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Research Paper/Technical Note/Review Article

A 2d numerical model of salinity distribution pattern on the estuary of Jeneberang River

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ABSTRACT

Hydrodynamic factors and aquatic environment at the mouth of the Jeneberang River are a major concern for the management of coastal areas and estuaries because can affect estuary utilization activities. This study uses a two-dimensional numerical model to reveal the dynamic and physical characteristics of the waters during the dry season at the mouth of the Jeneberang River. Measurements of tides, flow velocity, temperature and salinity were carried out prior to using numerical modeling to describe the tidal-driven flow circulation. The simulation model shows that the salinity distribution pattern follows the flow pattern so that it affects the distribution of the salinity distribution. The modeling results show a decrease in salinity downstream of the Janebarang River estuary. The upstream part has a relatively high salinity compared to the downstream part, between 36.4 PSU - 36.8 PSU. The downstream part of the water has a salinity level ranging from 34.5 PSU - 35 PSU showing a fairly dynamic salinity pattern. Based on the spatial distribution, this area is a mixed area with the farthest distance is between 850 meters to 1050 meters from the mouth of the estuary of the model domain area.

1. Introduction

There are several hydrodynamic factors that need to be considered in the management of coastal areas, namely wind, currents, tides, river estuaries, erosion, abrasion, and sedimentation. [1,2,3]. The use of the coastal area at the mouth of the Jeneberang River has long been used by the surrounding community for transportation, fisheries and so on. River estuaries are transitional areas between land and open seas, so that there is an interaction between the two [3]. The Jeneberang River which empties into the coast of Makassar City has an important role in providing raw water, shipping and controlling floods in Makassar City and Kab. Gowa. The water conditions in the estuary are very dynamic due to influences such as strong river currents and tides, which impact on flow circulation patterns, salinity, the level of mixing of salt water and fresh water and sedimentation [4,5,6]. Tidal propagation into the estuary is accompanied by changes in temperature and salt water intrusion, it is important to know the dynamics in the estuary. Water dynamics and salinity distribution due to tidal influence and river geometric factors can be seen with numerical modeling approaches [7,8,9]. Models can provide a simple description of the real system to help solve a problem (Thomann, 1987; Jorgensen, 1994 *in* Zaman and Syafrudin, 2007) [10]. Rizal, *et al.* 2009 says the modeling is designed on a desired boundary condition to approach the actual state. Several models have been

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applied to both open and closed boundary conditions [11]. The equations describing flow in rivers, estuaries and water bodies are based on the concepts of mass and momentum conservation. The 2D horizontal (flow equation is*depth averaged*)derived by integrating the three-dimensional equation of mass and momentum transport with respect to the vertical coordinates from the bottom to the water surface, assuming that the vertical velocity and acceleration are negligible and the salinity concentration is the same for each depth [11]. 2D *flexible mesh* numerical model is a numerical model solution based on *flexible mesh* with ease of resolution in configuring*coastlines*and bathymetry [11, 12,13,14]. Understanding the importance of managing the estuary area requires sustainable management. One of the environmental aspects that is important to know so that the management of the estuary area can be implemented properly is to understand the dynamics of the waters. Tide, bathymetry, flow velocity and salinity surveys were carried out at the mouth of the Jeneberang River. This study aims to model the current circulation patterns and salinity in the estuary of the Jeneberang River that are generated by tides. It is hoped that the benefits from the research results can be used as input in environmental management around the Jeneberang River estuary area.

2. Research Methodology

3.1 *Research Location and Time The research*

Location was at the mouth of the Jeneberang River, Makassar. Geographically, the location of the model is at the coordinates of UTM 50S UTM 763000m E 767000m E and 9426000m S-9426000m S. Data retrieval and recording were carried out from October 1, 2019 - November 11, 2019.

