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Review Study and Assessment for Sedimentation Models Applied to Impounding Reservoirs

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Abstract: Sedimentation of impounding reservoirs is a complex phenomenon and it is governed by many factors and these factors are related to river morphology and hydraulics, hydrology of the catchment, catchment characteristics and landuse. Sedimentation of a reservoir is important, because it may affect storage capacity, production of hydropower, navigation, water supply and turbine operation and dam safety. The monitoring of reservoir sedimentation can help to take the precautionary measures for effective maintenance. But, the lack in modern instrumentations, manpower and financial allocations are the main obstacles encountered to implement such monitoring plan. The advancement in mathematical modeling and computer technology can help to overcome these obstacles. There are many mathematical models used to predict the sedimentation in an impounding reservoir. The models can be divided to 1 Dimensional (1D), 2 Dimensional (2D) and 3 Dimensional (3D). In the present study, evaluation of these models is presented with special emphasis on 1D model. The weakness and strength is highlighted and models with accurate prediction are recommended.

Key words: Reservoir, sedimentation, models, evaluation, navigation, factors

INTRODUCTION

All reservoirs contain sediment and can be considered as a natural channel, in which a mixture of water and sediment is flowing. The sediment flow is mainly depends on the water flow rate. Usually, sediment load can be determined from the sediment rating curve for a river.

Reservoir sedimentation varies with several factors such as sediment production, sediment transportation rate and sediment type, mode of sediment deposition, reservoir operation, reservoir geometry and streamflow variability. Sediment is transported as suspended and bed loads by streams and rivers coming into a reservoir. Due to flow deceleration, when a river approaches a reservoir, the sediment transport capacity decreases and some of the incoming sediment is trapped and deposited in the reservoir (Frenette and Julien, 1996). In addition, the deposited sediments may consolidate by their weight and the weight of overlying water through time. Predicting the sediment coming into a reservoir, its deposition and its accumulation throughout the years, after construction of the dam, has been important problems in hydraulic engineering. Despite the advances made in understanding several of the factors involved in reservoir sedimentation, predicting the accumulation of sediment in a reservoir is still a complex problem (Julien, 1998).

Reservoir sedimentation rates results from the complex interrelationships between climate, drainage basin, fluvial system and human activities and it depends mainly on the size of reservoir relative to the amount of sediment flowing into it; a small reservoir on an extremely muddy river will rapidly lose capacity; a large reservoir on a very clear river may take centuries to lose an appreciable amount of storage. Storage capacity losses in reservoir mean financial losses due to the shortening of their useful life time (Simon and Senturk, 1992). The annual loss of storage in reservoirs is roughly 1% corresponding to an about 50 km^3 world wide (Mahmood, 1987). Some reservoirs have a much higher storage loss that may be exceeding 1.7% yearly (Patrick *et al*., 1996).

Reservoir sedimentation can be a serious problem with many disadvantages and control of sedimentation needs good instrumentations, trained man power and financial support. Sedimentation of a reservoir may affect hydropower generation due to the abrasion of turbines and other dam components. The efficiency of a turbine is largely depends upon the hydraulic properties of its blades. The erosion and cracking of the tips of turbine blades by water-borne sand and silt considerably reduces their generating efficiency and can require expensive repairs. Reservoir sedimentation also affects the navigation, water supply and flood mitigation. This highlights the importance of studying this problem.

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The reservoir sedimentation problem has increased worldwide year after year due to the increase of numbers of dams and increase of their size. This problem can not be totally avoided, once the dam is built, the reservoir will filled up by sediment that are present in all rivers. Then steps must be taken for at least to control this problem. The main step is to avoid, as much as possible, soil erosion in the contributory basin. This because when, the reservoir is filled by sediment, little can be done to remove them.

