SUHARJOKO, MOHAMMAD BISRI, RISPININGTATI, MUHAMMAD RUSLIN ANWAR / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 3, Issue 1, January -February 2013, pp.231-237

Modelling Of Groyne Placement On The River Bend Based On Sedimentation Analysis Using Numerical Simulation Approach By Finite Difference Method

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ABSTRACT

Modelling of groyne placement on the riverbend based on sedimentation analysis having a goal to development the good placement of groyne to be considered of the sedimentation accumulation volume on groyne field. To solved Modelling groyne placement would be simulation many case of groyne placement using mathematical modeling approach by finite different method.

This research plant to simulation for the 450 cases, that were combinations of various the groyne position, various the groyne length, various of the flow velocities, various of the radius bend and various of the suspended load concentrations. From the data simulation outcome, can be solved by regression analysis to obtain suitability coefficients $C_{vol.}$.

Keyword : groyne placement, riverbend, sedimentation analysis, mathematical modeling.

I. INTRODUCTIONS

On the issues of concerning the groyne placement, has been studied as follows; Suharjoko 1999 [1] and (2001) [2], has analyzed and reviewed groyne has carried out to get changes conduct of flow pattern and the best distance between groynes impermeable using Computational hydrodinamics simulations on a straight channel. The results of the analysis was obtained relationship between the Froude number (*Fr.*) with long of embankment protected and other parameters the results can be used to shown the best distance between the groyne. Jungseok, 2005 [3], that research has carried out the distance between groyne used Numerical Modeling to single permeability Groyne on rectangular channel (CFD) Flow-3D Software. While Heereveld (2006) [4], built the groyne river with consider the contradictive assertions such as the reduction of the riverbed flow velocities and an increase fairway on the the top. At the extremities of the main channel, the aforementioned bed level increase is expected to be larger, but this will be countered through the Island and lengthening of the groyne head in the direction of flow (Louvre Groyne). Effectively, overcompensation is possible so that the deposition height resulting from the constriction scour is minimized and the frequency of occurrence and size of undepths is minimized. The sheltering effect of the flow through the opening and the Island / lengthening of the groyne head itself turn the sediment balance in the groyne fields from net-erosion to net-deposition, thus minimizing the sediment load on the fairway during emerged state. Because of this, it is expected that maintenance dredging can be minimized importantly. Fang, (2005) [10], To improved of bend flow sediment transport model has been developed by taking the influence of secondary current vertical velocity on vertical sediment concentration distribution into account. But existing vertical velocity profiles of secondary current and vertical sediment concentration profiles in river bends are hardly available, further experiment study is necessary for improving bend flow sediment transport models. Duan 2006 [6], developed applications of numerical hydrodynamics modeling two dimensional depth averaged to simulate suspended sediment at the confluence of the rivers to get an illustrated of the sediment concentration distribution around groyne. Zhang (2007) [7], this study investigates the flow and process of riverbed change at a river rehabilitation projects by using physical model and mathematical model. Prohaska (2007) [5], results showed that conservative methods to determine erosion and to control erosion around krib. The analysis gives the effective value of the critical erosion shear stress to be smaller than the average value of the assent shear stress. Susceptibility of erosion sediment to contaminated pollutants is difficult to predict of the time physical processes because its had complex influence, chemistry and biology, as well as the lack of information. Armanini, 2010 [8], doing analysis experiment results of research with physical models in problems of scouring and deposits around groyne. Formation of the groyne shown clearly the influence of processes Improved a-gradations between the river groyne.

The research mentioned has been applied to simulate the currents flow pattern around groyne and to get shown the distribution of sedimentation concentration included concentration of Vortex-flow around the groyne. But there has been no research to get the good placement of groyne that considered of sedimentation accumulation volume on groyne field using numerical simulation approach by depth averaged two-dimensional fined difference flow models.