Fig 1. Model Domain Location

3.2 *Research Flow*

The methodology in this study consists of data collection, model design, model simulation, model validation of measurement data, and tidal dynamics analysis of the model simulation results. The illustration of the methodology flow chart in this study can be seen in Fig. 2

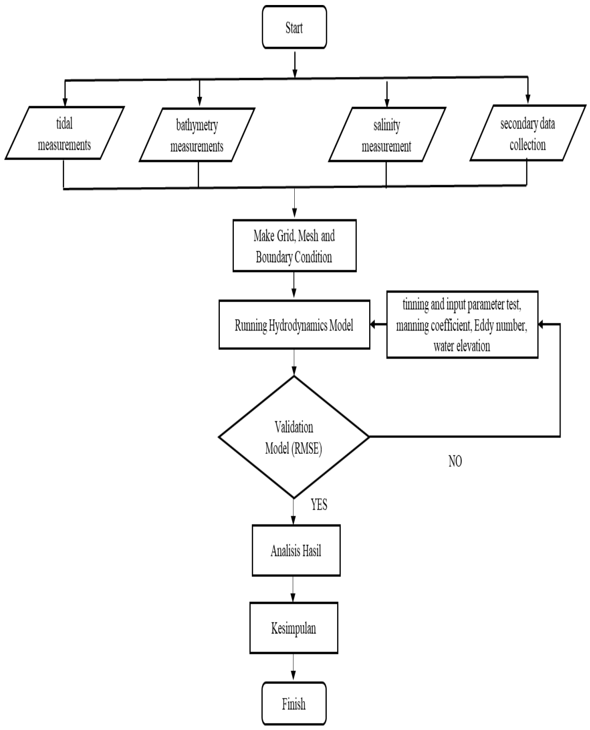

Fig 2. Flowchart of research methodology

2.3 *Hydrodynamic model*

The movement of water mass in waters can be approximated by using the law of conservation of mass (continuity) and conservation of momentum. 2D *flexible mesh* numerical model is a numerical solution to a model based on *flexible mesh* with easy resolution in configuring *coastline* and bathymetry. The solution to the numerical calculations in this module can be applied to the estuary environment.two-dimensional numerical solution *Reynolds' incompressible* to the mean of the *Navier - Stokes equation* which consists of the basic equations of mass conservation and conservation of momentum, salinity, in 2D solutions using sigma coordinate transformations. In this study, a 2-dimensional hydrodynamic numerical model is used to simulate the current circulation patterns and salinity. The horizontal integration of the momentum equation and the equation with respect to $h = \eta + d$ depth in two dimensions gives the continuityequation for continuity:

$$\frac{\partial h}{\partial t} + \frac{\partial h\bar{u}}{\partial x} + \frac{\partial h\bar{v}}{\partial y} = hS \quad (1)$$

The equation for motion in the x and y directions:

$$\frac{\partial h\bar{u}}{\partial t} + u\frac{\partial \bar{u}}{\partial x} + v\frac{\partial \bar{u}}{\partial y} = F_{\vec{v}h} - gh\frac{\partial \eta}{\partial x} - \frac{h}{\rho_0}\frac{\partial \rho}{\partial x} - \frac{gh^2}{2\rho_0}\frac{\partial \rho}{\partial x} + \frac{\tau_{sx}}{\rho_0} - \frac{\tau_{bx}}{\rho_0} + \frac{1}{\rho_0}\left(\frac{\partial s_{xx}}{\partial x} + \frac{\partial s_{xy}}{\partial y}\right) + \frac{\partial}{\partial x}(hT_{xx}) + \frac{\partial}{\partial y}(hT_{xy})\ hu_s s \quad (2)$$

$$\frac{\partial h\bar{v}}{\partial t} + u\frac{\partial \bar{v}}{\partial x} + v\frac{\partial \bar{v}}{\partial y} = -F_{\vec{u}h} - gh\frac{\partial \eta}{\partial y} - \frac{h}{\rho_0}\frac{\partial \rho}{\partial y} - \frac{gh^2}{2\rho_0}\frac{\partial \rho}{\partial y} + \frac{\tau_{sy}}{\rho_0} - \frac{\tau_{by}}{\rho_0} + \frac{1}{\rho_0}\left(\frac{\partial s_{yx}}{\partial x} + \frac{\partial s_{yy}}{\partial y}\right) + \frac{\partial}{\partial x}(hT_{xy}) + \frac{\partial}{\partial y}(hT_{yy})\ hv_s s \quad (3)$$

Where the solution indicates the value of the mean depth, which is the velocity at the mean depth given by:

$$h\vec{u} = \int_{-d}^{\eta} udz, \qquad h\vec{v} = \int_{-d}^{\eta} vdz \quad (4)$$