Due to advances in mathematical modeling and computer technology, mathematical models for predicting reservoir sedimentation are increasing. Mathematical models are economically affective compared with the site monitoring and model selection is essential. Methods to predict reservoir sedimentation using one dimensional model has been studied by Thomas and Prashum (1977), Toniolo and Parker (2003), Chang (1984), Molinas and Yang (1986), Hamrick (2001) and Gessese and Yonas (2008). Two dimensional models were applied by Thomas and McAnally (1985), Spasojevic and Holly (1990), Luettich and Westerink (2004) and Lee *et al.* (1997). Blumberg and Mellor (1987) and Olsen (1994) used three dimensional modeling.

This study discusses the finding of application of 1-3D models by researchers including limitation, advantages and disadvantages, But the main focus is given to one dimensional computational model used for reservoir sedimentation however, brief overview of 2D and 3D models to provide comparison between models features.

Mechanism of sedimentation in reservoir: Reservoir is a sink resulting in hydraulic conditions that reduce the velocity of flow often to near zero within the reservoir (Simon and Senturk, 1992). The change in velocity sufficiently rapid as the water enters the reservoir that the deposition of the coarser-size fractions takes place near the entrance to the reservoir. As the water continues to flow into the reservoir and over the dam, the delta continues to grow in the direction of the dam until it eventually fills the entire reservoir volume. The process is quite slow but relentless. Typically, reservoirs may take 50-100 years to fill (Mahmood, 1987).

Figure 1 shows, the principle processes for sedimentation in the storage reservoir as presented by Sloff (1997). The most important distribution of this sediment can be divided into the following groups:

Course sediment deltaic deposits: Mainly, the sediment fractions are deposited in the head of the reservoir by backwater effects during high discharge, forming a delta proceeds into the reservoir while, the foreset slope can be considered as an area of instability and slumping.

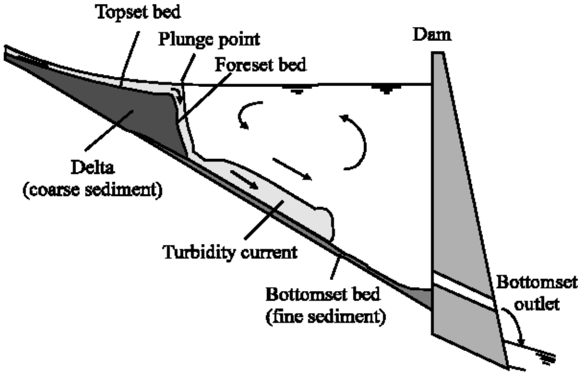

Fig. 1: Schematic presentation of principle sedimentation processes in storage reservoirs (Sloff, 1997)

Fine sediment in homogeneous flow: A large part of the fine sediments transported in suspension or as washload are transported beyond the delta after, which they settle out to form the bottomset bed. They are more spread than coarse sediment, but their distribution depends on reservoir circulation and stratification.

Turbidity current: Another important transport mode for fine sediment, i.e., silt and clay, is the turbidity current. It is formed when the turbid river inflow plunges below the clear reservoir water and continues as density underflow. Also, another process can generate them, such as underwater slides (slumping or delta front) or coastal erosion. Turbidity currents are driven by an excess gravity force due to the presence of sediment-laden water in a clear ambient fluid. These low velocity currents are capable of transporting large quantities of sediment over long distance. They become more and more accepted as potential measure to reduce sedimentation although their contribution is less than deltaic deposit processes (usually they create mud deposits near the dam) (Sloff, 1997).

Sediment transport models: To manage any system requires a model, which predicts future behavior and response to perturbation. All models are born as mental image and depending on the situation, they may grow in complexity to include graphics, desktop calculation, numerical calculation and physical scale modeling.

