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EVALUATION OF MUD SETTLING POND PERFORMANCE IN A SALT POND ENVIRONMENT IN LOSARANG DISTRICT, REGENCY OF INDRAMAYU, WEST JAVA, INDONESIA

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ABSTRACT: Losarang District, located in the Indramayu Regency, is one of the prominent salt producers in Indonesia. Like other producer districts, Losarang is faced with a challenge: too many unwanted substances in the raw water. Hence, this study aimed to evaluate the efficiency of a mud-settling pond and a series of breakwaters in reducing the suspended sediment content. This study included field measurement and numerical modeling. First, field measurement is conducted to obtain bathymetry, topography, water level, current velocity, and sediment sampling. The data is then utilized to construct numerical models using Delft3D-FLOW for global models and a Surface-water Modelling System for local models. The models performed well and resulted in a good validation result. Two scenarios were tested, with and without a settling pond. It is found that the settling pond successfully reduces the suspended sediment. Furthermore, it is recommended to maintain the depth of the settling pond by planning routine dredging.

Keywords: Numerical modeling, Delft3D-FLOW, SMS, Salt, West Java, Indonesia.

1. INTRODUCTION

Indonesia is one of the largest archipelago countries globally, with thousands of islands and over 50,000 kilometers of shoreline. With this immense territory, Indonesia possesses much potential in maritime fields. However, Indonesia was ranked 36th for national salt production between 2010 and 2013 [1]. Moreover, Indonesia still used imported salts to fulfill 50% of the national demand. In 2020, Indonesia consumed about two million tonnes of salts imported from another country, roughly the same as national production [2].

In Indonesia, almost every province has its respective salt-producing region. However, Indonesia's leading salt producer provinces are West Java, Central Java, and East Java. The salt production from these four provinces covers over 80% of the national production [3]. Nevertheless, the total production does not fill the national demand in terms of quantity and quality [4-6]. Moreover, the production is still dominated by small, traditional enterprises using conventional technology, while the government-owned factory, PT Garam, contributes about 15% to the national production [3].

Salt production starts with flowing raw water (seawater) into the channel system. This channel system is divided into primary, secondary, and tertiary channels and isolated from the freshwater system. The tertiary channels distribute raw water into multiple evaporation ponds and crystallizers with an engineered elevation so that the water can flow using gravity. Raw water is usually around 3-3.5^{o}Be and the salt crystals extracted are targeted at around 26.5-30.5^{o}Be [7],[8]. The suspended sediment plays a crucial role in determining the quality of the extracted salt [9].

Various efforts can be made to improve the quality of salt crystals. In crystal form, washing plant equipment is used to purify. Alternatively, higher salt crystals can be extracted from better-quality raw water in which there are fewer unwanted substances than the original. One method proposed in this research is to achieve cleaner raw water is trapping the suspended sediment in a mud-settling pond. The settling pond implementation is assessed using numerical modeling in the study case of Losarang District, located in Indramayu Regency, West Java, Indonesia. The investigation will concentrate on the settling pond's performance in reducing the study area's suspended sediment and bed change.

2. METHODOLOGY

This chapter describes the overview of the study location, the conducted field measurements, and the numerical model configuration and scenarios.

2.1 Study Location

The study location is in Indramayu Regency, in West Java, Indonesia. The area of interest is the Losarang District, known as one of the significant salt producers in the regency. Indramayu Regency is marked as a yellow box in Figure 1(a), and Losarang District is presented in Figure 1(b).

