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RESEARCH ARTICLE

Hydro-Oceanographic Conditions in the Development of Tinobu Port Lasolo Sub-district North Konawe Regency Southeast Sulawesi Province, Indonesia

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Abstract

Indonesia is one of the world's largest maritime countries, with many small islands scattered from Sabang to Merauke. Therefore, the presence of a port plays a crucial role in maritime transportation, which is highly essential for the Indonesian population. When planning a port, there are numerous aspects to consider, ranging from environmental to structural aspects of the port's development.

In this context, researchers conducted a study to analyze the water conditions around Tinobu Port, specifically focusing on topography, bathymetry, and tides, often referred to as Hydro-Oceanography. These three aspects of Hydro-Oceanography play a vital role in port planning, as topography and bathymetry shape the land and water contours, and tidal analysis determines elevation bindings.

Keywords: Harbor, Topography, Bathymetry, Tide, Hydro-Oceanography

1. Introduction

The commitment of the Joko Widodo-Jusuf Kalla government to promote Indonesia as the world's maritime axis offers hope for the improvement in both the quantity and quality of ports. Ports serve as vital nodes in building a robust maritime territory. Ports play a catalytic role in stimulating the growth of economic sectors, such as industry, trade, and tourism. (Adam & Dwiastuti, 2015).

Indonesia is a country with a vast expanse of ocean. Its strategic location lies on the equator, positioned between two oceans, the Indian Ocean and the Pacific Ocean, and two continents, Asia and Australia. Indonesia's waters, initially covering approximately 3.166 million square kilometers according to the Archipelagic State concept, expand to approximately 6 million square kilometers under the Exclusive Economic Zone (EEZ) concept, while the total area of all the world's oceans is about 361 million square kilometers. Coastal waters, including beaches and estuaries (river mouths), are extensively utilized by the local communities. (Chen & Mao, 2018).

As the world's largest archipelagic nation, Indonesia requires a well-developed and efficiently managed port sector. The competitiveness of producers in both the domestic and international markets, internal distribution efficiency, and more broadly, the coherence and integrity of the national economy, are greatly influenced by the performance of the port sector. (Desiani, n.d.).

The development of transportation is aimed at bridging regional disparities and promoting a more even distribution of development outcomes. Maritime transportation plays a crucial role in facilitating trade due to its high economic value, including its capability to carry a large volume of goods at a relatively low cost. To support trade and cargo traffic, ports are created as focal points for the transfer of goods, where ships can dock, moor, load, and unload cargo, and forward them to other regions. (Putra & Djalante, 2016a).

In the planning or construction of a port, several studies are conducted before the actual construction takes place. The first study for port development is usually the Feasibility Study, in which the port location typically consists of multiple study locations. These locations are then assessed and scored to determine which one is suitable for the construction of a port. The next study is the Port Master Plan (Rencana Induk Pelabuhan or RIP). During the Port Master Plan study, field surveys are conducted once again, and data from the selected port location in the Feasibility Study is further processed. This stage involves more types of surveys and is more specific compared to the Feasibility Study. The last study is the Detail Engineering Design (DED). As the name suggests, in the DED phase, a detailed engineering design is created concerning the model and function of the port to be built. In other words, this stage involves the creation of working drawings for the physical construction of the port after the tender process has been completed. (Gema Teknik Konsultan, 2020).

The development of Tinobu Port in the Lasolo Sub-district, located in North Konawe Regency, Southeast Sulawesi Province, is a very special endeavor for the local community. With the presence of this port, the standard of living and the local economy can improve. Transportation access and the availability of goods and services will become more accessible. Lasolo Sub-district, especially in the Tinobu Village area, serves as a highly strategic gateway for North Konawe Regency. The Tinobu Village, the location for the construction of Tinobu Port, is situated in the middle section of North Konawe Regency. This advantageous location makes it very convenient to distribute goods that will enter Tinobu Port in the future. (Primatama Prima Konsultama, 2021).