The models can be classified as computational (numerical) models and physical models. The use of computational models for solving sediment transport and fate problems is relatively recent compared with the use of physical models. Several considerations govern the choice between physical and computational models; namely, the nature of the problem that needs to be solved, the available resources and the overall cost associated with the problem solution. In some specific problems a combination of physical and computational models can be used to obtain a better understanding of the processes under investigation (Athanasios *et al*., 2008). Computational (numerical) sediment transport models are available to simulate flows in 1-3 dimensions. However, most modeling is performed with one dimension models, which are far more robust than their 2 and 3 dimensions. Molinas and Yang (1986) noted that 2 and 3 dimensional models required extensive amount of computer time and calibration data and may be not desirable for solving engineering problem with limited data and resources, when the problem can be analyzed within the context of one dimensional model, because river system and most reservoirs have highly elongated geometry. The assumption of one dimensional flow is appropriate for the analysis of many types of sediment problems.

Broadly speaking, these models can be classified on the basis of the range of their applications (e.g., suspended load versus bed-load; physical versus chemical transport) and their formulation in the spatial and temporal continua (e.g., 1-Dimensional model (1D); 2-Dimensional model (2D); or 3-Dimensional model (3D); and steady versus unsteady). The choice of a certain model for solving a specific problem depends on the nature and complexity of the problem itself. The chosen model capability to simulate the problem requires data availability for model calibration, data availability for model verification and overall available time and budget for solving the problem.

Many mathematical models have been developed for simulation of sediment behavior. All computer sedimentation models include three major components: water routing, sediment routing and special function modules. Most models include the option of selecting alternative sediment transport formula, but none provide the criteria for making that selection. Most models use the finite difference technique to simulate unsteady flow for a series of steady flow. In most equilibrium transport models, the sediment is assumed to reach equilibrium conditions during each model time step. Different models may be produced significantly different results, even when they were run with same set of inputs. All models are strongly data dependent and required an adequate data for calibration and verification. But in practice the field data required for this purpose are often lacking. All models required a great deal of professional judgment and field experience for explanation of their outputs (Morris and Fan, 1999).

MATERIALS AND METHODS

Numerical models are becoming a useful tool to predicte sediment transport. Numerical models solve the mass transport equation for suspended sediment and the mass conservation equation for bed sediment after the hydraulic field is solved. In the following, numerical models are reviewed based on the number of dimensions of the model.

One dimensional models: One dimensional mathematical model is used to analyze sediment transport along reaches of rivers or in reservoir where essential transport processes can be simulated with a one dimensional flow field. They are applied to problem such as sediment accumulation in reservoirs as a function of the operating regime, sediment pass through and scour below dams.

One-dimensional models solve the unsteady, cross-sectionally averaged equation for the mass balance of suspended sediment:

$$\frac{\partial(Ac_i)}{\partial t}+\frac{\partial(Qc_i)}{\partial x}=\frac{\partial}{\partial x}\left(AD_x\frac{\partial c_i}{\partial x}+S_i\right) \tag{1}$$

Where:

A = Cross-sectional area (m^2)

Q = Discharge ($m^2\ sec^{-1}$)

c_i = Cross-sectionally averaged sediment volume concentration ($m^3\ m^{-1}$ of constituent i

t = Time

D = Dispersion coefficient ($m^2\ sec^{-1}$) in the streamwise direction x

S_i = Source (erosion) and sink (deposition) terms ($m^2\ sec^{-1}$) for constituent i

Most 1D models are mainly designed for non-cohesive sediment transport with the capacities to simulate simple processes of cohesive sediment transport. These models include HEC-6, which developed by US Army Corps of Engineers (1993), GSTARS 2.1, GSTARS3 and GSTAR-I D, which developed by Yang *et al.* (2005). EFDClD model that developed by Hamrick (2001) is a 1D sediment transport model includes settling, deposition and resuspension of multiple size classes of cohesive and non-cohesive sediments. A bed consolidation model is implemented to predict time variations of bed depth, void ratio, bulk density and shear strength.

Below briefly describe some of sediment transport models that may be useful for analyzing sedimentation issues associated with reservoirs.

