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The Effect of Tide to Current and Sedimentation Pattern in Amurang Bay, North Sulawesi

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Abstract
Winds, tides and river discharges largely drive coastal currents. The strength of tidal currents, river runoff, meteorological conditions, shoreline configuration, water depth and topography are the factors that affect coastal water circulation. Generally, currents are the flowing of water mass caused by wind, difference of density or tide moving. The existence of currents direction and sedimentation to nearshore of Amurang Bay was studied with using computer model tools as the hydrodynamic model by determine currents speed and its direction and mud transport model.
The study took place in Amurang Bay as the province of North Sulawesi Indonesia with the geography position around 1012'16.16" N-124027'04.33" E to 1015'43.80" N-124032'01.06" E. The bathymetry and tide data used in this research from Indonesian Coastline Environmental map of year 1995 with scale 1:50,000 from BIG (Badan Informasi Geospasial) with a satellite data from Google earth of year 2018 and LANTAMAL Manado, the wind and current data was obtained from BMKG Bitung. Time simulations are taken from 25 November to 23 December 2016 as a wet season and 25 May to 23 June 2016 as a dry season. As analytical tools, MIKE3 hydrodynamic mode are used and Mud Transport model. The currents pattern plays an important role in sediment transport process, so the study of the currents pattern has been important as well.
The result of this study indicates that the tide plays the role of current occurance in Amurang bay. Without considering the effect of wind the result of simulation shows that the pattern of current direction at nearshore is to East, Southeast and Southwest with current velocity average of 0.06 m/s. Current direction at boundary point of bay or near seaward is to southeast, northeast and north with average velocity of 0.16 m/s. The sedimentation pattern showed to south direction with more concentrating to nearshore of Moinit area. The pattern of current and sedimentation followed the pattern of tide movement.

Keywords — *Sea Tide, Low Tide, Sedimentation, Amurang Bay*

I. INTRODUCTION

Tidal current of water flows into or out of bays and harbors caused by the rise or fall in sea level as a tide crest approaches and passes Water rushing into an enclosed area because of the sea level rise as a tide crest approaches is called a flood current. Water rushing out because of the fall in sea level as the tide trough approaches is called an ebb current. Tidal currents reach maximum velocity midway between high tide and low tide. Slack water, a time of no currents, occurs a short time after high and low tides when the current changes direction.

Winds, tides and river discharges largely drive coastal currents. The strength of tidal currents, river runoff, meteorological conditions, shoreline configuration, water depth and topography are the factors that affect coastal water circulation. Generally, currents are the flowing of water mass caused by wind, difference of density or tide moving. As winds and runoff increase, coastal currents intensify (Gross,1990). Sedimentation as the transport mechanics are most influenced by coastal morpho dynamics system. The sediment cycle in the beginning are from the erosion process, which the particle or fragment were shaped from the erosion of rock material. The action of water, wind, plants and animals are major contributor to earth's erosion (Kennish, 2001). The bigger the flow rate, the higher the sediment transport. The mass of sediment transport can be caused by landslide, debris and mud.

II. AREA OF RESEARCH

The area of research is located at the bay of Amurang as part of the province of North Sulawesi with geographical position at 1012'16.16" N-124027'04.33"E to 1015'43.80" N-124032'01.06"E (Fig. 1).