Where :

t	= time (sec)
x, y, z	= direction in Cartesian coordinates
η	= water level elevation (m)
d	= water depth (m)
$h = \eta + d$	= total depth (m)
ρ	= density of water (kg.m-3)
ρ_0	= density at initial conditions (kg.m-3)
u, v	= velocity component in thedirection *x*, y
$f = 2\Omega sin\phi$	= coriolis parameter
g	= Acceleration due to gravity (m / s2)
$\vec{u}, \vec{v}$	= component of current velocity averaged against depth in thedirection *x*, *y* (m.det-1)
τ_{bx}, τ_{by}	= *Stress* base for direction-*x* direction-*y*(m2sec-2)
T_{xx}, T_{xy}, T_{yy}	= *shear stress*(m2sec-2)

Equations (2) and (3) contain the local velocity change term, the convective term, the coriolis affected term, the pressure gradient, the *stress* basic, and the turbulence term. The coriolis term is not used because the study area is relatively small and is located around the equator.

2.4 *Model Design.*

2.4.1 *Boundary ConditionBuilder of Numerical Model*

This modeling uses three types of boundary conditions, and is implemented in the domain model [15,16]. The boundary conditions used are:

1. Sea Level Boundary Requirements, numerical modeling 2D *flexible mesh* has certain boundary conditions at sea level (z = η)
2. Sea Level Boundary Requirements, 2D numerical modeling has certain boundary conditions on the seabed (z = -*d*).
3. Closed boundary conditions, closed boundaries are boundary conditions used at the meeting between sea and land. At this limit it is assumed that no current is perpendicular to the closed limit. (DHI, 2010; Sprintall *et al.*, 2014; Gao *et al.*, 2015) [15,16]

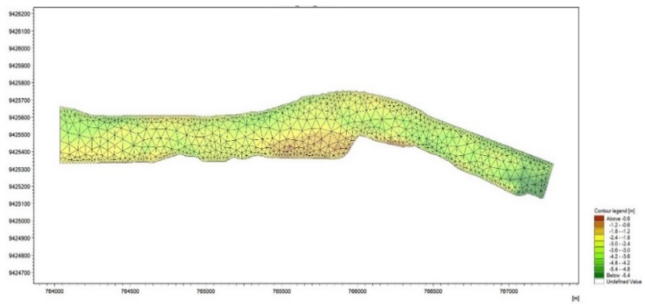

Fig 3. Numerical modeling domain of the Jenebarang River estuary with flexible mesh elements: 10000 m2

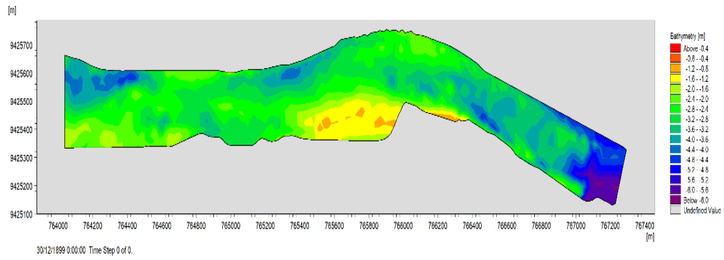

Fig 4. Bathymetry resulting from triangular flexible mesh interpolation, domain model of the Jenebarang River estuary with a depth range of 0 to - 6.0 meters.

2.4.2 *Numeric Model Builder Input Variables (Input Data)*

In the modeling analysis, there are some data used as input. These data are:

a. Coastline
Data This data is obtained from Landsat 8.0 satellite imagery data for the Makassar waters, focused on the waters of the Janeberang River estuary. The coastline determines the closed boundary conditions model, which represents the meeting between sea and land or can be used as a dry*area*.
b. Bathymetry
Data This data is data obtained from bathymetry generalization data, which was carried out during the implementation of field investigations, the data used is also bathimetric data that has been corrected for elevation changes.
c. Tide Elevation Data The tide
elevation data used is obtained from the tide logs using a *tide logger.* The tidal data will be used as the boundary of open conditions from

2Dmodeling, which *flexible mesh* is the extraction of the harmonic components from the implementation of measurements carried out in the field.

d. Salinity
Data The salinity data is obtained from the results of measurements using the CTD instrument, these results are the existing conditions. Next is a spatial representation of the existing distribution conditions, numerical modeling studies approach the *initial condition* 0.

2.5 *Numerical Modeling Validation Analysis*

Model validation is done by comparing the value of the modeling results with the value of the measurement investigation in the field. This is necessary to decide the model results have relative errors so that they can be used for further needs. The level of error (*error probability*) is carried out using the equation 5 approach.

$$\text{Error} = \frac{1}{N}\sqrt{\left[\sum_{i=1}^{N}\left|\frac{x_s - x_d}{x_d}\right|\right]}\ \text{x}\ 100\% \qquad (5)$$

with, x_s the value of the simulation result; x_d measured value; N is the amount of data.

