]   Labbe JM, Hadley KS, Schipper AM, Leuven R, Gardiner CP (2011) Influence of bank materials, bed sediment, and riparian vegetation on channel form along a gravel-to-sand transition reach of the Upper Tualatin River, Oregon, USA. Geomorphology journal. 125(1), 374–382.

[5]   Porasaf , F (2007) Study of Stream classification systems and application of them for Karoon and dez rivers. Proceedings of 7th International River Engineering Conference, ShahidChamran University, Ahwaz, Iran, pp:1-7.

[6]   Surian N , Rinaldi M , Pellegrini L, Audisio C, Maraga F, Teruggi L, Turitto O, Ziliani L (2009) Channel adjustments in northern and central Italy over the last 200 years. Geological Society of America Special. 451, 83–95.

[7]   Rostami A, AkbarpourSar-eskanrood M And AsqariSareskanrood S (2008) Severe erosion in Urtasoo (Hashtrood) river basin, result of neglect of geomorphology. Proceedings of First National Conference of Position of Geomorphological Studies on Spatial Planning and Environment Management, Islamic Azad University Central Tehran Branch, Tehran, Iran, pp.1-10.

[8]   Sabzivand R, Hashemi J, majdzadeh MR and Shafaee- Bajestan M (2007) Morphological rivers Classification, Setavndyazd Publication. pp: 88.

[9]   Najafi A and VatanfadaJ(2011) Environmental Challenges in Trans-Boundary Waters, Case Study:HamoonHirmand Wetland (Iran and Afghanistan). International Journal of Water Resources and Arid Environments. 1(1), 16-24.

[10]   Torabi S, Tajrishi M, Sarang S and Burqa'ei S (2001) Sistan River hydraulic analysis of one-dimensional flow. Proceedings of 6Th Iranian Hydraulic Conference, Tehran University, Iran, pp:1-13.

[11]   Bagnold R.A. 1966. An approach to sediment transport problems from general physics. USGS professional paper 422-1. p.37

[12]   Engelund .F. and Hansen. E. 1967. A monograph on sediment Transport. TekniskVerlag. Copenhagen. Denmark.

[13]   Van Rijn L. C. 1984a. Sediment transport part I Bed load. J. Hydraulic Engineering. ASCE 110 (10): 1431-1456.

[14]   Van Rijn L. C. 1984b Sediment transport part II suspended load transport..J. Hydraulic. Engineering. ASCE 110 (11): 1613-1641.

[15]   Guo Q-C and Jin, Y–C. 1999. Modeling sediment transport using depth-averaged and moment equations. J. Hydraulic Engineering. ASCE 125 (12). 1262-1269.

[16]   Zhang B , Ai N , Huang ZW , Yi Ch and Qin F (2008) Meanders of the Jialing River in China: Morphology and formation, Chinese Science Bulletin. 53(2), 267-281, DOI: 10.1007/s11434-007-0516-2 .

[17]   Molinas A, Yang C T. Computer Program User's Manualfor GSTARS (Generalized Stream Tube Model for AlluvialRiver Simulation) ［M］. U. S. Bureau of ReclamationEngineering and Research Center, Denver, Colorado,USA,1986.

[18]   Yang C T, Molinas A, Song C C S. GSTARSgeneralizedstream tube model for alluvial river simulation. Twelve Selected Computer Stream SedimentationModels Developed in the United States,Subcommittee on Sedimentation, Interagency AdvisoryCommittee on Water Data, Interagency Ad Hoc SedimentationWork Group, edited by Fan S S. Federal EnergyRegulatory Commission. Washington, D.C.,USA.1988.

[19]   Yang C T, Simões F J M. User's Manual for GSTARS3(Generalized Sediment Transport Model for Alluvial RiverSimulation Version 3.0)［M］. U. S. Bureau of Reclamation,Technical Service Center, Denver, Colorado,USA,2002.

[20] Chang, H. Generalized computer program FLUVIAL-12 ［C］. Mathematical Model for Erodible ChannelsUser'sManual, 1990.

[21] Yang C T, Song C C S. Theory of Minimum Energy andEnergy Dissipation Rate ［M］. Encyclopedia of Fluid Mechanics,vol. 1, Chap. 11. Edited by N. Cheremisinoff.Gulf Publishing Company, (1986). 353-399.

[22] Yang C T, Song C C S. Theory of minimum rate ofenergydissipation ［J］. Journal of the Hydraulics Division,ASCE, (1979), 105(HY7): 769-784.

[23] Yang C T. Force, energy, entropy, and energy dissipation-rate ［C］. Entropy and Energy Dissipation in WaterResources.Edited by Sing V P and Fiorentino M. KluwerAcademic Publisher, Netherlands, (1992).63-89.

[24] Yang C T. Sediment Transport: Theory and Practice ［M］. McGraw-Hill Companies, Inc., New York, NY,1996. Reprint by Krieger Publishing Company, Malabar,Florida, USA, 2003.

[25]   Sadek, N. 2012. Island development impacts on the Nile River morphology. Ain Shams Engineering Journal 4, 25–4.

[26] Ahn, J, Yang, C, T. Application of GSTARS3 to Xiaolangdi Reservoir Sedimentation andFlushing. Hydrology Days 2010.

[27] Mahdi, T. Pairing geotechnics and fluvial hydraulicsfor the prediction of the hazard zonesof an exceptional flooding. Nat Hazards (2007) 42:225–236.

[28] Klump, C., Huang, J and Greimann, B. P., 2005, Sediment model of the arroyo pasajero and California aquedut, U.S Bureau of reclamation repared for the California department of water resources.