Fig 1: Amurang Bay

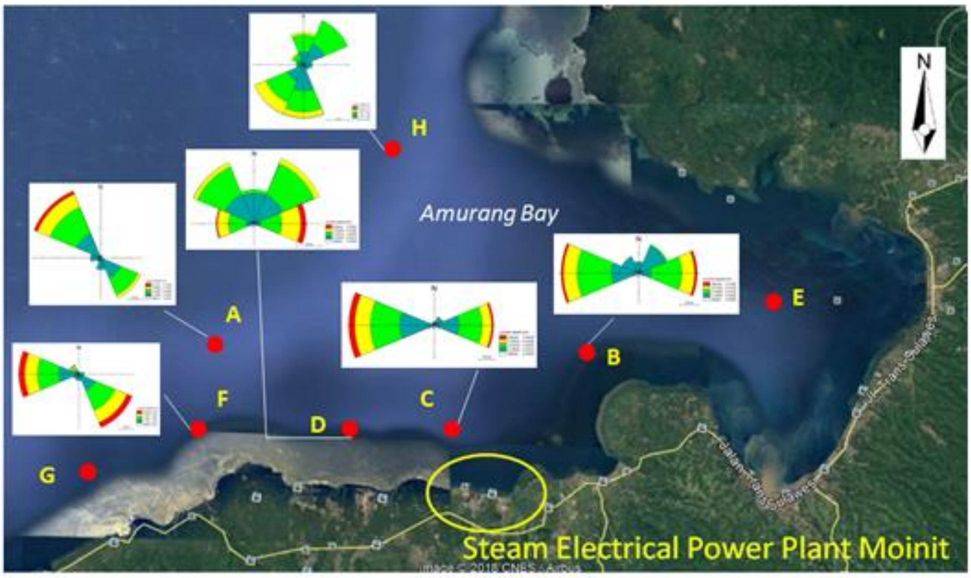


Fig 2: Assistance Dots (A to H) and Current-Rose as Result of Simulation, Scattered in Amurang Bay

III. RESEARCH METHODOLOGY

By using the MIKE3 computer tools, flow model flexible mesh hydrodynamic mode and mud transport mode. Assistance dots for research A to H are scattered in Amurang bay (Fig. 2).

IV. CALCULATION METHOD

Calculation method using finite approximation for hydrodynamic equation which is FEM/FVM. Model is based on solution from three-dimensional equation of incompressible Reynolds and Navier-Stokes, assumptions from Boussinesq and hydrostatic pressure.

Continuity equations:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=S \qquad (1)$$

Both horizontal direction momentum equation for components x and y:

$$\frac{\partial u}{\partial t}+\frac{\partial u^2}{\partial x}+\frac{\partial vu}{\partial y}+\frac{\partial wu}{\partial z}=f_v-g\frac{\partial_\eta}{\partial x}-\frac{1}{\rho}\frac{\partial p_a}{\partial x}-\frac{g}{\rho}\int_z^\eta\frac{\partial \rho}{\partial x}\partial z-\frac{1}{\rho h}\left(\frac{\partial s_{xx}}{\partial x}+\frac{\partial s_{xy}}{\partial y}\right)+F_u+\frac{\partial}{\partial z}\left(v_t\frac{\partial u}{\partial z}\right)+u_s S \quad (2)$$

$$\frac{\partial v}{\partial t}+\frac{\partial v^2}{\partial y}+\frac{\partial uv}{\partial x}+\frac{\partial wv}{\partial z}=-fu-g\frac{\partial \eta}{\partial y}-\frac{1}{\rho}\frac{\partial p_a}{\partial y}-\frac{g}{\rho}\int_z^\eta\frac{\partial \rho}{\partial y}dz-\frac{1}{\rho h}\left(\frac{\partial s_{yx}}{\partial x}+\frac{\partial s_{yy}}{\partial y}\right)+Fv+\frac{\partial}{\partial z}\left(v_t\frac{\partial v}{\partial z}\right)+v_s S \quad (3)$$

Wherein t is time ; x,y,z (m) is Cartesian coordinates ; η (m) is surface elevation; d (m) is still water depth; h=η+d is total water depth ; u,v,w is velocity components (m/dt) in direction of x,y dan z ; f=2ΩSinϕ is Coriolis paramter; Ω (^{0}) is rate revolution angle and (ϕ) is geographic latitude; g (m/dt^2) is gravitation velocity ; ρ (kg/m^3) water density; S_{xx},S_{yx},S_{xy},S_{yy} (kg/dt^2) are radiation stress current components; v_t (m^2/dt) is turbulent (eddy) vertical viscosity; p_a (Pa) is atmospheric pressure; S is debit amount relative to source point and u_s, v_s is velocity; F_u and F_v are horizontal stress term. For the purpose of attaining simulation result dots are scattered in Amurang bay area from point A to point H.

The geographical position of each dots are:

A 1.240 N - 124.450 E;
B 1.240 N - 124.530 E;
C 1.225 N - 124.490 E;
D 1.205 N - 124.475 E;
E 1.240 N - 124.600 E;
F 1.220 N - 124.450 E;
G 1.210 N - 124.420 E;
H 1.300 N - 124.500 E.

Horizontal stress term is described using gradient-stress relation which is simplified into:

$$Fu=\frac{\partial}{\partial x}\left(2h_t\frac{\partial u}{\partial x}\right)+\frac{\partial}{\partial y}\left(h_t\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)\right) \quad (4)$$

$$Fv=\frac{\partial}{\partial x}\left(h_t\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)\right)+\frac{\partial}{\partial y}\left(2h_t\frac{\partial v}{\partial y}\right) \quad (5)$$

Where ht (m^2/s) is horizontal eddy viscosity.

