

Topographic and hydro-oceanographic feasibility of a chemical port in Morowali

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Abstract

The industrial growth in Morowali Regency, Central Sulawesi, drives the need for port infrastructure to support the distribution of chemicals and fuel. This study aims to evaluate the technical feasibility of developing a liquid bulk terminal in Labota Village, Bahodopi District. The assessment involved hydro-oceanographic and topographic surveys, including a 15-day tidal observation, a 25-hour current measurement, and bathymetric and land surveys. The tidal analysis identified a mixed tide with semi-diurnal dominance and a tidal range of up to 2.66 meters. Current measurements recorded maximum surface speeds of 42 cm/s. Bathymetric data revealed varying depths up to -40 meters and an underwater mound at -10.21 meters, which may require dredging or navigational marking. The land topography is relatively flat and uniform, suitable for port development. Based on these findings, the site is considered feasible for the construction of a liquid bulk terminal capable of serving vessels up to 50,000 DWT with safe maneuvering and berthing operations. This research provides technical recommendations to support industrial logistics in the region, ensuring safe and efficient port operation while considering environmental sustainability. The study offers a comprehensive analysis of chemical and fuel terminal planning in Eastern Indonesia, contributing new insights to port infrastructure development research.

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INTRODUCTION

In the transportation and maritime sectors, seaports play a vital role as a key element supporting the flow of goods and logistics [1]. With advances in global logistics, ports have become key hubs in distribution networks. Today, more than 90% of global export trade moves by sea, making maritime transport the most efficient long-distance option [2]. The distribution of chemicals and fuel is also a key part of the global maritime transport system [3]. Therefore, port management is highly strategic, as seaports act as the main gateways for a country's import and export activities [4]. However, stakeholders must still prioritize environmental sustainability, as port

activities can significantly contribute to pollution in surrounding areas [5].

Ports are vital to trade and industry in Indonesia, a vast archipelago of over 250 million people with 60% of its landmass covered by water and a 50,000 km coastline [6]. These conditions highlight the need for a strong maritime transport system to connect regions and support growth [7]. Port development needs to be carried out in an integrated manner to ensure the entire system operates optimally and efficiently [8].

Every port must have a Port Master Plan outlining the use of land and water areas [9]. The plan ensures ports operate as terminals, maintain navigational safety, and integrate transport, while projecting cargo demand and future ship traffic

[10]. These projections guide the design of facilities and infrastructure at each development stage. Unlike most previous studies focused on western Indonesia, this study combines geodetic-standard hydro-oceanographic and topographic surveys with 25-hour current observations, which are rarely conducted in eastern Indonesia, providing accurate baseline data for planning a liquid bulk terminal and serving as a model for similar coastal areas.

This study focuses on a port in Morowali, Central Sulawesi, designed to handle fuel and chemical cargo for the industrial sector despite land constraints [11]. A feasibility analysis is needed to assess infrastructure and water depth to support efficient vessel docking and cargo handling, which are essential for industrial port development planning [12]. Project investment, whether new or expanded, requires significant funds and carries high risks, making a feasibility evaluation essential. Preliminary and full studies assess strengths, weaknesses, and overall viability to ensure effective execution and optimal benefits.

Economic and financial feasibility in port development includes port-area and hinterland analysis, land-facility needs, and studies of investment costs, operational expenses, and projected revenues and benefits [13]. This study analyzes the port area, hinterland, infrastructure, and water conditions to ensure they support port development [14]. The evaluation results provide recommendations for guiding long-term port development planning. This study assesses water depth, currents, tides, and coastal stability to determine if conditions support a safe and efficient liquid bulk terminal for tankers up to 50,000 DW.

METHOD

The study included hydro-oceanographic and topographic surveys, 100 ha of bathymetry, 15 days of tidal monitoring, 25 hours of current measurements, and a 10 ha land survey at the Labota Village site, Bahodopi District, Morowali Regency (Figures 1 and 2).