Based on the background information provided for port development, there are several crucial factors that need to be considered before planning a port, especially the existing conditions and the water conditions at the port. One of the mandatory steps for a planner before constructing a port is to conduct data collection surveys, including both primary and secondary data. The purpose of this research is to analyze the existing conditions of the port and the water conditions in the vicinity of Tinobu Port in the Lasolo Sub-district of North Konawe Regency.

2. Research Methods

The method used by the author in collecting data is by collecting primary data directly at the study location at Tinobu Harbor. Primary data collection took the form of carrying out several field surveys including topographic, bathymetric and tidal surveys. These surveys were carried out by the author and assisted by several friends, this is because there are several surveys that must be carried out simultaneously, such as bathymetric surveys must be carried out simultaneously with tidal surveys every 15 minutes during the bathymetric survey, and topographic surveys must also be carried out on when a temporary bathymetric survey is taking place to obtain elevation ties between land and sea.

In this research, the data obtained was mostly carried out directly in the field which is primary data, and was obtained from related agency offices such as BMKG which is secondary data. The following is some data collection that has been carried out by the author at the study location:

2.1 Topographic Survey

A topographic survey was carried out by the author using a Topcon GM55 series total station tool. This survey aims to obtain an overview of the shape of the land surface in the form of the situation and height and position of features in the research location area and the surrounding area. Topographic surveys map the area, position and elevation of land relative to tides for accurate land improvement and leveling volumes. The survey area extends parallel to the coastline. The results are then mapped with a certain scale and contour interval. The method used is terrestrial, land elevation to the lowest water level and its position to global coordinates.

2.2 Bathymetric Survey

Bathymetric surveys are carried out to determine the depth of the seabed relative to the water surface. Bathymetric surveys are very important to determine the depth required based on the planned specifications for the largest ship that will dock at a port. The depth of the water (seabed) will be tied to the land elevation which is the result of a topographic survey and then a contour will be made connecting the land elevation and water elevation. The measurement process uses a single beam bathymetry tool type GPS Maps 585 Plus, with the help of a fishing boat the sounding process is carried out around the waters of Tinobu Port.

2.3 Tidal Survey

Tidal conditions in the study area will greatly influence the characteristics of waves, currents and planned sea level heights which will then determine the stability analysis of coastal structures and determination of their peak elevations. In this regard, the author has conducted a study and analysis of tidal data in the waters of Tinobu Harbor. This study and analysis is based on tidal data at the location. Ocean tides are the rise and fall of sea levels that occur periodically due to the gravitational influence of celestial bodies, especially the moon and sun. Tidal observations aim to obtain sea level height tied to a vertical datum or certain elevation reference plane, by taking sea level height data for a predetermined time period. The simplest tidal observations are carried out using measuring poles which are usually called palms (peil schaal), with an observation time interval of one hour, and carried out for 15 (fifteen) days. The choice of location for installing the peil schaal is conditioned in such a way that when the position is low, the palm tree remains in a submerged condition. The data in this research is processed and analyzed using a computerized system, this is done to make data analysis easier and reduce human error. The applications used in this research are Microsoft Office 2019, Autocad Land Desktop 2009, Autocad 2012, Autocad Civil 3D 2015, Maps Sources, Basecamp, Google Earth, Sokkia Link, Topcon Link and several other supporting applications.

3. Results and Discussion

3.1 Tinobu Existing Condition of Tinobu Port

Pelabuhan Tinobu is located in the Lasolo District of North Konawe Regency, where it is the only port within the Lasolo District. The Lasolo District has a land area of 139.40 square kilometers and a population of 8,129 people, comprising 4,168 males and 3,961 females. The population of Lasolo District is the largest among the 13 districts in North Konawe Regency. Currently, Pelabuhan Tinobu cannot be considered a proper port as it lacks essential facilities and supporting infrastructure that a port should have. Furthermore, there is no available data on cargo handling or the number of vessels.