Transport equation for mud is :

$$\frac{\partial c}{\partial t}+\frac{\partial uc}{\partial x}+\frac{\partial vc}{\partial y}+\frac{\partial wc}{\partial z}-\frac{\partial w_s c}{\partial z}=\frac{\partial}{\partial x}\left(\frac{\upsilon_{Tx}}{\sigma_{Tx}}\frac{\partial c}{\partial x}\right)+\frac{\partial}{\partial y}\left(\frac{\upsilon_{Ty}}{\sigma_{Ty}}\frac{\partial c}{\partial y}\right)+\frac{\partial}{\partial z}\left(\frac{\upsilon_{Tz}}{\sigma_{Tz}}\frac{\partial c}{\partial z}\right)+S \quad (6)$$

Wherein *t* (s) is time, *x*,*y* and *z* (m) are Cartesian coordinates, *u*,*v* and *w* (m/s) are flow velocity components, *c* (kg/m^3) is mass concentration, w_s (m/s) is velocity settling, σ_{Tx} is Schmidt number for turbulent, v_{Tx} (m^2/s) is anisotropic eddy viscosity, *S* is source term.

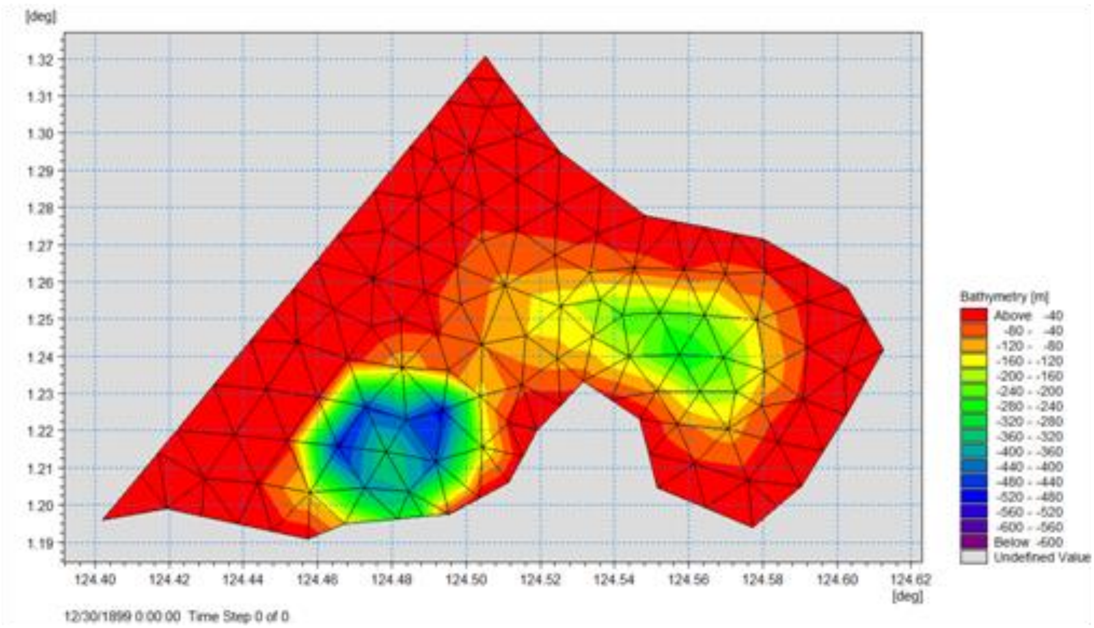


Fig 3: Model Area, Unstructured Mesh and Bathymetry

V. RESULTS AND DISCUSSIONS

The comparison of water level between the data and the result of simulation on research points C and D can be seen in Fig. 4. The unconformability between data's graphic and simulation result for the current-rose occurs because field data not only covers the effect of the high and low tide but should also calculate other parameters such as wind etc. or the natural conditions that occurs, the simulation only calculates the effect of high and low tides.

