International Conference on Estuaries and Coasts
November 9-11, 2003, Hangzhou, China

NUMERICAL SIMULATION AND ANALYSIS OF THE YELLOW RIVER ESTUARY SEDIMENT MOVEMENT

Dongfeng LI
Department of Hydraulic Engineering
Zhejiang Water Conservancy and Hydropower College, Hangzhou, 310016,China
E-mail:lidongfeng998@163.com

Bing ZOU, Huijun HU & Mei CHEN
Department of Hydraulic Engineering, Zhejiang Water Conservancy and Hydropower College, Hangzhou, 310016,China, E-mail: chenmei6666@163.com

Abstract: The Yellow River is famous for its great amount of sediment transport and high concentration. Because of many limitations, it is very difficult to study tides, tidal currents, sediment movement and bed deformation in the estuary. Based on the observed field data, satellite remote sensing data, a 2-D finite element numerical model and its calculation results, typical tidal current vector charts and sediment concentration distribution diagrams are presented. These diagrams indicate that the tide in the Laizhou Bay is of a semi-diurnal type and sediment diffuses and moves under the action of both tidal current and river runoff. The tongue-shaped sediment concentration isolines show that, on the one hand, they sway with flood and ebb tides, on the other hand, they decrease more quickly longitudinally than transversally. The simulated results also show that in this region the tide and tidal current characteristics vary greatly temporally. Sediment diffusion and deposition are discussed and the results are also in good agreement with the field data and satellite remote-sensing data.

Key words: Numerical simulation, The Yellow River estuary, Sediment movement

1. INTRODUCTION

The laws of the Yellow River estuary tide, tidal flow and sediment diffusion deposition motion is important to many fields of local social economics and construction around delta areas, such as coast harbor construction, the development of Shengli oil field, the second largest one in China, seashore and sea-embankment construction, the stability of river channel and estuary flow path, estuary sand bar planning and harness. Such researches can be seen in these books, such as Cheng Guodong (1991), Zang Qiyun (1996),Cheng Yiji (2001),etc

Up to now, owing to many limits, it is difficult to obtain enough data, such as tidal flow, tidal level, sediment concentration and seabed elevation. so analysis methods data to observed field data and satellite remote sensing are still ones for the related researches, but numerical simulation method can get enough data, so this method can solve these problems. On the basis of the established numerical model (Li Dongfeng,YRCC,2001,) and the results, some laws are given.

2. NUMERICAL SIMULATION BASIC THEORY

2.1 GOVERNING EQUATIONS (LI DONGFENG,1999,2001, ZHANG SHIQI,1990, ZHANG HONGWU,1993)

The equations of continuity:

$$\frac{\partial Z}{\partial t}+\frac{\partial (U_i H)}{\partial X_i}=0$$

The equations of motion:

$$\frac{\partial U}{\partial t}+U_j\frac{\partial U_i}{\partial x_j}+f\sigma_{ij}U_j+g\frac{\partial Z}{\partial x_i}+\frac{gU_i\sqrt{U_jU_j}}{C^2H}=\varepsilon_{ij}\frac{\partial^2 U_i}{\partial x_i\partial x_j}\text{(i, j=1, 2)}$$

in which, U_i is flow velocity; H is water depth; Z is elevation of sea surface level ;C is Checy's coefficient and

$$C=\frac{1}{n}R^{1/6}$$

Continuity equation of sediment: $\frac{\partial S}{\partial t}+U_j\frac{\partial S}{\partial x_j}-\varepsilon_s\frac{\partial^2 S}{\partial x_j\partial x_j}=-\frac{K_1 a_* \omega}{H}\left(f_1 S-S_*\right)$

Bed deformation equation of sediment: $\frac{\partial Z_b}{\partial t}-\frac{K_1\alpha_*}{\gamma_0}\omega_i\left(f_1 S-S_*\right)=0$

Calculation of some coeffcient is given in References(Zhang Hongwu,1993)

2.2 INITIAL CONDITION

At initial time tidal level and velocity is given：

$$\begin{cases} z(x,y,0)=z_0(x,y) \\ u(x,y,0)=u_0(x,y) \\ v(x,y,0)=v_0(x,y) \end{cases}$$

2.3 BOUNDARY CONDITION

At rigid boundary, $u_n= v_n=0$

At the inlet, sediment concentration and discharge are given: s(x,y,t)= s_0(x,y,t), Q(x,y,t)= Q_0 (x,y,t)