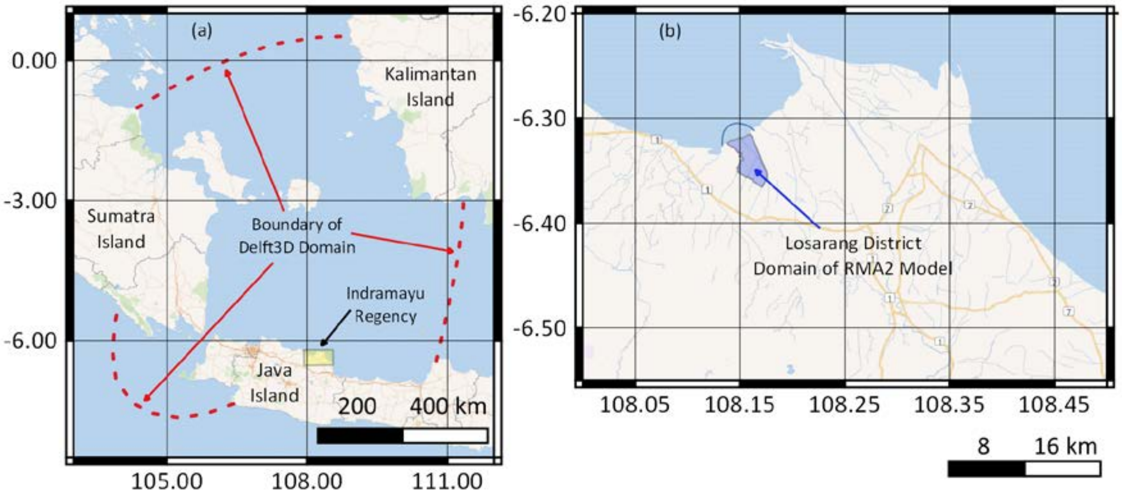

Fig. 1 Overview of study location in (a) global and (b) local domains

Indramayu Regency has been one of the significant contributors to national salt production. Table 1 presents the national and Indramayu salt production from 2012 to 2020 [10,11]. On average, Indramayu contributes over 11% of the national product.

Losarang District is the leading producer in Indramayu Regency at the regency level. From 2011 to 2014, the contribution of the Losarang District to regency production is valued at between 54.6 to 65.4% [12]. Indeks Kesesuaian Garam (IKG), or the Salt Suitability Index, states that eight parameters determine salt production: rainfall, soil permeability, soil type, sunlight intensity, humidity, wind speed, evaporation, and raw water quality [13]. In Losarang and most salt-producing regions on Java Island, the production rate is highly dependent on rainfall [14-17]. A summary of El Nino, La Nina, and IOD's impact on the salt production season is presented in Bramawanto et al. [17].

2.2 Field Measurements

Field measurements were carried out to provide the required research data, such as topography, bathymetry, hydro-oceanography, and sediment. A topography survey aimed to assess the elevation of the salt pond environment components concerning the lowest water level (LWL). The survey coverage is given in Figure 2, shown as a yellow area. The area includes rivers for fresh water and channels for raw water from the ocean. The topography survey uses a total station, and the bathymetry survey was carried out using an echo sounder. The survey extended 1 km in the across-shore direction.

The hydro-oceanography survey included a water level and current velocity survey. The water level was observed hourly from April 7th to April 22nd, 2012, at a single point. Hourly current velocity was taken at two points, three days each, with relatively short observation durations. In addition, sediment samples were collected from six points on the seabed and further analyzed in the laboratory to find the grain size. The measurement points are shown in Figure 2.

2.3 Numerical Modelling

In this research, two-dimensional ocean/coastal modeling was performed to understand the hydrodynamics of the study area and investigate the efficiency of a mud-settling pond in reducing sediment transport in the study area. Two sequences were applied in the modeling: the global and local models. The global model extended over the Indian Ocean, Karimata Strait, and the Java Sea, as shown in Figure 3(a). The local model covered a specific region in Losarang District, as shown in Figure 3(b).

The global model was modeled using curvilinear mesh in Delft3D-FLOW of Deltares

Table 1 National and Indramayu annual salt production from 2012 to 2020 in millions of tonnes.