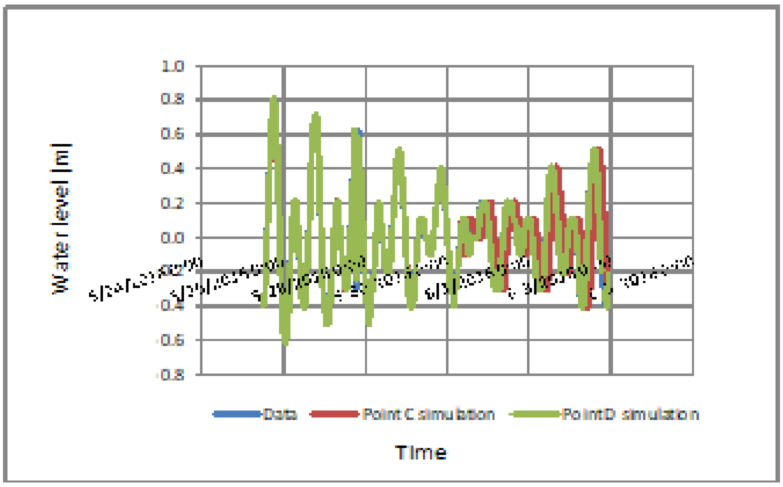
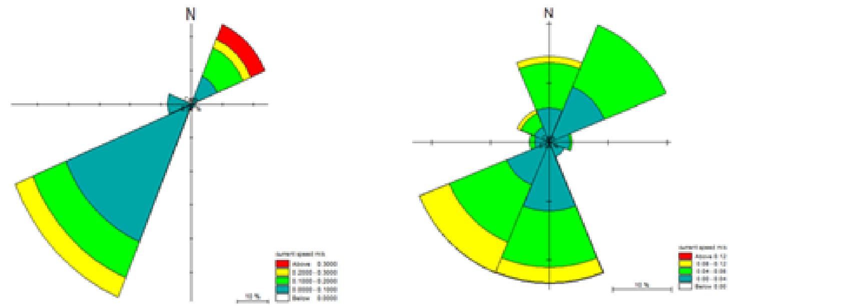


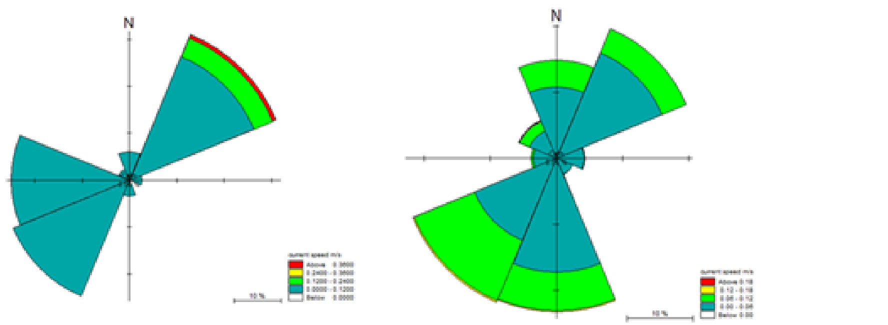
Fig 4: Comparison of Water Level Between Point C and Point D with Data

The scale of current and its direction is configured incurrent rose form. The current rose comparison between the data and simulation results is pointed out in Fig. 5 and Fig. 6 each in the rain season and dry season.



Current rose data 25 nov-14des 2016   Current rose simulasi 25 nov-14des 2016

Fig 5: Current Rose Data and Simulation on November 25 - December 14, 2016



Current rose data 25 mei-26jun 2016   Current rose simulasi 25 mei-26jun 2016

Fig 6: Current Rose Data and Simulation on May 22 – June 26, 2016

Fig. 5 and Fig. 6 explain the current direction towards Northwest and Northeast still present for the data and simulation result. For the research points near coastal area of points F, C, B and D current direction caused by tide is dominantly towards East, Southeast and Southwest accompanied by low reverse current with average velocity of 0,06m/dt. The bay's outer points or near offshore of points A and H are dominant towards Southeast and Northeast and also towards North with average velocity of 0.16m/dt (Fig.7 and Fig.8)