HEC-6: HEC-6 is a one dimensional movable boundary open channel flow that computes sediment scour and deposition by simulating the interaction between the hydraulic of flow and the rate of sedimentation flow. The model has been developed by US Army Croup of Engineering (1991). The model incorporated the assumption that equilibrium conditions are achieved between the flow and the bed material transport within each time step, an assumption also made in most other sediment transport models.

HEC-6 simulate a main river plus tributaries and local inflows. The hydraulic profile is simulated by the standard step method and Manning's equation to solve one dimensional energy equation. At each time step, the hydraulic computations are initiated at the downstream boundary of the model and proceed upstream and then the sediment computations are initiated at the upstream boundary and proceed downstream. The bed elevation and grain size is adjusted throughout the model reach and hydraulic computations for the next time step are initiated. Sediment transport capacity is calculated each time step interval. Transport potential is calculated for each grain size class in the bed as though that size comprised 100% of the bed material. This transport potential is then multiplied by the fraction size of each size class percent in the bed to determine the transport capacity of each size class.

Key advantages of this model include good documentation, continuing support and development by the hydrologic engineering center, a long history of use, familiarity to many reviewing agencies and availability of training through the croup of engineering. A particular strength of HEC-6 model for reservoir analysis is its ability to simulate both deposition and scour for wide range of grain size, including silt and clay. Many other stream sedimentation models do not incorporate two capabilities to simulate fines.

GSTARS: The General Stream Tube model for Alluvial River Simulation (GSTARS) was developed by the US Bureau of Reclamation. GTARS is a steady non-uniform flow, one dimensional model, which simulates certain aspects of two dimensional flows by using the stream tube concept for hydraulic computation. It is also capable of solving for channel width as an unknown variable, based on the concept of stream power minimization.

Hydraulic computation may use the Manning's, Darcy Weisbach, or Chezy equation and computation can be carried through both subcritical and supercritical flows without interruption. Geometry is specified by channel cross section and roughness coefficients are specified as a function of distance across the channel.

The model uses stream tubes to compute the lateral variation in hydraulic and sediment transport condition within the cross section. Stream tubes are bounded by streamlines, each stream tube has the same discharge. The user determines the number of stream tubes to be used and when, a single tube is used, the model become one dimensional in conventional sense.

In GSTAR the sediment load is computed for each size class individually as if the entire bed consists of that size. The resulting load is multiplied by the fraction of bed material corresponding to that particle size to give the bed material load for each size class. But the model will not simulate the scour and deposition of silt and clays.

FLUVIAL: The FLUVIAL model is a one dimentional model developed by Chang (1984) and it is used to analyze the reservoir sedimentation. It is contains five major components: hydraulic routing, sediment routing, change in channel width, change in channel bed profile and change in transverse bed geometry due to curveture. A particular feature of this model is the ability to simulate the development ot the transverse bed slope in a curveture reach.

Model geometry is spesified by a series of cross sections. Bed material composition is spesified at the upstream and downstream boundaries of the model and may be spesified at other locations as well. Hydraulics, sediment transport and bed and width adjestment are simulated iteratively. Hydraulic routing can be performed as a series of steady approximations by the computationally faster standard step method, or as dynamic wave unsteady flow. Bed roughness can be input in the form of Manning's values to predict alluvial bed roughness. Six different sediment transport formulas are incorporated into the model and aroming computations are performed. The model does not simulate silts and clays. Table 1 summarizes examples of the applications of 1D models.

Two dimensional models: Since the 1990s, there has been a development in computational research toward the 2D models. Most of the 2D models have the capability that made them user-friendly and popular because of the easy data input and visualization of results. 2D models can provide spatially varied information about water depth and bed elevation within the rivers, lakes and estuaries.