At the outlet, tidal level is calculated by the formulation：

$$z(x,y,t)=z(t)=A_o+\sum f'H\cos(qt+G(v0+\mu)-g')$$

3. THE SOLUTION OF THE EQUATIONS AND VERIFICATION OF MODEL

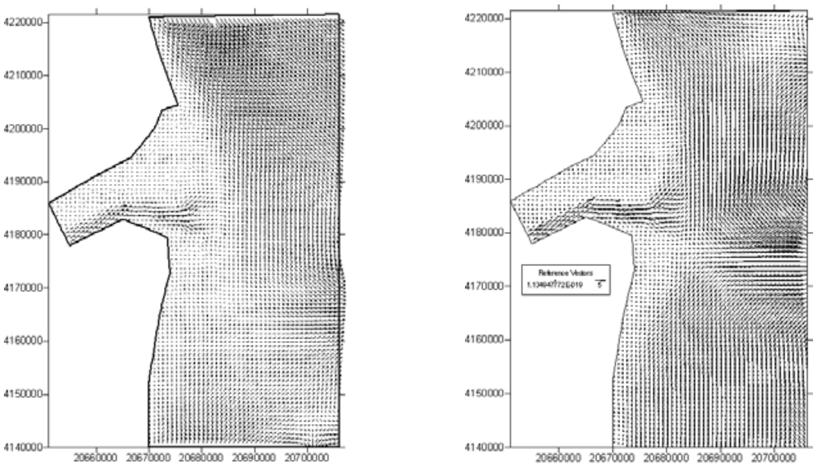
These equations are solved by finite element method. and water and sediment varibles are work out by using the non-couple method, verification of the model is shown in Reference(Li Dongfeng,2001)

4. THE ANALYSIS OF RIVER CHANNEL FLOW AND TIDAL CURRENT

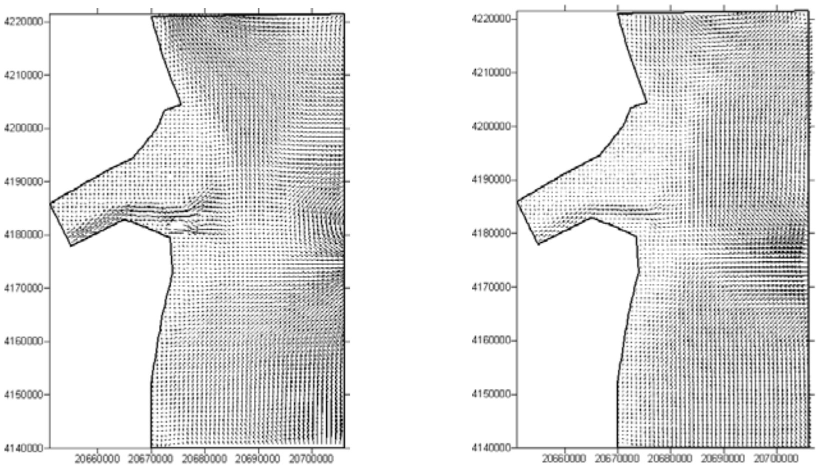
Fig.1 (a) and Fig.1(d) are current flow fields in estuary channel and in LAIZHOU gulf shallow sea when river channel discharge is equal to 1,000m^3/s, Fig. 1(b) and Fig.1(c) are those of 2,000m^3/s.

Because of the LAIZHOU gulf tidal current are in the control of half closed BOHAI coastline and tidal wave of YELLOW sea, the Yellow River delta is project BOHAI sea, after the tidal wave from Yellow sea pass through the BOHAI gorge, owing to the LAZHOU gulf coastline is spread, the tidal wave is separate. One part go to the bottom of LAIZHOU gulf and reflected. The other part go straight forward the Bohai gulf and reflected along the delta north. When the wave reflect to top of the delta, it is separated, one part go ahead, the other swerve and flow into the LAIZHOU gulf at the anticlockwise. It is in this LAIZHOU gulf, where the channel river goes, the special tide phenomenon, such as the tide rising and falling in north and in south at the same time, rising in north and falling in south or at other way round, full-day tide in the north area and half-day in the south area, is formed by the above mentioned all kinds of waves, which is in different direction, time and strength.