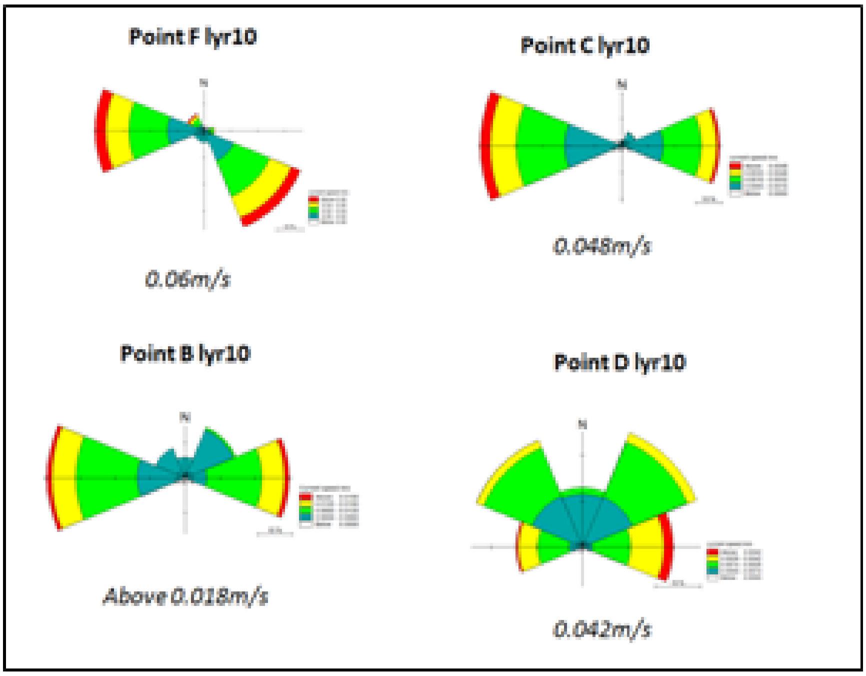


Fig 7: Current Rose of Low Tide at Point F, Point C, Point B and Point D

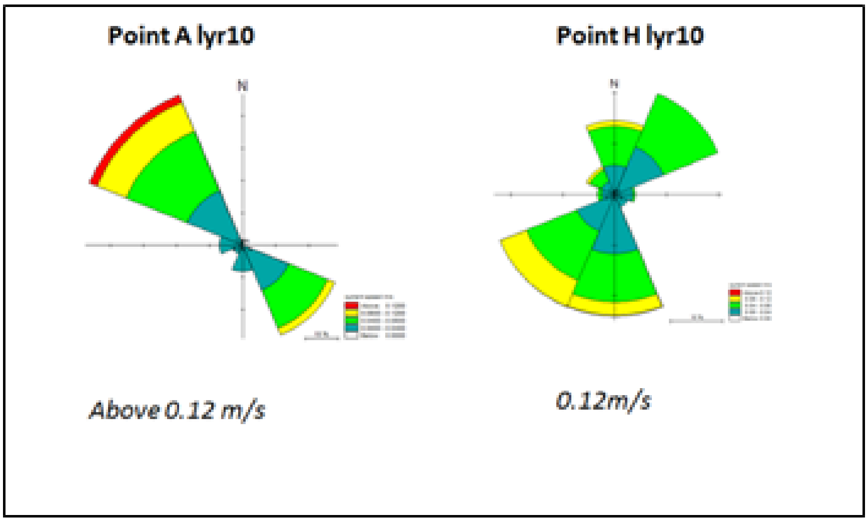


Fig 8: Current Rose of Low Tide at Point A and Point H

The sedimentation pattern is measured by using the MIKE tools which is Mud Transport Mode. This measurement is started by inserting values at initial condition for SSC (Suspended Sediment Concentration) simulation. The value of 0.01 kg/m^3 and 0.001 kg/m^3 are set as initial condition for the scattered dots A to H at Amurang bay. The initial condition of SSC on dry season in May-June and wet season in November-December is as the effect of low tide.

Fig. 9 and Fig. 10 exposed that setting initial condition for SSC with value of 0.01 kg/m^3 and 0.001 kg/m^3 has presented a trend of dropping SSC as increasing of simulation time at point A to point H caused by low tide on wet season.