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020
National	2.07	1.09	2.19	2.80	0.12	1.10	2.72	2.88	2.07
Indramayu	0.23	0.04	0.31	0.32	0.00	0.17	0.34	0.36	0.40
Contribution (%)	11.13	3.32	14.21	11.33	1.28	15.38	12.35	12.54	19.56

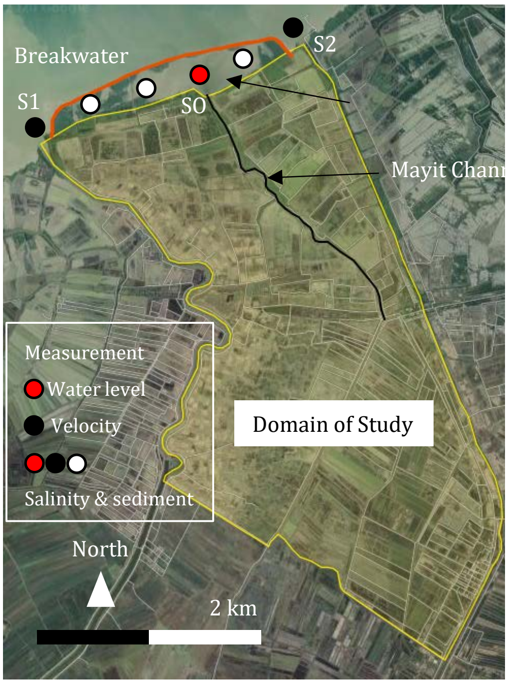

Fig. 2 Coverage of field measurements.

[18]. The mesh resolution was 6 x 12 km^2 to 1 to 2 km^2, and the GEBCO dataset was applied in this model. The objective of this model was to derive the boundary conditions for the local model. Meanwhile, boundary conditions of the model itself were generated from NaoTide, provided that NaoTide produced good predictions in offshore stations [19].

The local model was introduced since the study area was a specific coastal environment consisting of essential features with small dimensions, such as ponds, rivers, and channels. The surface-water modeling system (SMS) of Aquaveo was used to accommodate this challenge since SMS offers flexible mesh, which allows the mesh resolution to be refined with a smooth transition [20].

Figure 3(b) shows the local model domain, implementing 100 x 100 m^2 to 15 x 15 m^2 mesh resolutions. Two types of boundaries were used, water level from the global model at the offshore boundary and river discharges at river boundaries. The river discharges were obtained from hydrology analysis. Two constituents were considered in the model, hydrodynamics and sediment transport. The global and local models were run for one month for verification against survey and secondary data for validation purposes.

After the validation went through, an additional scenario involving a mud-settling pond at the coastal front was modeled. The objective was to evaluate the performance of the pond in trapping sediment and reducing sediment transport. Again, breakwaters protected the pond with tiny gaps to allow water exchange. The overview is presented in Figure 4.

3. RESULTS

This chapter presents the finding of this research. It is divided into model validation, hydrodynamics, and sedimentation.