3. Results and Discussion

3.1 *Model Validation*

Results of the 2Dnumerical modeling validation analysis *flexible mesh* can be seen in Figure 5 - Figureanalysis *8.Results of RMSE root mean square error*, the model error value for tidal recording measurements at station 1 is 2.26% and station 2 is equal to 5.47%. The magnitude of the error value for the current measurement value with the modeling results is *u-velocity* of 9.7% and *v-velocity* of 4.8%. The current distribution pattern of the two results between modeling and measurement in the form of apattern *sinusoidal* in Figure 8 shows that the current movement results from measurement and modeling are East - West, the measurement results also show that the component of current velocity that moves during measurement is dominated by the East - West component (*u velocity*) can be seen in Fig 7.

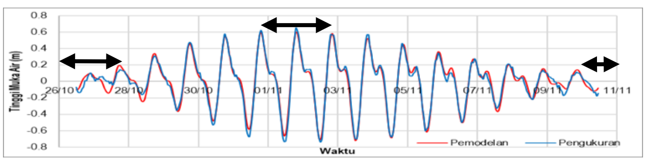

Fig 5. Graphic analysis of water level validation modeling and recording at the location of station 1, the mouth of the Jeneberang River

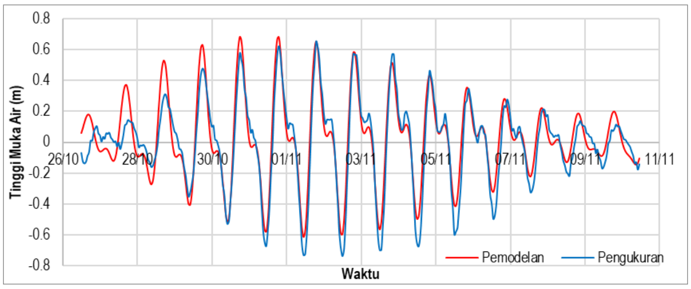

Fig 6. Graph of the analysis of the water level validation modeling and recording at the location of station 2, the mouth of the Jeneberang River

3.2 *Simulation Results of Tidal Flow Patterns*

After verification of the model is carried out, flow simulations are carried out. The current simulation result is a value that is averaged over the depth (2D). Based on this simulation, information is obtained about the current circulation pattern based on the tidal conditions that occur.

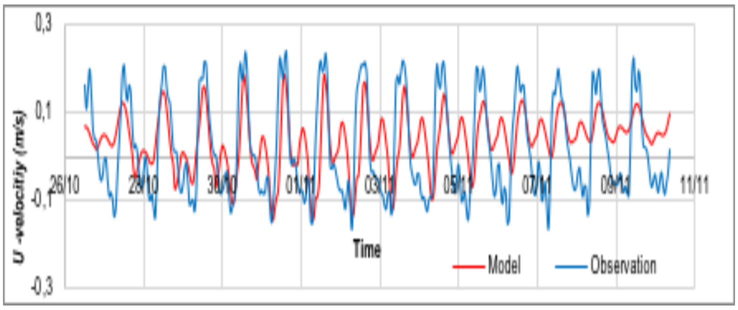

Fig 7. Graph analysis of the validation component of velocity (u-velocity) modeling and recording at the mouth of the Jeneberang River.

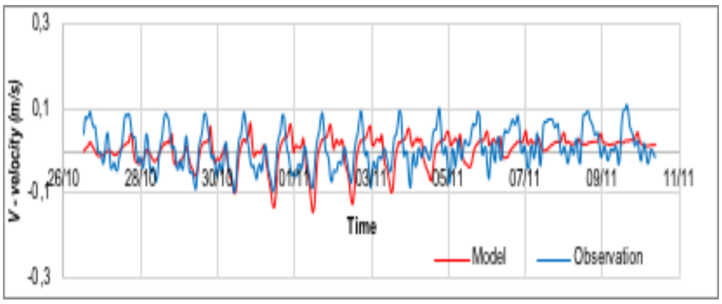

Fig 8. Graph validation analysis of velocity components (v-velocity) modeling and recording at the mouth of the Jeneberang River