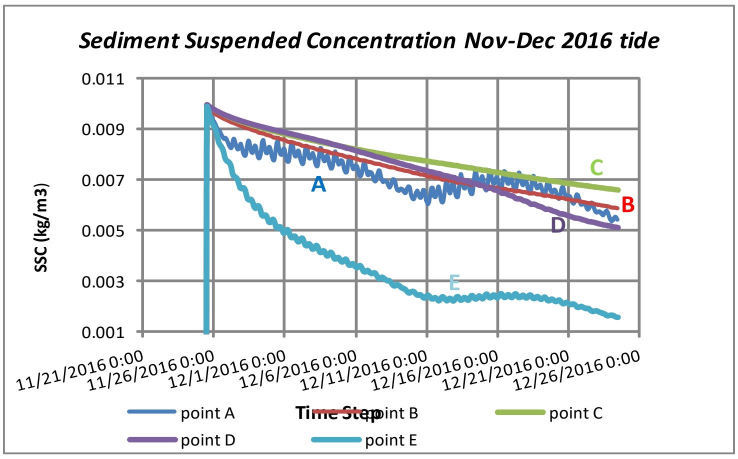


Fig 9: Sedimentation Pattern with 0.01 kg/m^3 as Initial Condition of SSC caused by Low Tide at Point A – Point H, in November-December 2016

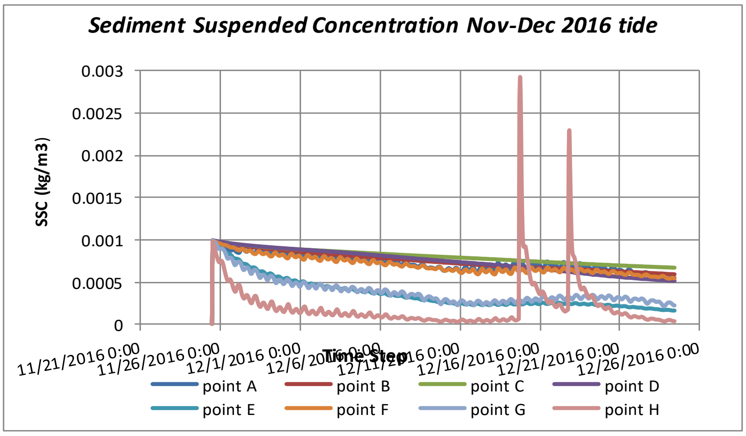


Fig 10: Sedimentation Pattern with 0.001 kg/m^3 as Initial Condition of SSC caused by Low Tide at Point A – Point H, in November-December 2016

Fig. 11 and Fig. 12 exposed that setting initial condition for SSC with value of 0.01 kg/m^3 and 0.001 kg/m^3 has presented a trend of increasing SSC for certain simulation time, and a trend of dropping SSC on the next simulation time, at point A to point H caused by low tide on dry season.

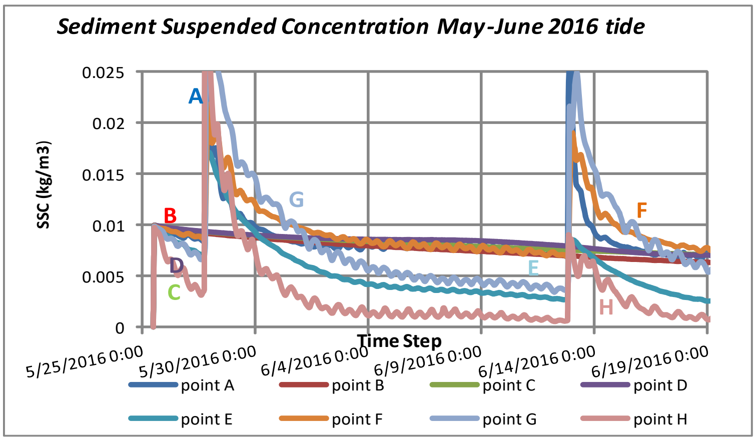


Fig 11: Sedimentation Pattern with 0.01 kg/m^3 as Initial Condition of SSC caused by Low Tide at Point A – Point H, in May-June 2016

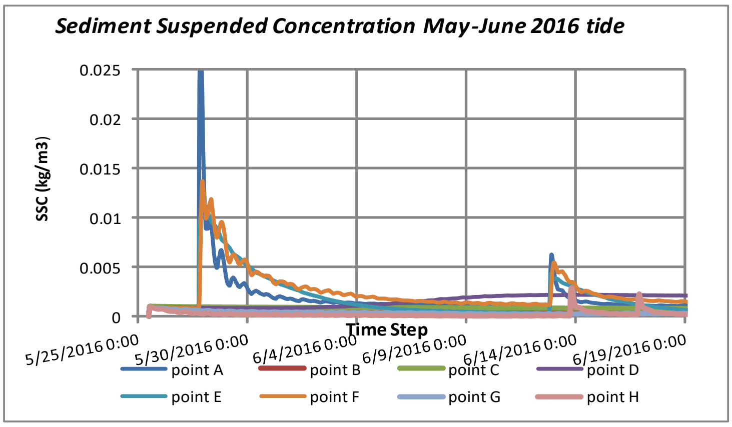


Fig 12: Sedimentation Pattern with 0.001 kg/m³ as Initial Condition of SSC caused by Low Tide at Point A – Point H, in May-June 2016