3.1 Model Validation

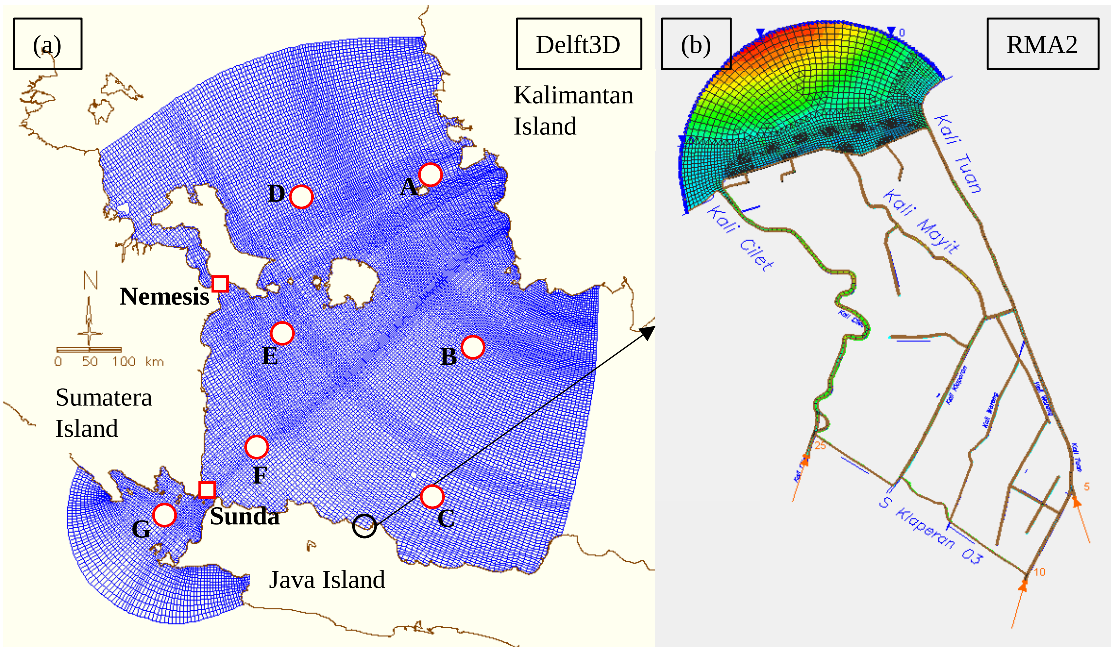

Fig. 3 Mesh implementation for Delft3D (global) and RMA2 (local) model.

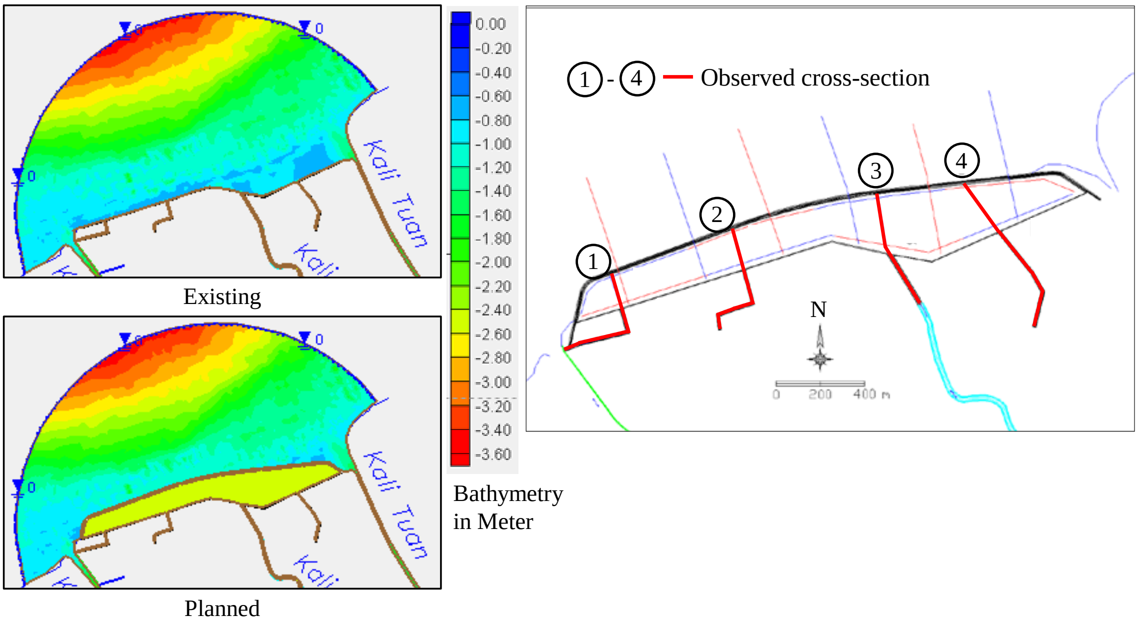

Fig. 4 Schematisation of settling pond, breakwater, and gaps at the planned scenario.

Global Model

Model validation was conducted to determine the reliability of the simulation. The good agreement indicates that the simulation could replicate the natural process with acceptable errors. The formula for error calculation is written in Eq. 1.