II. METHOD

A. Modelling groyne placement.

A modelling of groyne placement on the riverbend based on sedimentation analysis, having a goal to development the good placement of groyne that were to be considered of the volume sedimentation accumulation on groyne field. To solved Modelling groyne placement would be simulation many case of groyne placement using mathematical modeling. To development mathematical/numerical models were used, these models needed process verification and validation (V&V). *The expected outcome of the model V&V process is the quantified level of agreement between experimental data and model prediction, as well as the predictive accuracy of the model.*

B. Developing Mathematical Model and verification & validation

Developing the Conceptual Model involves identifying the computational objective, the required level of agreement between the experiment and simulation outcomes, the domain of interest, all important physical processes and assumptions, the failure mode of interest, and the validation metrics (quantities to be measured and the basis for comparison). Once the Conceptual Model is developed, the modeler constructs the Mathematical Model, and the experimenter designs the Validation Experiment. The Mathematical Model is a set of mathematical equations intended to describe physical reality. The Mathematical Model of hydrodinamics includes the mass conservation equation and momentum equations, the sedimentation equations and temporal domain, the initial and boundary conditions, the constitutive equations, and the relationships describing the model's uncertainty. (Thacker Ben H., 2004,[11]) More detail can be seen in figure 1 follow.

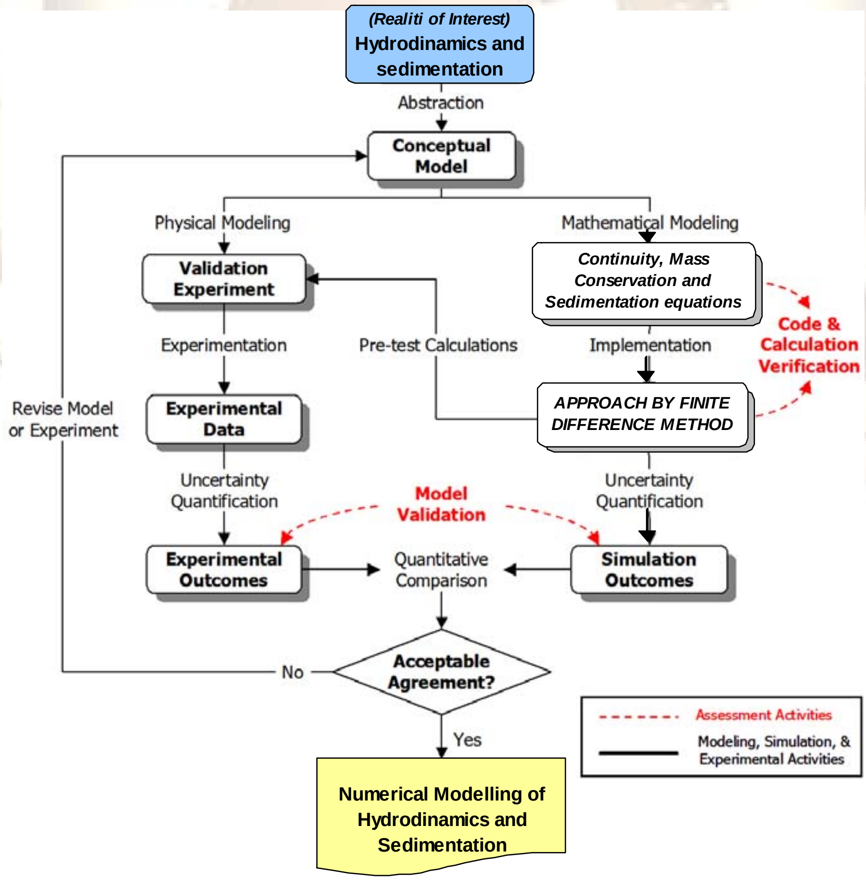


Fig 1: Detailed Numerical model development, verification, and validation process. (Thacker Ben H., 2004 [11], modified)

C. Conservation Equations

Mathematical Model of hydrodinamics includes the mass conservation equations and momentum equations. The Conservation Equations called Continuity equations was based on the conservation of mass concept, Abbort, 1979 [12]. The continuity equations two dimension horizontal be represented as follow

$$\frac{\partial \eta}{\partial t}+\frac{\partial (hu)}{\partial x}+\frac{\partial (hv)}{\partial y}=0$$

Where, η = water level fluctuations
h = Water depth,
u = mean velocity in the x direction,
v = mean velocity in the y direction.

D. Momentum equations

The Momentum equations was constructed based on the Newton II low [12], The momentum equations two dimension horizontal be represented as follow.