Figure 1. Research Location: Morowali Regency, Central Sulawesi, Indonesia

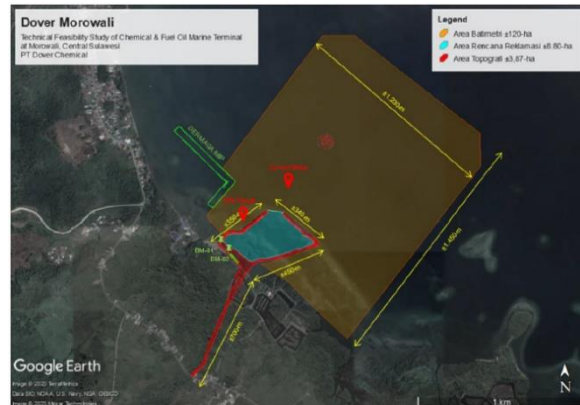


Figure 2. Plot of Study Area

During the February 2023 site visit, reclamation work was in progress over ± 12 -hectares, including ± 2.3 -hectares of reclaimed land, ± 8.8 -hectares planned for reclamation, and ± 1.5 -hectares for a ± 700 -meters access road. These activities were conducted to obtain accurate technical data for the port feasibility study and development planning.

Tidal Observation

Tidal measurements were taken continuously for 15 days at 30-minute intervals using a tide gauge. Sea levels were observed with a staff gauge placed in an area unaffected by low- or high-tide extremes. The data served as a reference for the bathymetric and current surveys. The staff gauge was tied to a nearby benchmark (BM) as a fixed reference point for all measurements [15]. The analysis of tidal sea level data was carried out through several stages. First, the measurement data were organized into tables and sea level graphs.

Subsequently, calculations were performed to determine the Mean Sea Level (MSL), the elevation of the High Water Spring (HWS), and the elevation of the Low Water Spring (LWS) [16]. These calculations, including the 18.6-year LWS prediction, served as the primary reference for the bathymetric and topographic surveys. A detailed analysis of tidal data is provided in the following section.

Bathymetric Survey

The bathymetric survey was conducted to produce a map illustrating water depth conditions at sea and in rivers within the project area [17]. Since depth measurements are significantly affected by tidal variations in sea level, the bathymetric survey must be carried out simultaneously with tidal observations [18]. This ensures that the data obtained is accurate and can be reliably used as a basis for technical planning.

Bathymetric observations were carried out during daylight hours under clear weather conditions to ensure optimal visibility and instrument performance [19]. Survey coordinates were preloaded into the equipment, with depth lines spaced 10 meters apart and observation points every 100 meters along each line. Measurement lines were set perpendicular to the shoreline at 50 m intervals (Figure 3), and a bar check was conducted to calibrate the equipment [20]. Calibration involved lowering a bar of known depth beneath the echo sounder to ensure accurate and reliable bathymetric data [21].

Each survey line was measured in a single pass from the shoreline toward the sea. The equipment layout during the bathymetric survey is shown in Figure 4, ensuring systematic and accurate underwater topographic mapping [22]. Sounding lines, the vessel's depth-measurement paths, were spaced 50-100 meters apart, closer near the planned wharf, with fix points every 10 meters [23]. Depth data were recorded every 50-100 meters along each sounding line, based on area and resolution needs [24]. In addition to depth, the GPS records X and Y coordinates using satellite signals, referenced to the UTM projection and WGS 84 datum [25]. GPS eliminates the need for fixed control points, allowing real-time positioning and improving the efficiency and accuracy of bathymetric data collection. Figure 5 illustrates the sounding line layout, demonstrating the systematic approach for accurate bathymetric data collection.