Two-dimensional models solve the depth-averaged or width-averaged convection-diffusion equation with appropriate boundary conditions. Usually, three types of boundary conditions are encountered in a 2D numerical model. At the inlet boundary, the sediment concentration is given. At the outlet boundary, there is no concentration gradient. At solid boundaries, there is no horizontal flux

Table 1: Applications for selected 1D models

Model and references	Applications
HEC-6; Thomas and Prashum (1977)	Prediction of the flow and sediment transport along with the bed level change of the Saskatchewan River below Gardiner Dam, Canada _Krishnappan (1985) Prediction of the bed profile for the eroded and redeposited delta sediment upstream from Glines Canyon Dam, Washington, US Department of Interior, Bureau of Reclamation (1996)
GSTARS; Molinas and Yang (1986)	Prediction of the variation in channel geometry for the unlined spillway downstream Lake Mescalero Reservoir, New Mexico
FLUVIAL 11; Chang (1984)	Simulation of flow and sediment processes of the San Dieguito River, Southern California Chang (1984). Simulation of flow and sediment processes of the San Lorenzo River, Northern California Chang (1984)

normal to the solid surface. The 2D depth-averaged advection-dispersion equation for cohesive sediment transport is:

$$\frac{\partial(Dc_i)}{\partial t}+\frac{\partial(Duc_i)}{\partial x}+\frac{\partial(Dvc_i)}{\partial y} = \frac{\partial}{\partial x}\left(DxD\frac{\partial c_i}{\partial x}\right)+\frac{\partial}{\partial y}\left(DyD\frac{\partial c_i}{\partial y}\right)+S_i \qquad (2)$$

Where:

D = Depth (m)
c_i = Depth-averaged concentration
u, v = Velocity components (m sec^{-1}) in the directions, x and y, respectively
t = Time (sec)
D_x, D_y = Dispersion coefficients (m^2 sec^{-1}) in the x and y directions, respectively
S_i = Source (erosion) and sink (deposition) terms (m sec^{-1}) for constituent i

Two-dimensional models have been applied to channel sedimentation and harbor sedimentation studies, where the variation of flow parameters with depth or width can be neglected.

The main specific features of some models are described as:

TABS-2: A group of finite element based hydrodynamic and sediment transport computer code developed by USACE Waterway Experimental Station (Thomas and MCAnally 1985). These codes are applicable to rivers, reservoirs and estuaries. The main components of TABS-2 are the hydrodynamic component, the sediment transport component and the water quality component.

MOBED-2: A finite-difference hydrodynamic and sediment transport model used in a curvilinear coordinate system, developed by Spasojevic and Holly (1990). The model can simulate water flow, sediment transport and bed evolution in natural waterways such as reservoirs, estuaries and coastal environments where depth averaging is appropriate.

USTARS: This model is a modified form of GSTARS that is also based on the stream tube concept (Lee *et al.*, 1997). The hydrodynamic and sediment equations are solved with a finite-difference scheme in a rectilinear coordinate system. As in GSTARS, the theory of minimum stream power is used here to determine the optimum channel width and geometry for a given set of hydraulic, geomorphologic, sediment and man-made constraints.

ADCIRC-2D: A finite-element hydrodynamic and sediment transport model developed by Luettich *et al.* (1992) in a rectilinear coordinate system for simulating large-scale domains by using 2D equations for the external mode but using the internal mode for obtaining detailed velocity and stress at localized areas. The internal mode is achieved by specifying the momentum dispersion and the bottom shear stress in terms of the vertical velocity profile. The wave-continuity formulation of the shallow-water equations is used to solve the time-dependent, free-surface circulation and transport processes. Table 2 summarizes examples of the different 2D models applications.