These figures show that the offing tidal current is to and fro flow, because of the half closed BOHAI coastline. In the action between runoff and tidal current, the velocity decreases sharply near the gate, so the sediment capacity reduces and sediment falls and deposits. This is also the main factor of estuary forming sand bar. In the north of Laizhou bay, the velocity is great, this area is also that of the zone of no-tides, in this high velocity zone, it is difficult for sediment to fall, and it can be easily transported Duo to the position and time of spring-tide and ebb-tide is different, an anticlockwise vortex flow is formed at the north-east corner of the estuary. This detailed in Fig. 3, the special tidal current can stop channel sediment going this northeast area.These results are good agreement with filed data(Fu Maochong,1985, Li Zegang,1984).



(a) spring-tide in south and north **(b)** ebb-tide in south and north



(c) ebb-tide in north and spring-tide in south **(d)** ebb-tide in north and spring-tide in south

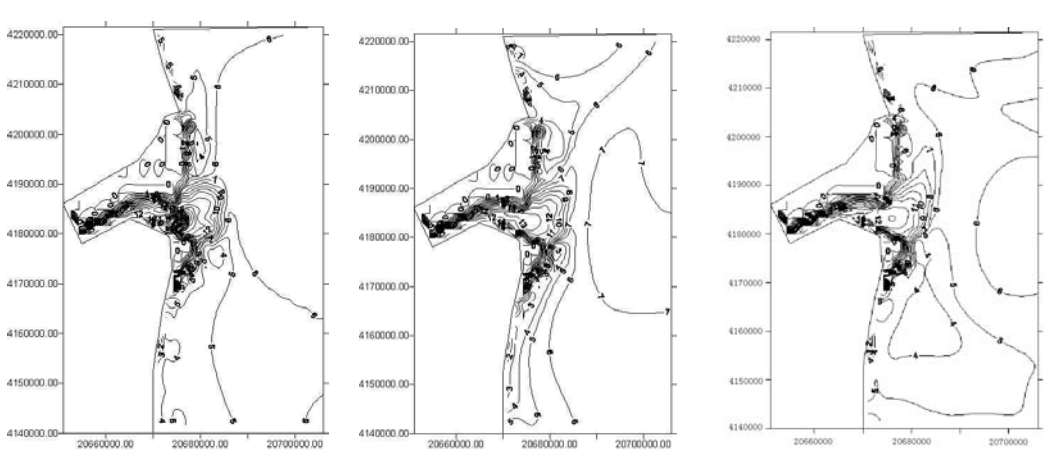
Fig. 1 Typical Tidal Current Field

5. ANALYSIS OF RIVER SEDIMENT DIFFUSION

Sediment concentration isoline at flood-tide and ebb-tide typical time and a whole cycle are shown in Fig. 2-1(a),(b) and (c), Figure2-2(a), (b) and (c). These figures show that sediment isoline distributing is well accord with those satellite remote-sensing interpreted map, the sediment value and attenuation gradient is also in agree with the remote-sensing data declared in References (Xu Dianyuan,1990)

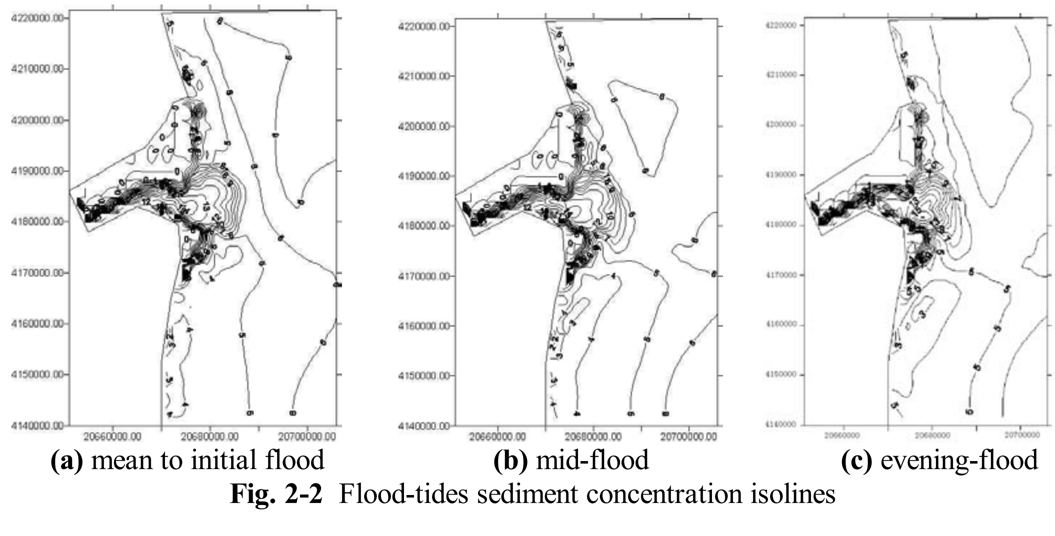
In order to analyse the sediment movement, on the basis of sediment value, a classification named first (high-concentration) second and third grade is given, the classification is respectively the first grade (high-concentration)- that is greater than or equal to $10.0m^3/s$, the second grade-that is greater than or equal to $6.0m^3/s$ and less than $10.0m^3/s$, the third grade-that is less than $6.0m^3/s$.