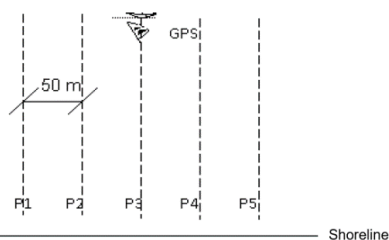


Figure 3. Determination of Fix Point Position

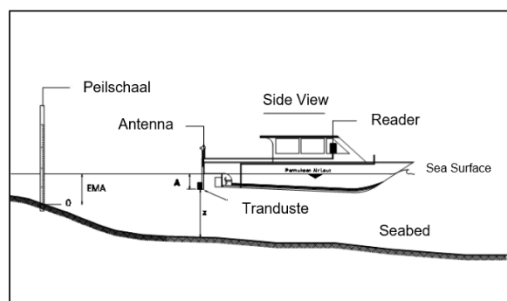


Figure 4. Sketch of Equipment Placement for Bathymetric Survey

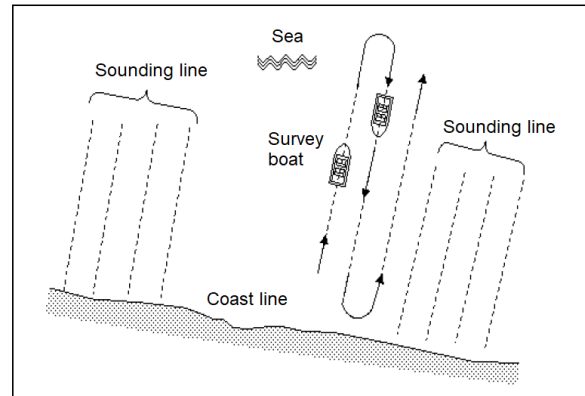


Figure 5. Sounding Lines in Bathymetric Survey

Measurement of Sea Current Direction and Velocity

Sea current measurements determine flow speed and direction at specific locations. Using a current meter operated from a boat, measurements are taken hourly at set points by submerging the instrument for a defined period. [26][27]. The number of rotor turns is recorded, with higher rotation counts indicating higher current velocity. This data collection is performed continuously over 25 hours at fixed measurement points to capture both ebb and flood tidal cycles.

The data from the fixed-point current measurements are then analyzed by compiling a table showing the current speed and direction recorded hourly at three vertical depths in the water column: 0.2d (near surface), 0.6d (mid-depth), and 0.8d (near bottom), where d represents the total water depth from the surface to the seabed [28]. Subsequently, the collected current data (speed and direction) are correlated with tide-level variations observed during the same measurement period. This combined analysis helps provide a clearer understanding of how tidal changes influence current behavior at the site and is essential for designing port infrastructure, ensuring safe vessel maneuvering, and assessing environmental impacts [29].

Topographic Survey

The topographic survey is conducted to produce a map that illustrates the land's physical conditions, including its shape, existing structures, and other relevant details, both man-made and natural [30]. The measurements are carried out using the tacheometric method [31]. The situational survey aims to capture detailed surface features and elevation contours. All natural and artificial features are measured accurately to ensure reliable topographic data.

The coordinate system used is the World Geodetic System 1984 (WGS-84), which serves as a model of the Earth [32]. The WGS-84

spheroid is geocentric, with axes forming a right-handed system, similar to GRS-80. GPS determines position by measuring distances to multiple satellites, providing 3D coordinates (X, Y, Z or ϕ, λ, h) referenced to WGS-84. Figure 6 illustrates the basic geodetic GPS concept.

GPS measures points statically or kinematically, using absolute or differential positioning. Detailed topography was collected via tachymetry with a Total Station or Geodetic GPS [33]. Measured points were referenced to benchmarks or polygon stations, with positions determined using angles and distances. Topographic points were plotted in AutoCAD (Figure 7).

The survey used two geodetic GPS receivers with an average 2-hour observation time, adjusted to the baseline length between BM points and national control points (Table 1). Spot elevations (Figure 8) were measured to obtain coordinates and heights for terrain representation and contour mapping using a theodolite, ETS, or Geodetic GPS. Elevation points were measured across the entire area at 5 × 6.5-meter intervals, adjusted for terrain variation denser in steep areas and wider in flat areas.