Three-dimensional models: In many hydraulic engineering applications, one has to resort to 3D models when 2D models are not suitable for describing certain hydrodynamic/sediment transport processes. Flows in the vicinity of piers and near hydraulic structures are examples, in which 3D flow structures are ubiquitous and in which 2D models do not adequately represent the physics. Three-dimensional (3D) models solve the full convection-diffusion equation, with appropriate boundary conditions. The general equation of transport of cohesive sediment is written:

$$\frac{\partial c_i}{\partial t}+\frac{\partial(uc_i)}{\partial x}+\frac{\partial(vc_i)}{\partial y}+\frac{\partial(wc_i)}{\partial z}=\frac{\partial}{\partial x}\left(D_x\frac{\partial c_i}{\partial x}\right) +\frac{\partial}{\partial y}\left(D_y\frac{\partial c_i}{\partial y}\right)+\frac{\partial}{\partial z}\left(D_z\frac{\partial c_i}{\partial z}\right)+\frac{\partial}{\partial z}(ax_i) \qquad (3)$$

Where:

c_i = Volume concentration
t = Time (sec)
u, v = Velocity components (m sec^{-1}) in the directions, x, y and z, respectively
D_x, D_y, D_z = Dispersion coefficients (m^2 sec^{-1}) in the x, y and z directions, respectively
u = Sediment fall velocity (m sec^{-1})

Table 2: Applications for selected 2D models

Model and references	Applications
TABS-2; Thomas and McAnally (1985)	Simulation of the flow and sediment transport processes in the Black Lake, Alaska
MOBED2; Spasojevic and Holly (1990)	Simulation of mobile-bed dynamics in the Coralville Reservoir on the Iowa River, Iowa
USTARS; Lee *et al.* (1997)	Routing of flow and sediment of the Shiemen Reservoir, upstream Tan-Hsui River, Taiwan
ADCIRC; Luettich *et al.* (1992)	Simulation of the flow and sediment transport processes of the natural cap in the Matagorda Bay, Texas

Table 3: Applications for selected 3D models

Model and references	Applications
ECOMSED; Blumberg and Mellor (1987)	Simulation of the flow and sediment transport processes of Lavaca Bay, Texas
SSIIM; Olsen (1994)	Tested against experimental data from Colorado State University
CH3D-SED, Spasojevic and Holly (1990)	Evaluation of the relative impact of different sediment sources on the shore areas of the Western basin of Lake Erie, Ohio

Recently, a general 3D sediment transport model was developed in China by Fang and Wang (2000). This is a sophisticated model that uses equation for sediment laden water with variable density; this means that the model can take account of stratified flow, which is the case of most Chinese rivers.

The US Army Corps of Engineers developed a 3D sediment transport model, CH3D-WES, that solves the complete 3D advection-dispersion equation using a finite-difference method (Athanasion *et al*., 2008). EFDC model was developed by Environmental Fluid Dynamics Code is another 3D surface water model for hydrodynamic and sediment transport simulations in rivers, lakes and estuaries. The model has also capabilities to predict toxic contaminants and water quality state variables. The physics of the EFDC model and many aspects of the computational scheme are similar to the US Army Corps of Engineers' 3D code CH3D-WES.

The model solves the 3D, vertically hydrostatic, free surface, turbulent averaged equations of motion for a variable density fluid. Other 3D models such as SSIIM, which is a finite volume hydrodynamic and sediment transport model that is based on an unstructured grid system (Olsen, 1994). The model has the capability of simulating sediment transport in a movable riverbed with complex geometries. It includes the modeling of meandering and bed forms in rivers and bed load and suspended load transport of nonuniform sediment and associated sorting and armoring processes. The model has been extended to such other hydraulic engineering applications as spillway modeling, head loss in tunnels, meandering in rivers and turbidity currents. The model has also been used for water quality and habitat studies in rivers.

The SSIIM is a general three dimensional sediment transport model. Although not developed for reservoir sedimentation, the model was used for this objective. SSIIM model was used by Olsen (1994) to simulate deposition pattern in two reservoir in Costa Rica and reservoir in Thailand. For the Thai reservoir, the author stated that due to unavailability of field data a direct comparison between the calculated results and the field data can not be made. Table 3 summarizes examples of different applications of 3D models.

RESULTS AND DISCUSSION

One dimensional models for reservoir application have been available since the end of 1970s (Van, 1986). Most of the 1D models are formulated in rectilinear coordinate system and solve the differential conservation equation of mass and momentum of flow along with the sediment mass continuity equation by using finite-differences schemes.