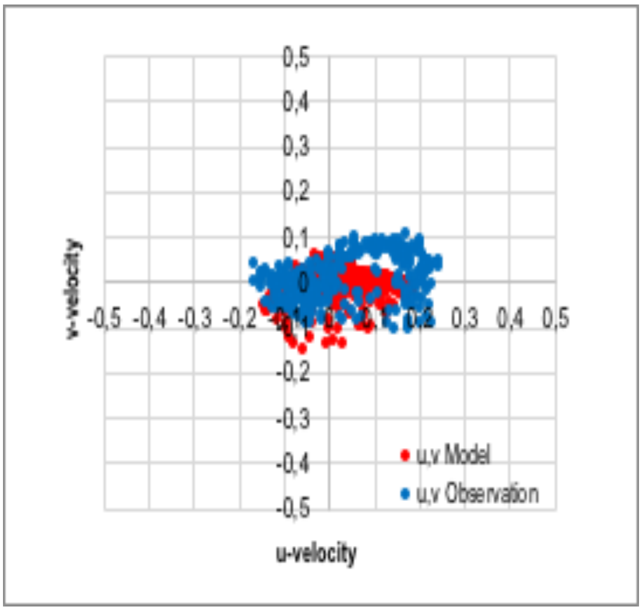

Fig 9. Verify the flow of model results with field measurements

Modeling results show that when the *spring tide is* at low tide, the current velocity is 0.16m / s - 0.2 m / s and at low tide the current velocity is 0.21 m / s - 0.25 m / s. When the *neap tide is* at low tide, the current velocity is 0.06m / s - 0.2 m / s and at low tide the current velocity is 0.16m / s - 0.2 m / s.

3.3 *Current Circulation Patterns and Salinity*

2D numerical modeling simulation is *flexible mesh* carried out with the salinity parameter as one of the water masses with two time conditions, the condition when (*t = 0*) thesalinity value *fresh water* (~ 0 PSU), and the condition (*t = 1*) the condition during the simulation after it occurs. mixing along the estuary canal of the Janebarang River, resulting in spatial stratification along the river canal. The condition t = 1 is the time condition where the water has entered upstream of the canal from the mouth of the Janebarang River, in other words, the mouth of the Janebarang River completely has the same salinity value as the open water conditions in the Makassar Sea waters. The simulation is continued from t = 1 to t = n, so that it fulfills the existing conditions.

The low tide elevation towards the tide during *spring tide* and *neap tide* gives the same pattern even at the neap tide with a lower magnitude. Salinity moves in from upstream to downstream due to current transport in the range of 36.75 PSU - 37 PSU, can be seen in Figure 11 and Figure 13 elevation towards *spring tide .At tideneap tide*, the current moves toward the ebb, causing a number of current vectors to show movement to downstream. This results in a number of salinity moving out of the canal body of the river estuary with values ranging from 35 PSU - 36 PSU being downstream from the Janebarang River as in Figure 10 and Figure 12. This occurs due to the transport force that encourages the mass of water to spread across the river. downstream from the Janeberang River canal.

3.3 *Comparison of Salinity Measurement Results and 2D Numerical Modeling Results along the Janebarang River Estuary Survey Investigation Station*

The comparison between the results of the salinity investigation survey at the mouth of the Janebarang River with the simulation results of 2Dnumerical modeling is *flexible mesh* shown in Figure 135. The comparisons were carried out for as many days as the investigative survey was carried out, namely for 15 days. The overall results show *trendline* a linearbetween measurement and modeling. These results indicate a decrease in salinity to the lower reaches of the Janebarang River estuary. The upstream part has a relatively high salinity compared to the downstream part, ranging from 36.4 PSU to 36.8 PSU. The lower reaches of the waters have salinity levels ranging from 34.5 PSU to 35 PSU. *Trendlines* at stations 4, 5, and 6 show a fairlysalinity pattern dynamicwith the previous salinity values. This indicates that the spatial distribution of this station is aarea mixed. Stations 4, 5 and 6 are stations quite close to the downstream with the farthest distance is between 850 meters to 1050 meters from the downstream end of the model domain area. The events that occur on the Janebarang River, with relatively low salinity in the downstream part, are likely to occur due to the accumulation of salinity in the middle to the upstream part of the canal since the weir was built.