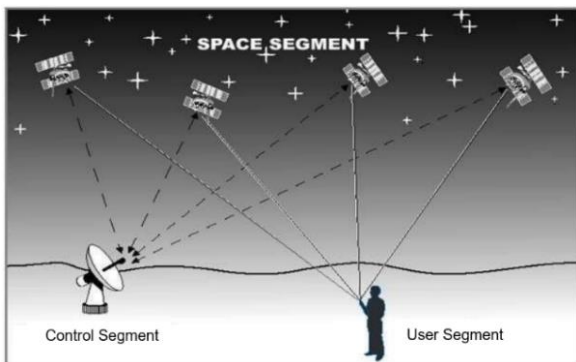


Figure 6. Position Determination Using Geodetic GPS

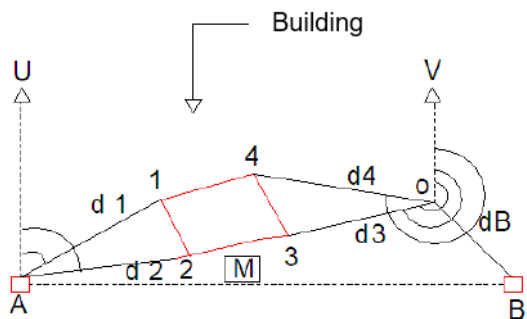


Figure 7. Topographic Survey Using the Tachymetry Method

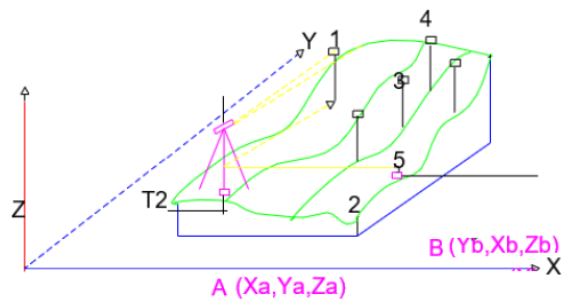


Figure 8. Spot Elevation Measurement

Table 1. Typical Observation Procedure using Geodetic GPS

Baseline Length (distance between pillar and control point)	Typical Observation Duration Single Frequency	Typical Observation Duration Dual Frequency
1 – 3 km	15 minutes	10 minutes
3 – 5 km	20 minutes	15 minutes
5 – 10 km	30 minutes	20 minutes
10 – 20 km	2 hours	1 hour
20 – 100 km	4 hours	2 hours
100 – 200 km	6 hours	3 hours
200 – 500 km	12 hours	6 hours
> 500 km	24 hours	12 hours

Points A and B serve as control points with known coordinates. A total station placed at point A uses the known coordinates of A and B, along with instrument height, to accurately calculate the position and elevation of spot points 1–5.

RESULTS AND DISCUSSION

Based on the tidal observations, the tide staff was installed on the east side of the reclamation embankment (Figure 9). These calculations were used to generate a 20-year tidal prediction. The analysis, using the Least Squares Method, produced tidal constants based on nine main tidal constituents (M2, S2, N2, K2, K1, O1, P1, M4, MS4), as shown in Table 2. After determining these constituents, the tidal type could then be classified:

$$F = \frac{A(O_1) + A(K_1)}{A(M_2) + A(S_2)} \quad (1)$$

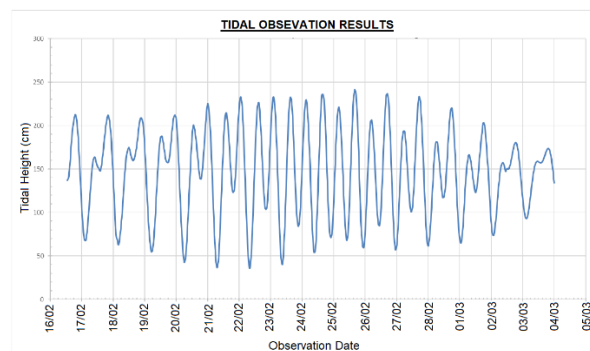


Figure 9. Tidal Graph

Table 2. Tidal Components

Constant	S ₀	M ₂	S ₂	N ₂	K ₁	O ₁	M ₄	MS ₄	K ₂	P ₁
A (cm)	147	49	28	16	21	18	0	1	9	8
G (°)	0	189	129	124	245	162	101	192	129	245

Table 3. Tidal Type

F Value	Tide Type	Description
0.00 < F ≤ 0.25	Semi-diurnal	Two high tides and two low tides occur in one day.
0.25 < F ≤ 1.50	Mixed tide, prevailing semi-diurnal	Two high tides and two low tides occur in one day, but sometimes one high and one low tide occur with varying heights and periods.
1.50 < F ≤ 3.00	Mixed tide, prevailing diurnal	One high tide and one low tide occur in one day, but sometimes two high and two low tides occur with different heights and periods.
3.00 < F	Diurnal	One high tide and one low tide occur in one day.

Table 4. Tidal Datum Elevations

No.	Remarks	Elevation (m) Peil Schaal	Elevation (m) 0 LWS
1	HWS (<i>Highest Water Spring</i>)	2.8	2.66
2	MHWS (<i>Mean High Water Spring</i>)	2.35	2.21
3	MHWL (<i>Mean High Water Level</i>)	2.23	2.09
4	MSL (<i>Mean Sea Level</i>)	1.47	1.33
5	MLWL (<i>Mean Low Water Level</i>)	0.7	0.56
6	MLWS (<i>Mean Low Water Spring</i>)	0.58	0.44
7	LWS (<i>Lowest Water Spring</i>)	0.14	0

According to the 2021 Technical Guidelines for Seaport Planning, the proposed Morowali terminal meets Class II criteria, with berth depths ranging from -10 to -15 m LWS. Bathymetry confirms safe berthing for tankers up to 10,000 DWT. LWS = 0.00 is referenced to benchmark BM-01 (Figure 10).