According to the above classification and Fig. 2, It makes out that sediment transport and diffusion scope and attenuation gradient are controlled by river channel runoff seacoast tide and tidal current, both flood tide and ebb-tide, both first and second sediment concentration muddy area is concentrated in the narrow area near the estuary, the sediment concentration isoline is in tongue-shape and in two sides of estuary, tongue-shape axes are respectively in the direction of south and southeast during flood-tide and north and northeast during ebb-tide, tongue-shape isolines sway with flood and ebb tides and it decrease from river to sea more quickly than that of two sides. The third grade area is in a large area.



(a) mean to initial ebb **(b)** mid-ebb **(c)** evening-tide

Fig. 2-1 Ebb-tides sediment concentration isolines



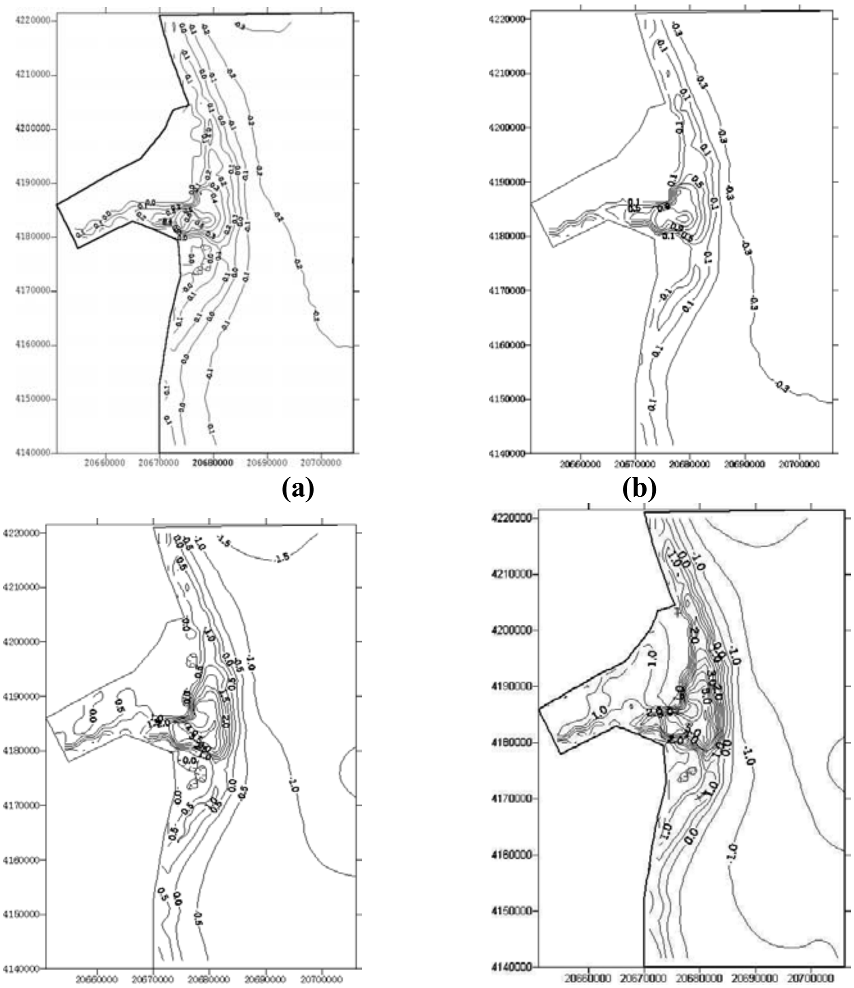
(a) mean to initial flood **(b)** mid-flood **(c)** evening-flood