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-g\frac{\partial \eta}{\partial x}+\frac{g}{C_z^2}u\sqrt{u^2+v^2}+\upsilon\nabla^2 u,$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-g\frac{\partial \eta}{\partial y}+\frac{g}{C_z^2}v\sqrt{u^2+v^2}+\upsilon\nabla^2 v,$$

Where, $\nabla^2=\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)$.
Cz = Chezy Coefficient
g = gravitation accelerations

E. Equation of suspended sediment dispersed

Wexier (1992) on Signh 2005 [13] developed an analytical solution for two-dimensional advection-diffusion equation including source-sink term. Diffusion coefficients and velocity profile were taken constant spatially. He developed an analytical solution for the following form of the advectiondiffusion equation, which can be derived by assuming unit depth and spatially constant diffusion coefficients and velocity profile.

$$\frac{\partial C}{\partial t}+U\frac{\partial C}{\partial x}+V\frac{\partial C}{\partial y}=k_x\left[\frac{\partial^2 C}{\partial x^2}\right]+\left[\frac{\partial^2 C}{\partial y^2}\right]-\lambda C$$

$$C=C_0,\quad x=0 \text{ and } y_1<y<y_2$$

$$C=0,\quad x=0 \text{ and } y<y_1 \text{ or } y>y_2$$

$$\frac{\partial C}{\partial y}=0,\quad y=0$$

$$\frac{\partial C}{\partial y}=0,\quad y=W$$

$$\frac{\partial C}{\partial y}=0,\quad X=L$$

F. Settling velocity

Liu 2001 [14], The settling velocity of the sphere of suspended sediment w_s give

$$w_s=\frac{1}{2.8}\sqrt{\left(\frac{36v}{d_n}\right)^2+7.5(s-1)gd_n}-\frac{36v}{d_n}$$

Where, d_n is normal diameter, s is relative density and v is water viscosity.

The Migniot (1989) on Signh 2005 [13] formula is used to calculate the cohesive sediment settling velocity:

$$w_{sc}=\frac{250}{d^2}w_s$$

Where : w_{sc} = settling velocitys of cohesive sediment flocs
w_s = settling velocitys of single cohesive sediment Stoke Law is used to calculate the single cohesive sediment particle

$$w_s=\frac{gd^2}{18\mu}(\rho_s-\rho)$$

G. Settlement of Suspended sediments

Dyer 1986 on Widagdo 1998 [15], introduce the equation to calculate the rate of setled sediment as follow,

$$\frac{dm}{dt}=Cw_s\left(1-\frac{\tau}{\tau_c}\right)$$

Where m is the mass sediment settle to be deposited, C is the sediment concentrations, τ, τ_c are the shear stress and critical shear stress for settlement respectively.

$\tau=\gamma RS$, for wide channels hydraulic radius R can be taken as the depth of flow h.

Indri,s formula on Signh 2005 [13] proposed the critical shear stress formulation for incipient motion of sediment particle are:

$$\tau_c=13.3d\left(\frac{s-1}{M}\right)+12.16 \quad if\ d<1.0mm$$

$$\tau_c=54.85d\left(\frac{s-1}{M}\right)-74.48 \quad if\ d>1.0mm$$

Where τ_c = Critical shear stress in gm/m^2, d = mean diameter of sediment in mm, M = uniformity coefficient

H. Bed Elevation Change

The bed elevation change due to sediment erosion and deposition can be represented by the following equation [13]:

$$(1-p')\frac{\partial z_{bk}}{\partial t}=\alpha\omega_{sk}(C_k-C_k^*)+\frac{(q_{bk}-q_{bk}^*)}{L_t}$$

Writing this equation to finite difference scheme for incorporating in the computation model to calculating the bed elevation change as follow;

$$(1-p')\frac{\Delta z_k^{n+1}}{\Delta t}=\alpha\omega_{sk}(C_k-C_k^*)+\frac{(q_{bk}-q_{bk}^*)}{L_t}$$

$$\Delta z_k^{n+1}=\frac{\alpha\omega_{sk}(C_k-C_k^*)\Delta t+(q_{bk}-q_{bk}^*)\Delta t/L_t}{(1-p')}$$

where Δz_k^{n+1} is the fractional bed elevation change at the n th time step due to the k th size class of gradation sediment. The total bed elevation changes after each time step can be calculated by summing all the fractional changes in bed elevation due to all class of gradation sediment.

I. Regression Analysis

Regression analysis can be provide from the relationship between variables from one or more free variables to get approximate predictions ,Triatmodjo 2001, [16] [17]. The purpose of regression analysis is to obtain a function as a forecast.