The bathymetric survey covered ±120 ha of water, and the topographic survey ±3.87 ha of land. Tidal-corrected maps are shown in Figure 11. Current measurements were taken 300 m north of the reclamation dike (2°52'26.78" S, 122°11'33.05" E) at depths of 0.2D, 0.6D, and 0.8D. At 0.2D, 25-hour observations showed an average velocity of 22.68 cm/s, with westward currents dominating 24.5% of the time (Figures 12–15). Figure 12 shows the current rose at a depth of 0.2D (20% of the total depth). Over 25 hours, the average velocity was 22.68 cm/s, with the dominant westward current reaching about 24.5% of observations. Figure 13 shows the current at 0.6D depth (60% of total depth), with a dominant westward flow. The highest frequency, about 24.5%, also points west, indicating consistent circulation with the surface layer and no major change in direction. Figure 14 shows the current at 0.8D (80% of the total depth), with an average speed of 18.48 cm/s. The dominant westward flow, with 24.5% frequency, indicates consistent circulation with the upper layers, though at slightly lower velocity. Figure 15 integrates hydrodynamic data with site geography and bathymetry, showing a dominant westward current averaging, 21.44 cm/s.

Water depths are suitable for jetty construction, providing a reference for facility layout and jetty orientation.

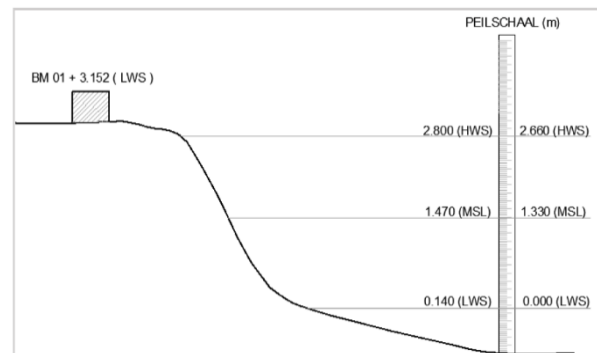


Figure 10. Peilschaal and BM-01 Elevation

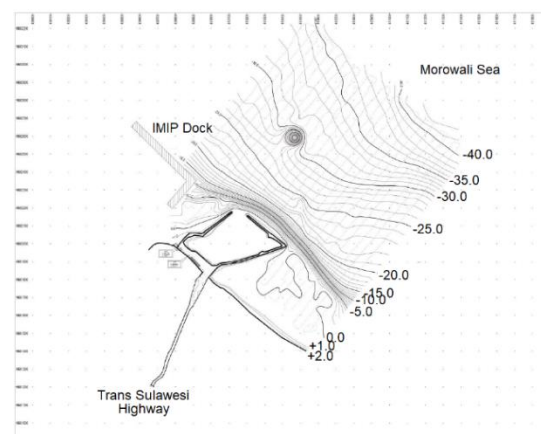


Figure 11. Topographic and Bathymetric Survey Maps

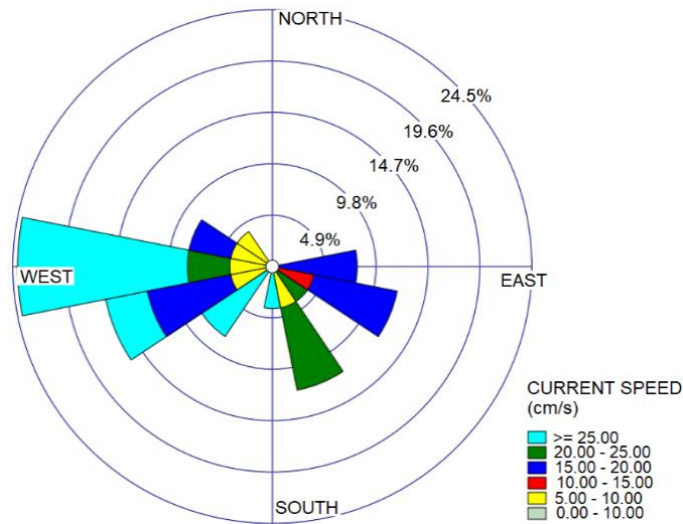


Figure 12. Current Rose at a Depth of 0.2D

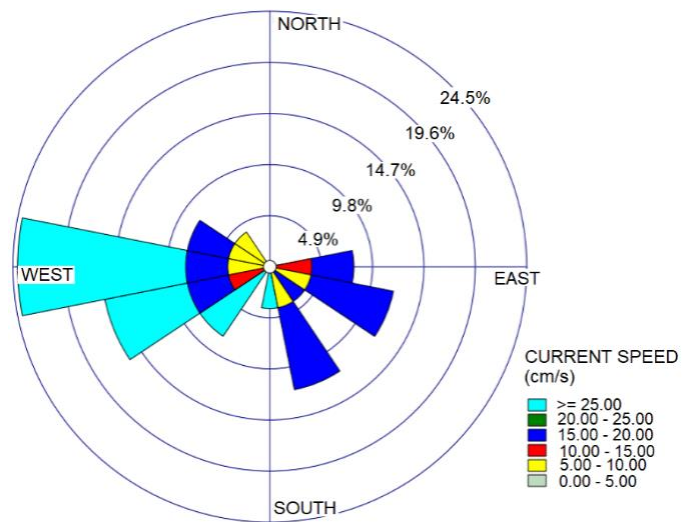


Figure 13. Current Rose at a Depth of 0.6D

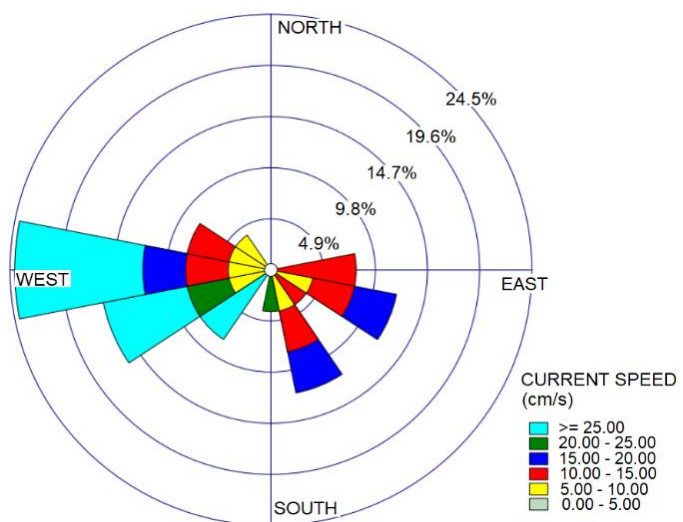


Figure 14. Current Rose at a Depth of 0.8D