Most of the one dimensional models can predict the basic parameters of a particular channel, including the bulk velocity, water surface elevation, bed elevation variation and sediment transport load. All of them can also, predict the total sediment load and grain size distribution of nonuniform sediment. All 1D models are applicable to unsteady flow condition except HEC 6.

Among other 1D models that use different coordinate system equation or scheme of solution are FLUVIAL by Chang (1984), who used a curvilinear coordinate system to solve the governing equation of this model and GSTARS by Molinas and Yang (1986), who implemented the theory of minimum stream power to determine the optimum channel width and geometry for a given set of hydraulic and sediment conditions.

Some of these 1D models have additional specific features, HEC 6 model, for example, decomposed energy losses into form loss and skin loss. FLUVIAL by Chang (1984) accounts for the presence of secondary currents in curved channels by adjusting the magnitude of the streamwise velocity. The same model can provide changes in the channel bed profile, width and lateral migration in channel bends.

HEC-6 model has been applied by Bhowmik *et al.* (2004) and calibrate and validate processes for the model were done using data for the Kankakee River from the Stateline Bridge to Kankakee Dam in Indiana State USA. The model was used to test different management scenarios and to handle sedimentation and sediment-

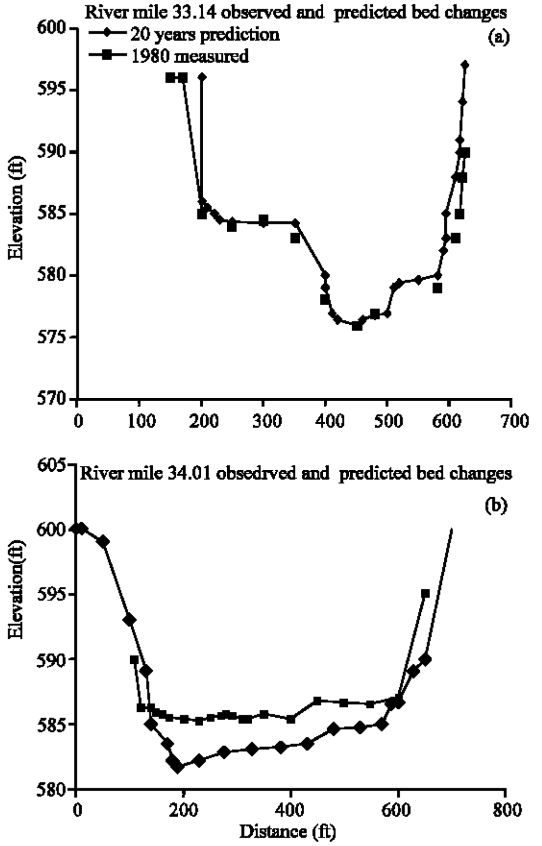

Fig. 2: Past and predicted cross-sectional changes within Six-Mile Pool of the Kankakee River at a) RM 33.14 and b) RM 34.01, by Bhowmik *et al*. (2004)

related problems. The HEC-6 modeling work incorporates hydraulic modeling and sediment transport modeling for the same segment of the river. Both the hydraulic and sediment transport components of the HEC-6 are one-dimensional. Thus, this modeling work encompasses the average changes and/or variabilities of the flow and river cross sections and profiles. The results of the study show a very good correlation between measured and computed parameters. Figure 2a and b show, the cross sectional change in two location of the study area, upstream station at RM 33.14 and downstream station at RM 34.01 for Kankakee River.

Another case of reservoir sedimentation by applying GSTARS3 for Tarbela Dam and Reservoir to compute reservoir sedimentation and delta movement was done by Tarbela Dam located in northern Pakistan along the Indus River. Figure 3a and b show, the results of sedimentation prediction for the reservoir. The sedimentation for 22 years of reservoir operation is predicted at different locations namely upstream and downstream.