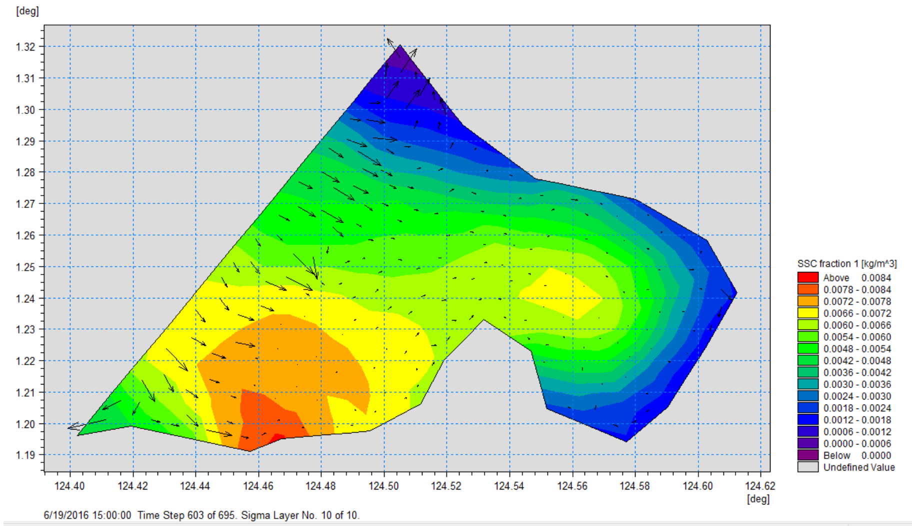


Fig 13: Sedimentation Pattern with 0.01 kg/m³ as Initial Condition of SSC caused by Low Tide in May-June 2016, at Time Step 603

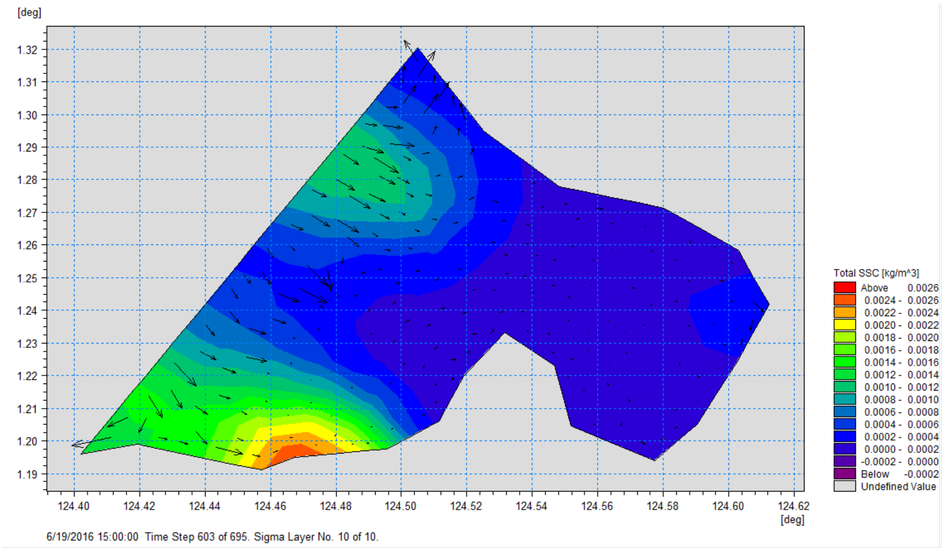


Fig 14: Sedimentation Pattern with 0.0001 kg/m³ as Initial Condition of SSC caused by Low Tide in May-June 2016, at Time Step 603