A linear regression equation with one independent variable *(x)*was,

$$y = a_0 + a_1 x$$

Or nonlinear/exponential regression analysis as follows

$$E_i = ae^{bx_i}$$

The exponential regression equation can solved to the linear regression equation as follows.

$$ln(E_i) = ln(a) + bx_i \, ln(e)$$

III. RESULTS AND DISCUSSION

A. The Relationship of SEDIMENTATION ACCUMULATION with the GROYNE PLAYCEMENT

There is a relationship that influence between the groyne placement with the sedimentation accumulation on the groyne field. Be expected that a good groyne placement will be given if volume the sedimentation accumulation on groyne field is bigger. The groyne placement, angle bend of the river and radius of the river bends are variables which have great impact to caused the sedimentation accumulation.

B. The relationship of Parameters

The relationship of parameters there were caused to changes of sedimentation deposition accumulation on groyne field shown in figure 1 are;

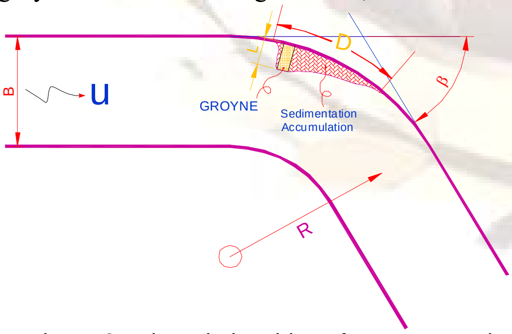


Figure 2 : The relationships of parameters that effected to the sedimentation accumulations.

The parameters were mentioned ;

a. *Morphology Factor*
- *B* : *River* width ,
- R : Radius Bend,
- β : Angle Bend

b. Hydrology and Hydrometry factor
- u : Flow Velocyties
- h : Water depth
- ρ : density of water
- ν : viscocty.

c. Suspended Load
- p : sediment concentration ,
- d_{50} : is mean diameter of soil grain size,
- γ : specific grafity of soil sediment,
- Vol : Sedimentation accumulation

d. Groyne placement factor
- : Position of Groyne,
- L : Lengt of Groyne,
- α : angle of Groyne placement, in this recearch α =90^0

Suharjoko (2001) [2], done research on directional groyne with different angles on the straight channel, have research resulting that's a groyne was placed perpendicular of the flow direction is the best. Based on this reference, research further was restricted to the groyne was placed on perpendicular of the flow direction (angle $\alpha = 90^0$). From the explanation above, the parameters that effected to sedimentation accumulations (*Vol*), can be expressed mathematically as follows ;

$$Vol = f\,(B, R, \beta, \alpha, u, h, v, p, d_{50}, \gamma, \rho, L, t)$$

C. Non-Dimentional Parameters

To get the parameters relationships of sedimentation accumulation on the groyne field be come a generaly formulation, be solved with non-dimensional analysis by Stepwise Method, Yuwono 1994 [18]. That is to get how the parameters relationships be come no-dimensional by elimination of dimension stage by stage. In the Table 1 below were shown a solved non-dimensional analysis by Stepwise method.

From the Table 1, non-dimensional value be expressed as follows.

$$\theta = \left(\frac{Vol}{h^3}, \frac{B}{h}, \frac{R}{h}, \frac{D}{h}, \frac{d_{50}}{h}, \frac{v}{\rho u}, \frac{h\gamma}{\rho}, \frac{gh}{u^2}, tg\beta, C, \frac{ut}{h} \right)$$

To be expected that Groyne placement have an impact of sedimentation accumulations on the groyne field was solved to compile an equations formulation from the non-dimensional value be expressed as a model that reflected the relationship of sedimentation accumulations with the parameters to have an impact, as follows,

$$\frac{Vol}{BRL} \approx C \frac{h}{d_{50}} \frac{\upsilon}{\rho u} \frac{\rho}{h\gamma} \frac{ut}{h} tg(\beta) Fr$$

, can be simplified

$$\frac{Vol}{t} \approx (BRL) \frac{C}{d_{50}} \frac{h\gamma}{\upsilon} tg(\beta) Fr$$

where :

- *(Vol)* sedimentation accumulation
- *C* is the suspended load concentration
- *Fr.* is *Froude Number* thats equal $Fr = {u}/{\sqrt{gh}}$

Afterwards to be correction inequalities formulations above be come an equations, will be done to obtain suitability coefficients $\boldsymbol{C_{vol.}}$. The value of this suitability coefficient can be generated from the data analysis from result of the simulation to many variety and combination of other parameters of groyne.