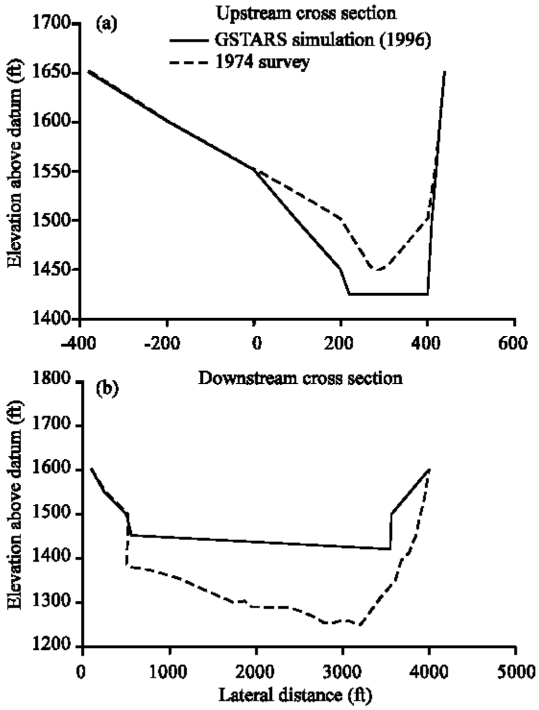

Fig. 3: Comparison of measurements and GSTARS3 computation for two cross sections in the a): upstream region and b): Tarbela reservoir

From the over cases, it clearly indicates that the Terbela reservoir is experiencing a sedimentation problem.

From the above two examples, it can be concluded that the sedimentation models HEC-6 and GSTARS are successfully applied to predict the sedimentation in reservoir.

CONCLUSION

The first computational models to be developed for reservoir sedimentation were one dimensional. This means that the downstream direction is the only dimension considered for modeling purposes. These models have several advantages, among them, the simplicity of the formulations and the few requirements of computer resources making possible the simulation of large reaches of rivers or reservoir. The main disadvantages of one dimensional are the impossibility of simulating curved flows and recalculating zones or secondary flows. Thus, if such phenomena are important, 1D model could not be used (Jose, 1999).

The two dimensional models are a particular case of 3D models. They have served as an initial step in the direction of three dimensional models since they use the 3D governing equations in two directions. Most 2D models solve the depth-average continuity and Navier-stockes equations along with the sediment mass balance equation using finite difference, finite element, or finite volume. All the 2D models are applicable to unsteady flow conditions and all of them can predict the total sediment transport load but only MOBED2, USTARS can handle multifractional sediment transport and can decompose the total sediment load into bed load and suspended load.

Three dimensional hydrodynamic models for reservoir sedimentation are necessary to compute lateral bed load transport of sediment and erosion deposition process, but the 3D models are still limited (Wu *et al*., 2000). Most 3D models solve the continuity and Navier-Stokes equations, along with the sediment mass balance equation through the methods of finite difference, finite element, or finite-volume techniques. Except for the SSIIM by Olsen (1994), all of the models are applicable to unsteady flow condition. EFDC3D by Hamrick (2001), CH3D-SED by Spasojevic and Holly (1990) and SSIIM by Olsen (1994) have the capabilities to predict the gradation of sediment mixtures, whereas ECOMSED by Blumberg and Mellor (1987) can not separate the total sediment load into bed load and suspended load.

The prediction of sediment transport and sediment accumulation in reservoirs has challenged many researchers. One and two dimensional models are commonly used for predicting the sediment scour and deposition. Those models are adequate for many engineering applications; however, for some problem, only a three dimensional model should be used.

In general, a model should be chosen in a way that the model hydrodynamic/sediment components retain all relevant terms related to a specific problem. The choice of a simple model may results in a risk that the model will not represent the real problem, whereas increasing the model complexity can complicate the problem formulation and need more input data preparation, calibration and verification cost.

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