The error was defined as the relative mean absolute error (rmae), which is the average of the absolute difference between the field (xf) and model (xm) data divided by the maximum range of field data (R). In addition, the global model was validated against seven sets of water level data generated from NaoTide, and two current velocity data taken from

Table 2 Validation of global model: Water level (NaoTide) at 7 points.

Points	A	B	C	D	E	F	G
Locations	Kari 1	Java 1	Java 2	Kari 2	Gaspar	Jakarta	Sunda
Errors (%)	5.64	3.57	4.43	4.21	4.35	4.79	0.55
Average				3.93			

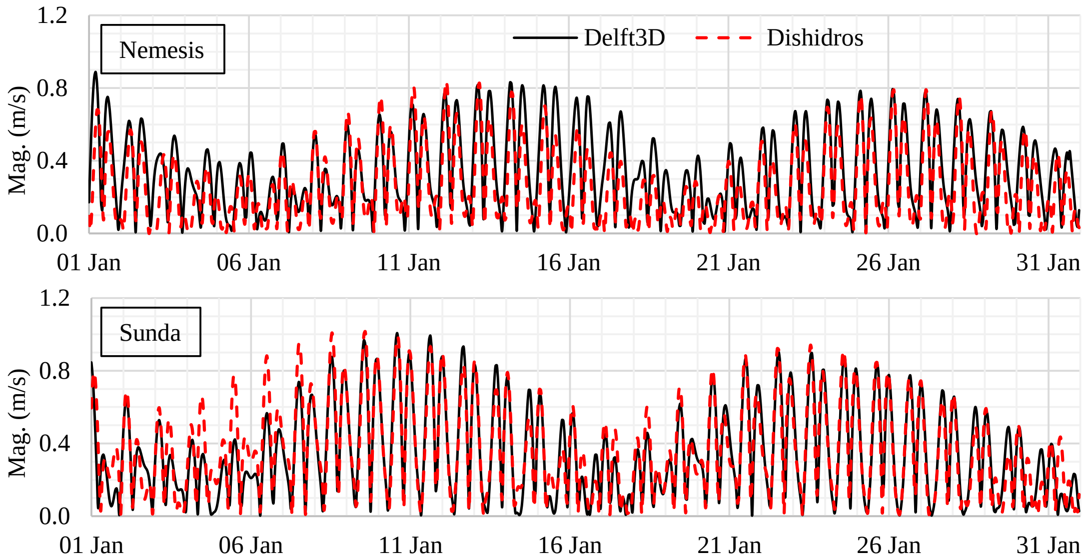

Fig. 5 Validation of global model: Current velocity at Nemesis and Sunda sites.

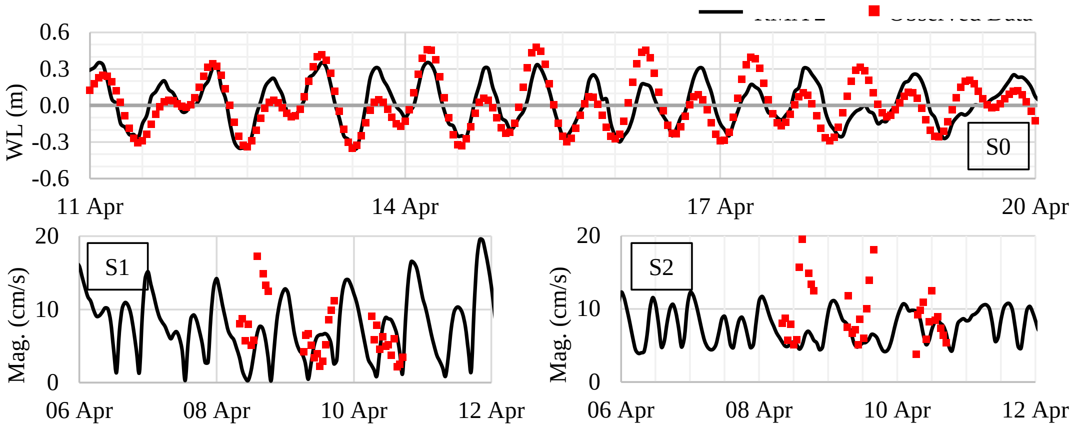

Figure 6 Validation of local model: Water level at S0 and current velocity at S1 and S2.