Fig. 2-2 Flood-tides sediment concentration isolines

6. SEDIMENT DEPOSITION PROCESS

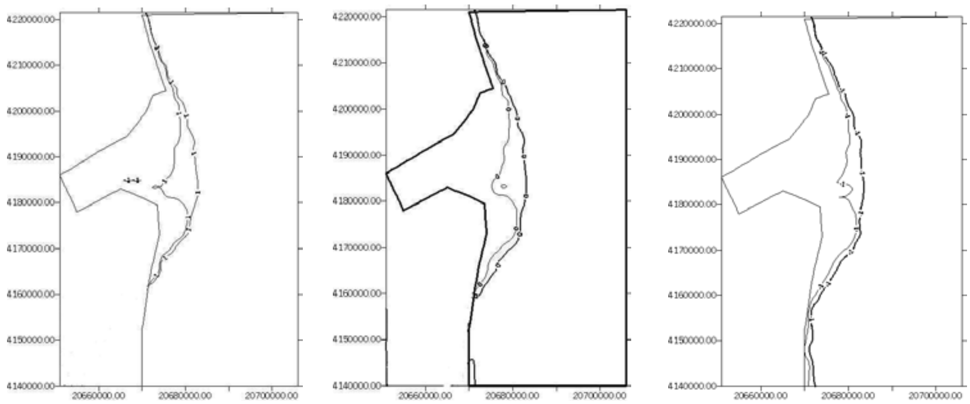
Four typical sediment deposition thickness isoline are shown from Fig. 3(a) –3(d) in the discussed period, sediment deposition and the sea bed elevation isoline (+1m, 0m and -1m) variation is given in Fig. 4(a),4(b),4(c), these illustrated the process of estuary extension forward.

These results reveal the three characteristics of sediment deposition: the one is that the more of the sediment and the thicker sediment deposition, From Fig. 3 (a) to (d),the deposition thickness increase from 0.6m,1.3m and 4.0m to 5.5m.this result is consistent with the data analysis of the References (Xu Dianyuan, Qian Yiying) in page 196 and page 197. the other is that at the initial and mid stages the deposition is mainly nearby the gate of estuary. The estuary extends forward quickly and two sides slowly. Fig. 3(c) and 3(d) indicate the third characteristics that there is erosion zone in this gulf. This is also agreement with the filed data result in Reference (Xu Dianyuan, Qian Yiying)



(a) (b) (d)

Fig. 4 Sediment deposition thickness process



（a）+1m （b）0m （c）-1m

Fig. 5 Sea bed elevation isoline variation process

7. CONCLUDING REMARKS

Based on the numerical simulation model, a plent of data can be given, so the sdiment movement precess can be revealed more clearly than by using little field data, These tidal current and sediment movement features are good agreement with the field data, satellite remote-sensing data and their analysis.

ACKNOWLEDGMENTS

This study was supported by YRCC special Program(98Z02) ,NSFC(59890200) and Zhejiang Water Conservancy and Hydropower College Foundation Program.

REFERENCES

Cheng Guodong (1991), The Yellow River Delta Modern Deposition Action and Model, *geological Press*(in Chinese)

Cheng Yiji,etc, 2001,Reaserch and Harness Practice of the the Yellow River Estuary, *Yellow River Conservancy Press*(in Chinese)

Fu Maochong,1985,Hydrology Characteristic Analysis of Yellow River Estuary, *J. of Shandong Ocean Institute*,vol.15,No.1(in Chinese)

Li Dongfeng,etc,1999,Finite Element Method of Simulating Yellor River and Sediment Movement, *Journal of Sedimentc Research*, No.4(in Chinese)

Li Dongfeng,etc,2001,Numerical Model of the Yellow River Estuary sediment, Report Institute of Yellow River Hydrulic Reaserch. (in Chinese)

Li Zegang, 1984, Tidal Current Analysis of the Yelloe River delta, *J. of Marine Report,*Vol.3 No.5(in Chinese)

Qian Yiying,etc,1994,Water and Sediment Change and Bed Fluvial Process, *China Construction and Material Press*(in Chinese)

Xu Dianyuan 1990,Remote-sensing Research on the Yellow River Estuary, *meteorological press* (in Chinese)

Zang Qiyun ,1996, the Yellow River Coastline Sediment *Ocean Press*(in Chinese)

Zhang Hongwu,1993,Bending Channel River Hydraulics, *Water Resource and hydropower Press*,Beijng(in Chinese)

Zhang Shiqi,1990,the Calculating Research of the Yellow River Estuary Sediment Transort and Bed Deformation, *Journal of Hydrulic Engineering* No.1 (in Chinese)