By getting the suitability coefficient of sedimentation accumulation $C_{vol.}$, the relationships with parameters that effect mentioned above, becomes a following equation.

$$\frac{Vol}{t} = C_{vol}\left(BRL\right)\frac{C\gamma}{d_{50}}\frac{h}{\upsilon}tg(\beta)Fr \quad \left(m^3/dt\right),$$

if to be considered in the different time, so this equation became the differensial equation as follow,

$$\frac{d(Vol)}{dt} = C_{vol}\left(BRL\right)\frac{C\gamma}{d_{50}}\frac{h}{\upsilon}tg(\beta)Fr \quad \left(m^3/dt\right).$$

This research planned simulation concerned to three variations of the groyne position; Position 1 is groyne position at the beginning of the arc riverbend, Position 2 is the groyne position at ¼ upper of the arc riverbend and Position 3 is the groyne position at the middle of the arc riverbend, More details can be seen in Figure 3 as below.

For all case research planned simulation, there were 360 times simulations, that were combinations of various the groyne position, various the groyne length, various of the flow velocities, various of the radius bend and various of the suspended load concentrations. To explained the research of Model groyne placement on the riverbend based of sedimentation analysis, more detail are shown in Figure 4.

From the data outcome of the 360 times simulation, will be analysis to get approximate predictions the suitability coefficient (C_{vol}) of relationship sedimentation accumulation with parameters be influential, using regression analysis.

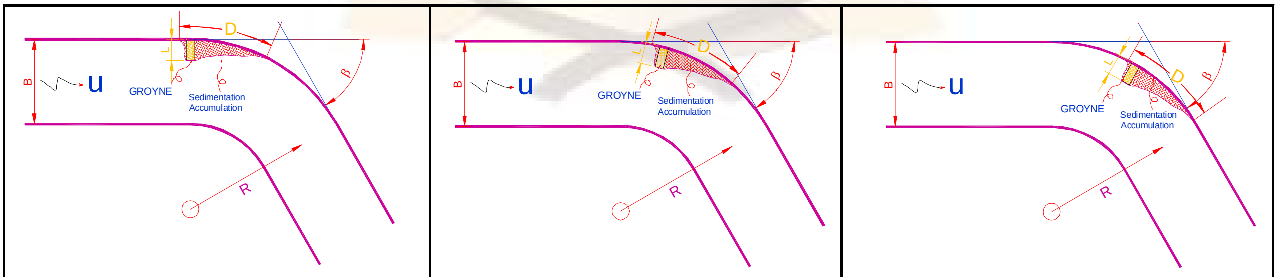
IV. CONCLUSION

This research planed to simulation for the 360 times, that were combinations of various the groyne position, various the groyne length, various of the flow velocities, various of the radius bend and various of the suspended load concentrations. From the data simulation outcome, can be solved by regression analysis to obtain suitability coefficients $C_{vol.}$. That is the suitability coefficient be added to the relationship of sedimentation accumulation with the parameters that's effected on groyne placement models.

Acknowledgements
Thanks to Prof Dr. Ir. Mohammad Bisri, MS, Dr. Ir. Rispingingtati, MEng. and Dr. Ir. Muhammad Ruslin Anwar, MSi. for helping to proofread this manuscript.

Tabel 1 ; A solved non-dimensi analisis by *Stepwise method*.

	Vol	**B**	**R**	**D**	**ρ**	**u**	**h**	**υ**	**g**	**d 50**	**γ**	**t**	**C**	**β**
ρ(M/L^2)	L^3	L	L	L	M/L^2	L/T	L	M/LT	L/T^2	L	M/L3	*T*	*L*	*1*
	Vol	*B*	*R*	*D*	ρ/ρ	*u*	*h*	υ/ρ	*g*	d_{50}	γ/ρ	*t*	*C*	$tg\,\beta$
u (L/T)	L^3	L	L	L	1	L/T	L	L/T	L/T^2	L	L^{-1}	*L*	*L*	*1*
	Vol	*B*	*R*	*D*		*u/u*	*h*	$\upsilon/\rho u$	g/u^2	d_{50}	γ/ρ	*ut*	*C*	$tg\,\beta$
h(L)	L^3	L	L	L		1	L	1	L^{-1}	L	L^{-1}	*1*	*1*	*1*
	Vol/h^3	*B/h*	*R/h*	*D/h*				$\upsilon/\rho u$	gh/u^2	d_{50}/h	$h\,\gamma/\rho$	*ut/h*	*C/h*	$tg\,\beta$



Position 1. : *Groyne at the upstream art of riverbend*	**Position 2**. : *Groyne at the 1/4 upstream art of riverbend*	**Position 3**. : *Groyne at the central art of riverbend*

Figure 3 : Various of groyne position on the riverbend.