Indonesian Navy stations in a tide tables book [21]. The locations of these validation points are shown in Figure 3.

$$rmae = \frac{1}{n}\sum_{i=1}^{n}\frac{abs(xf_i - xm_i)}{R} \quad (1)$$

The summary of water level validation at seven points is presented in Table 2. It produced a 3.93% average error, ranging from 0.55 to 5.64%, which was not surprising for comparing two sets of computed data. Current velocity validation at two points is presented in Figure 5. The Indonesian Navy and Delft3D data were compared for one month. They showed a good agreement. Although the amplitude gave a notable discrepancy after a few days, the overall comparison presented an acceptable result. The errors are 14.7 and 8.2% for Nemesis and Sunda Stations, respectively.

Local Model

The local model was compared against the surveyed water level and current velocity. Validation points are given in Figure 2, and the results are shown in Figure 6. Although the agreement was not as transparent as shown in the global model, the data amplitude and trend were still in the same range, which means the model is still taken as reliable.

3.2 Sedimentation

The effectiveness of the mud settling pond is evaluated by observing the total suspended sediment (TSS) and bed elevation. Figure 4 describes four longitudinal sections, representing the channels connecting the water and salt pond environment. Section 3 is the inlet of the Mayit Channel, the main channel supplying raw water.

The TSS changes in four longitudinal sections are presented in Figure 7. The black and blue lines represented the TSS value at the existing and planned scenario, given in kg/m^3. The difference between both models was approximately 0.001 and

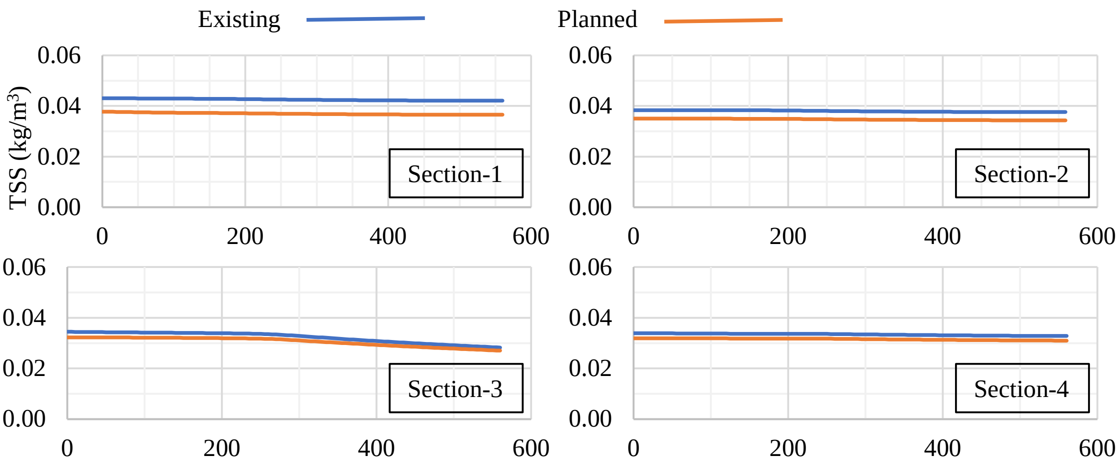

Fig. 7 Comparison between TSS at the existing and planned scenarios in four sections. The x and y axes represent the meters distances (onshore - breakwater) and TSS in kg/m^3, respectively.