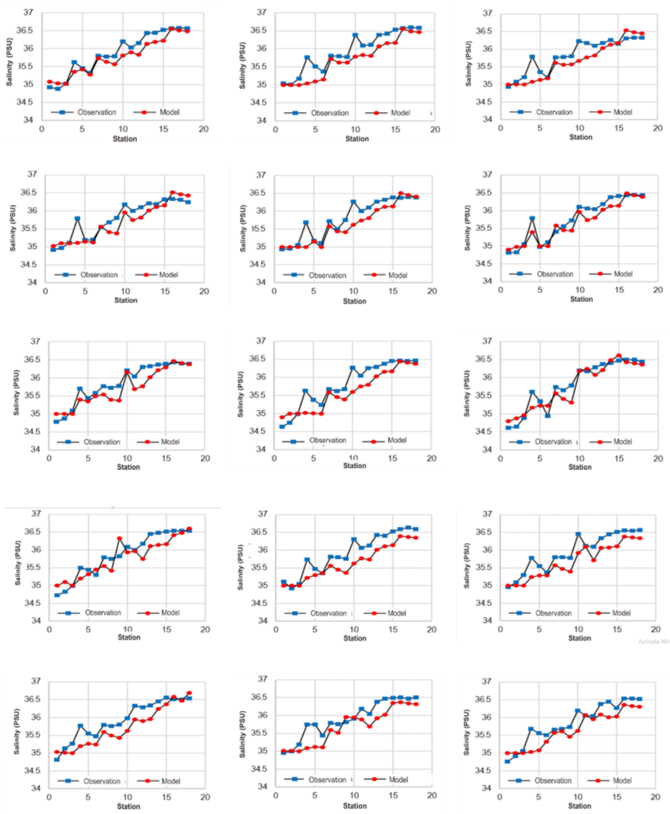

Fig 14. Salinity trendline measurement and modelling during the survey (15 days).

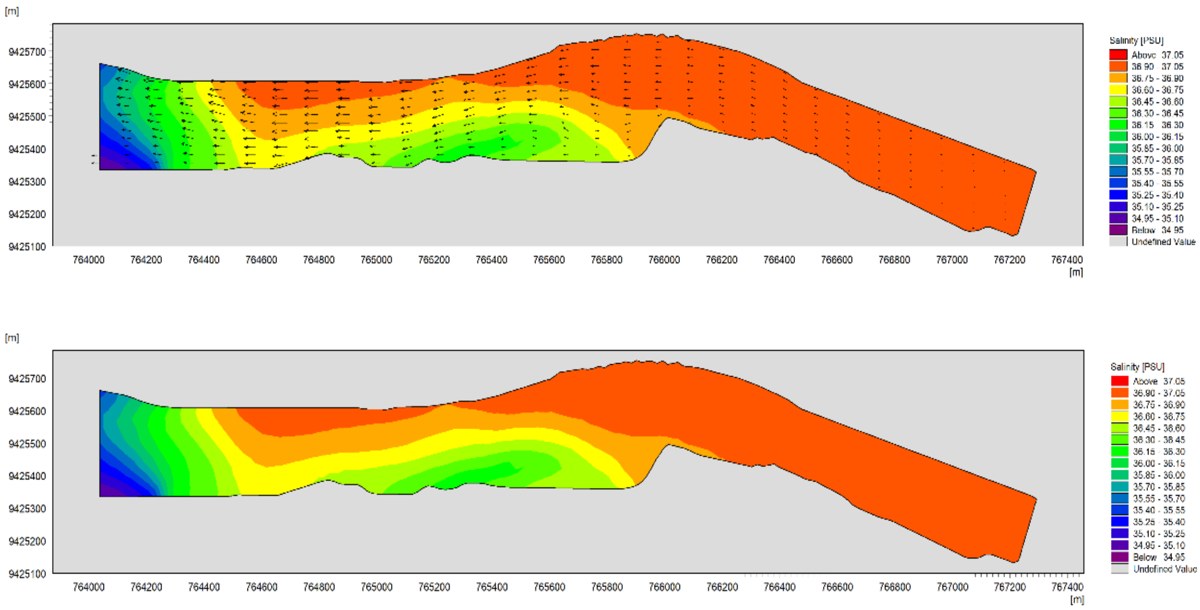

Fig 10. The plot profile of the salinity distribution at t = 1 tide elevation conditions towards low tide during the *spring tide* of the Janeberang River estuary. The top panel shows the current vector, and the bottom panel shows the salinity distribution.