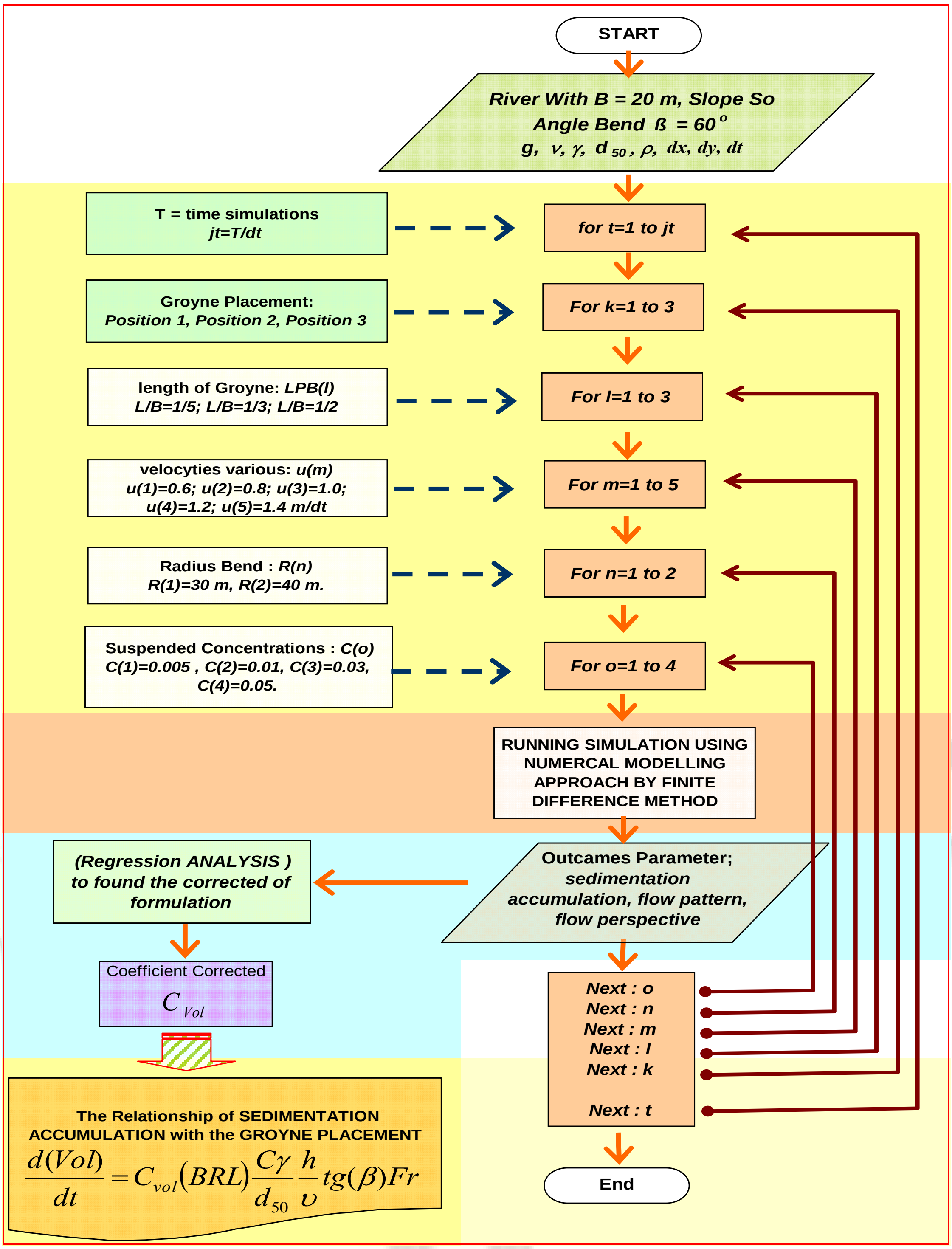


Figure 4 : Researches Method

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