Figure 15. Current Rose, Superimposed on Google Earth

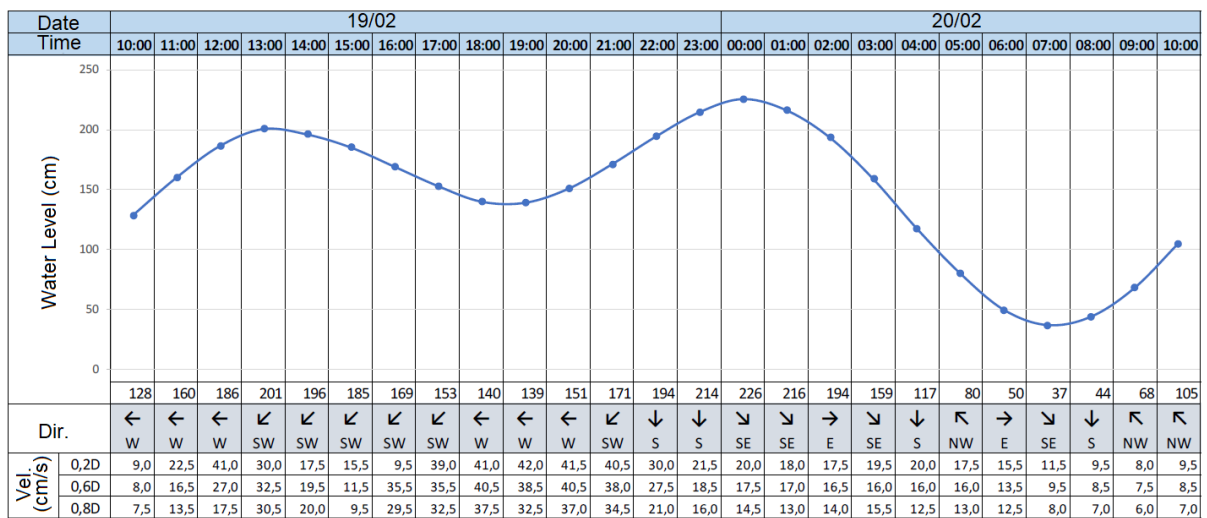


Figure 16. Results of Current Direction and Velocity Measurements

Table 5. Results of Current Direction and Velocity Measurements

Date	Water Level(0 LWS)	Current Direction(°)	(blow to)	Current speed (cm/s)		
				0.2D	0.6D	0.8D
19-02-23 10:00	128	80	W	9	8	7.5
19-02-23 11:00	160	80	W	22.5	16.5	13.5
19-02-23 12:00	186	80	W	41	27	17.5
19-02-23 13:00	201	60	SW	30	32.5	30.5
19-02-23 14:00	196	60	SW	17.5	19.5	20
19-02-23 15:00	185	60	SW	15.5	11.5	9.5
19-02-23 16:00	169	60	SW	9.5	35.5	29.5
19-02-23 17:00	153	60	SW	39	35.5	32.5
19-02-23 18:00	140	80	W	41	40.5	37.5
19-02-23 19:00	139	90	W	42	38.5	32.5
19-02-23 20:00	151	100	W	41.5	40.5	37
19-02-23 21:00	171	40	SW	40.5	38	34.5
19-02-23 22:00	194	10	S	30	27.5	21
19-02-23 23:00	214	340	S	21.5	18.5	16
20-02-23 0:00	226	320	SE	20	17.5	14
20-02-23 1:00	216	300	SE	18	17	14
20-02-23 2:00	194	280	E	17.5	16.5	14
20-02-23 3:00	159	300	SE	19.5	16	15.5
20-02-23 4:00	117	340	SE	20	16	14
20-02-23 5:00	80	120	NW	17.5	16	13
20-02-23 6:00	50	280	E	15.5	13.5	12.5
20-02-23 7:00	37	300	SE	11.5	9.5	8
20-02-23 8:00	44	340	S	9.5	8.5	7
20-02-23 9:00	68	120	NW	8	7.5	6
20-02-23 10:00	105	130	NW	9.5	8.5	7
Average Current Speed				22.68	21.44	18.56

In summary, the current measurements show that at 0.2D, velocities ranged from 8.0 to 42.0 cm/s, with an average of 22.68 cm/s; at 0.6D, from 7.5 to 40.5 cm/s, with an average of 21.44 cm/s; and at 0.8D, from 6.0 to 37.5 cm/s, with an average of 18.48 cm/s. The current direction and velocity results are shown in Figure 16 and Table 5.