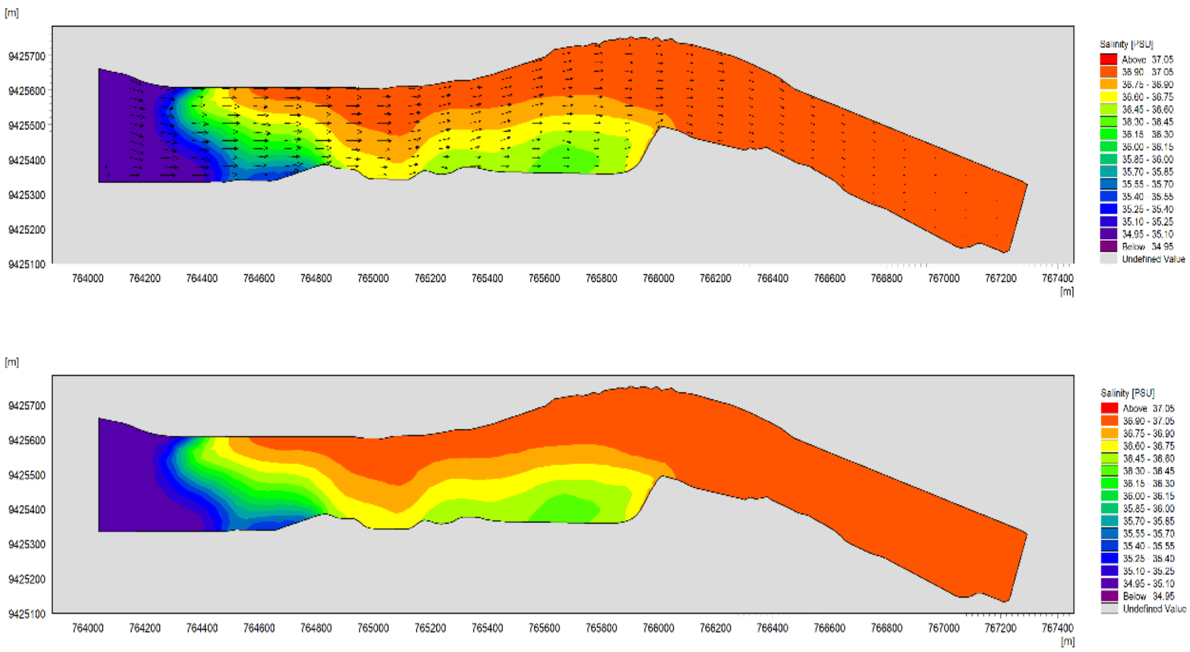

Fig 11. The plot profile of the salinity distribution at t=1, the elevation conditions recede to the tide during the *spring tide* of the Jeneberang River estuary. The top panel shows the current vector, and the bottom panel shows the salinity distribution.