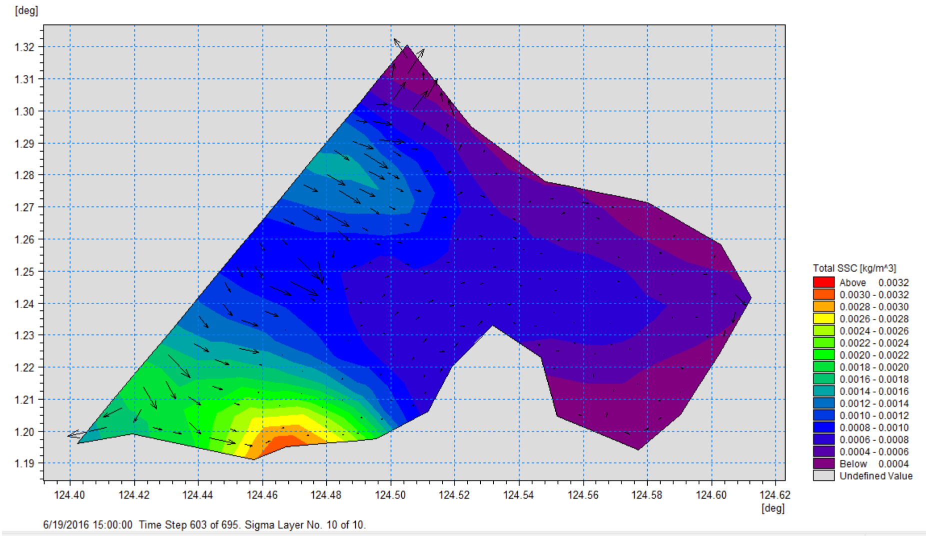


Fig 15: Sedimentation Pattern with 0.001 kg/m^3 as Initial Condition of SSC caused by Low Tide in May-June 2016, at Time Step 603

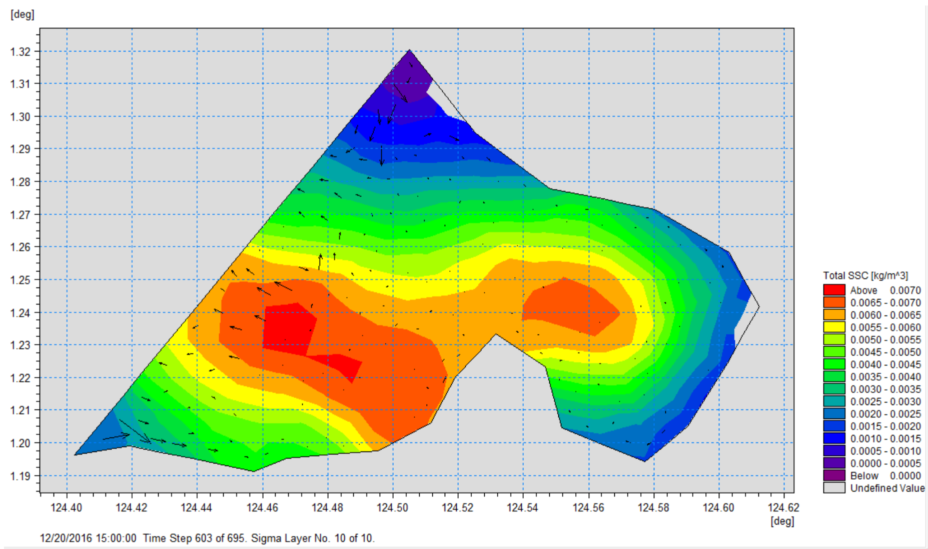


Fig 16: Sedimentation Pattern with 0.01 kg/m^3 as Initial Condition of SSC caused by Low Tide in November-December 2016, at Time Step 603

Fig. 13, Fig. 14 and Fig. 15 exposed the pattern and direction of sedimentation during dry season in May-June with given value of 0.01 kg/m^3, 0.001 kg/m^3 and 0.0001 kg/m^3 as initial condition of SSC. The simulation presents result that a lower value of initial condition produces smaller sedimentation. The direction of sedimentation follows the pattern of low tide. Fig. 16 exposed that the sedimentation pattern during wet season in November-December has a direction towards the Moinit coast.

VI. CONCLUSION

This research is conducted to study current pattern and sedimentation pattern as a result of tidal wave in the location of Amurang bay. Simulation results shows with valuation of initial condition for smaller sediment concentration produces smaller sedimentation, coastal current pattern is dominant towards east, southeast and southwest of Amurang bay with average speed of 0.16 m/det, sedimentation direction is more concentrated towards Southeast or Moinit coast, sedimentation pattern follows high and low tidal current pattern.

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