The ± 120 -hectare bathymetric survey revealed depths ranging from 0 to -40 m (Figure 11). A 1-hectare underwater mound at -10.21 m LWS was identified about 450 m northeast of the reclamation dike, requiring dredging or marking for safe navigation. Current measurements showed a dominant east–west flow, with average velocities of 22.68 cm/s at 0.2D, 21.44 cm/s at 0.6D, and 18.48 cm/s at 0.8D. The 15-day tidal analysis indicated a 2.66 m range and a mixed, mainly semi-diurnal pattern.

This study offers methodological and practical improvements over previous hydro-oceanographic and port-planning research. Measuring currents at three depths (0.2D, 0.6D, 0.8D) provides more accurate velocity and direction profiles for the design of subsea pipelines, mooring systems, and wharf structures. The integration of current rose diagrams with bathymetry on Google Earth enhances spatial interpretation for port layout and approach channels. The results align with Ministry of Transportation guidelines for Class II Special Terminals (TUKS). The study also recommends follow-up analyses on sediment transport and environmental impacts (AMDAL). Overall, it improves technical accuracy, spatial integration, and regulatory alignment.

CONCLUSION

Surveys and field assessments show that the ± 3.87 -hectare reclamation area in Labota Village has flat terrain suitable for a liquid bulk terminal accommodating vessels up to 50,000 DWT. The available sea depth of around -40 m supports efficient cargo handling and safe vessel maneuvering.

To strengthen the study, further sediment transport analysis is recommended to evaluate long-term sedimentation and erosion risks, along with a comprehensive EIA/AMDAL to assess impacts on marine ecosystems, coastal processes, and water quality. These steps will help ensure the terminal's environmental sustainability and reliable operation.

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