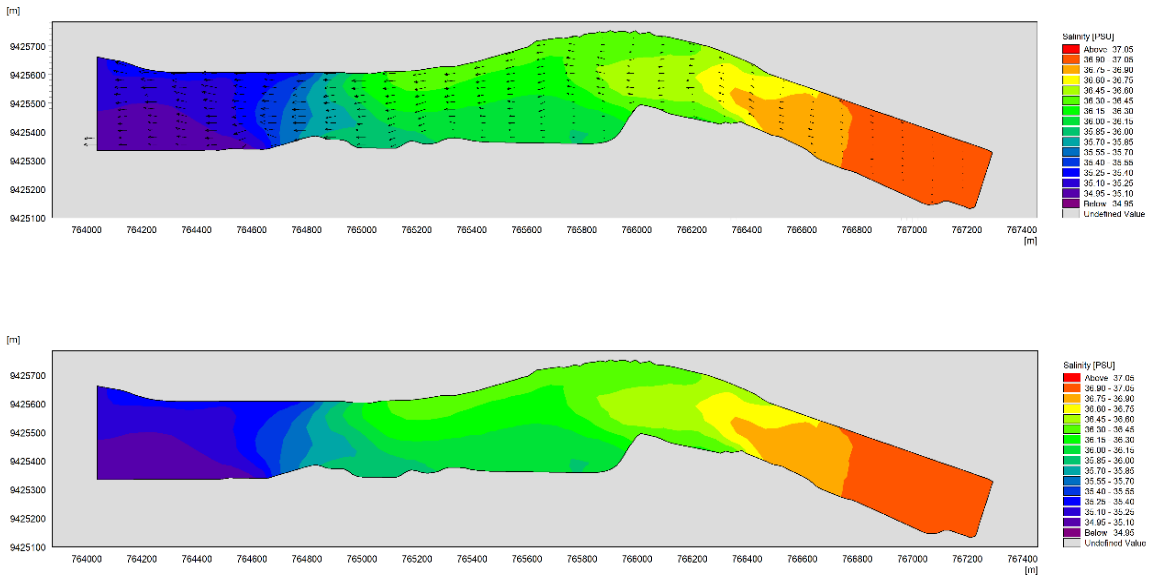

Fig 12. The plot profile of the salinity distribution at t = 1 tide elevation conditions towards low tideat neap tide, the location of the Jeneberang River estuary. The top panel shows the current vector, and the bottom panel shows the salinity distribution.

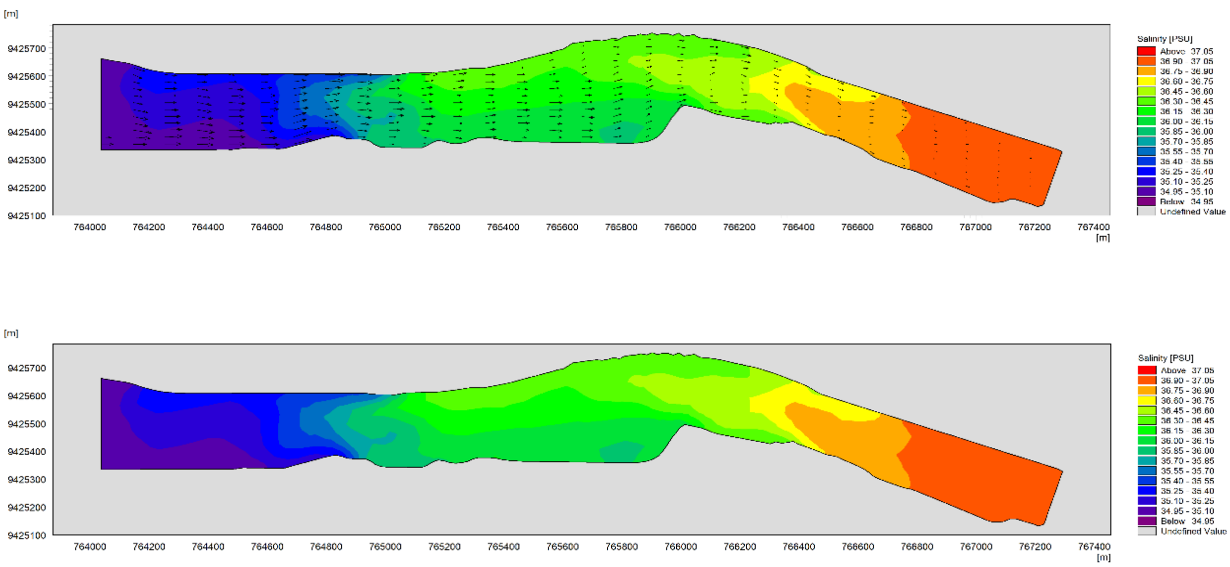

Fig 13. Plot profile of the salinity distribution at t = 1 tide elevation conditions recede to tide during neap tide bandages at the site of the mouth of the Jeneberang River. The top panel shows the current vector, and the bottom panel shows the salinity distribution.

4. Conclusion

The salinity equation function works on the momentum function in shallow water, resulting in changes in water depth which are directly proportional to changes in forces and salinity values. The circulating current velocity component gives the density difference. The difference in density is caused by changes in temperature and salinity of the water mass.

1. The modeling results show the current circulation pattern when the *spring tide* and *neap tide* show the suitability of the pattern, the difference is the magnitude of the current velocity. The current velocity at *spring tide* is higher than at *neap tide* with a current velocity of 0.21 m / s - 0.25 m / s.
2. The upstream part has a relatively high salinity compared to the downstream part, ranging from 36.4 PSU to 36.8 PSU. The lower reaches of the waters have salinity levels ranging from 34.5 PSU to 35 PSU
3. At low tide elevation to high tide when *spring tide* and *neap tide* salinity gives the same pattern, ranging from 36.75 PSU - 37 PSU.
4. At low tide elevation during *spring tide* and *neap tide*, the current vector shows movement downstream encouraging the water mass to spread downstream of the Janeberang River canal. The salinity value is between 35 PSU - 36 PSU.

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