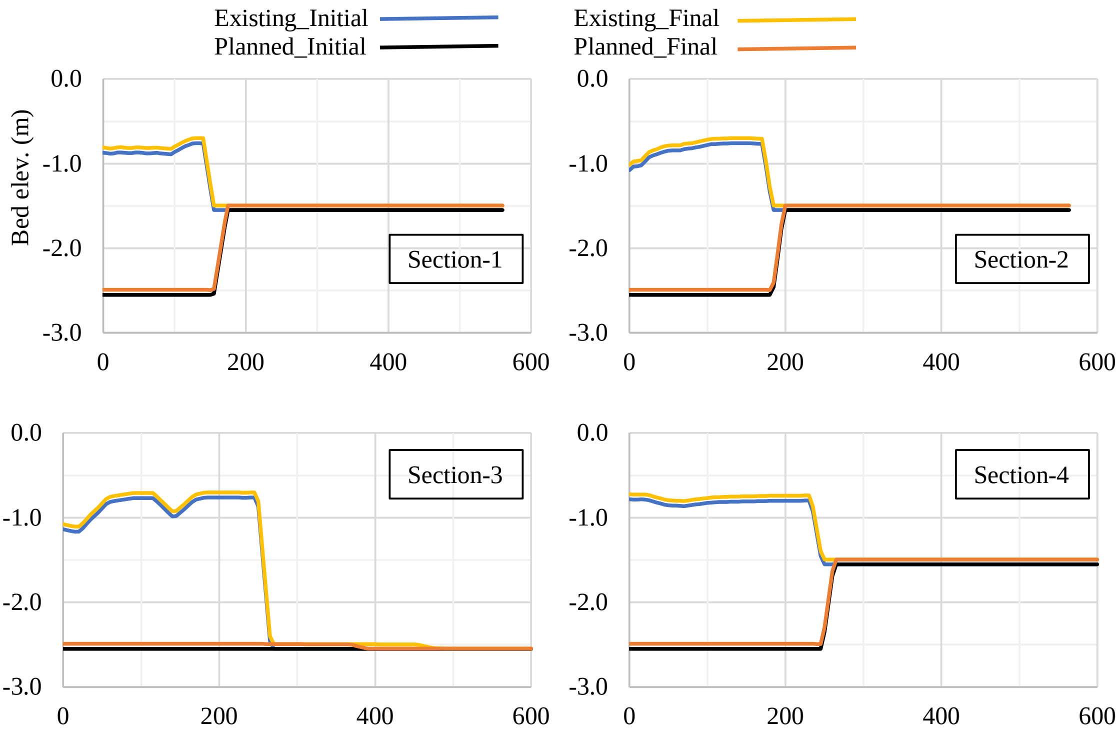

Fig. 8 Comparison between bed elevation at the existing and planned scenarios in four sections. The x and y axes represent the distances in m (onshore - breakwater) and bed elevation in m

0.005 kg/m^3, where TSS at the planned scenario always gave a lower value.

The bed elevations after simulation for the existing and planned scenarios are displayed in Figure 8. Sedimentation occurred in both scenarios, and the trend followed the TSS trend. The bed changes were about identical. However, the planned scenario's sedimentation rate is lower on a centimeter scale with a more detailed investigation.

For section-3, located at Kali Mayit, the TSS was 0.032 kg/m^3 at the offshore site and 0.026 kg/m^3 inside the channel. In the existing scenario, the values were higher, about 0.001 – 0.002 kg/m^3. However, after dredging for the mud settling pond and being equipped with a breakwater, the bed change inside Kali Mayit was declined at section 350 – 500 m.

4. CONCLUSIONS

Numerical modeling using SMS conducted at Losarang Salt Producers District showed a good performance. Models with two stages presented a proper validation against field water level and current velocity data. The model was then developed to investigate a mud-settling pond's efficiency, equipped with a series of breakwaters in the offshore region, to reduce suspended sediment content in raw water. The modeling indicated that the system successfully functioned by reducing the total suspended sediment inside the salt pond channel. However, sedimentation is still expected inside the settling pond, and a dredging routine is suggested.

5. ACKNOWLEDGEMENTS

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