At present, Pelabuhan Tinobu only consists of a causeway that extends from the Tinobu coastline into the sea, with a total length of 390 meters and a width of 4 meters. According to data collected by the survey team, this causeway is over 30 years old and was originally built by the local community of Tinobu Village and its surroundings, using large stones (known as "batu gajah") piled up to form the causeway. Several years later, the causeway, which was originally a community-driven initiative, received assistance from the local government (PEMDA). Subsequently, revetments were constructed on both sides, and it was filled with sand and embankment soil. Currently, the tip of the causeway has suffered severe damage due to wave impacts, and a lack of further maintenance has led to extensive cracking, making it potentially unsafe for use in the long term.

Throughout its history, Pelabuhan Tinobu has primarily served as a fish landing site for local fishermen. Currently, approximately 6 to 8 fishing boats use Pelabuhan Tinobu, with the fish caught being sold directly to collectors, local markets, or even shipped outside of Lasolo District and North Konawe Regency (source: observations and interviews with the local community, 2022).

Fig 1. Condition of the Surface of Tinobu Port's Causeway

Fig 2. The Damage Condition Occurring on Almost the Entire Body of Tinobu Port's Causeway

Fig 3. The Outer End Condition of Tinobu Port's Causeway Has Collapsed

Fig 4. Condition of the Main Road in Front of the Harbor

3.2 Tinobu Port Facilities

As mentioned earlier, Pelabuhan Tinobu cannot currently be considered a proper port because it lacks both primary and supporting facilities that a port should have. It only consists of a decades-old causeway, which is now the iconic feature of Pelabuhan Tinobu. However, its condition is highly concerning due to its age of over 30 years and the absence of maintenance on the port facility (causeway).

Currently, Pelabuhan Tinobu is used as a fish landing site for local fishermen in the vicinity of Pelabuhan Tinobu. For a clearer understanding, here are the details and structure of the causeway at Pelabuhan Tinobu.

Table 1. Condition of Tinobu Port's Causeway

Function/Purpose	Public Port
Structure Type	Causeway
Length (Meters)	390
Width (Meters)	4
Height (Meters)	2.5
Construction	Large Stones (Batu Gajah) Filled with Sand and Embankment Soil, Revetments Built on the Right and Left Sides to Form the Causeway Structure
Capacity (Tons/Square Meter)	Suitable for Vessels Ranging from Small Boats to Maximum 30 GT Wooden Boats
Owner	Local Community Around Tinobu Port

Source: Field Observations, 2022

3.3 Bathymetric Survey

3.3.1 Sounding Determination of Sounding Tracks

A sounding track is the path taken by a ship to conduct sounding measurements from the starting point to the ending point of a survey area. In areas prone to erosion, the sounding tracks are established at 25-meter intervals. Depth data for the water is collected at 25-meter intervals along each sounding track. The starting and ending points for each sounding track are recorded and then input into a measurement instrument equipped with GPS capabilities to serve as a reference for the boat's route along the sounding track (Figure 5).

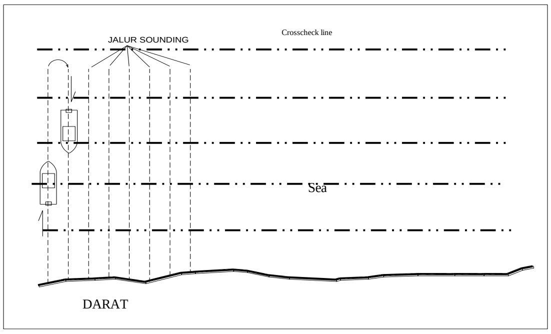

Fig 5. Sketch of Boat Movement Path Along Sounding Tracks for Bathymetric Survey.

Fig 6. The Process of Bathymetric Survey Execution at Tinobu Port

Data was recorded every 20 meters with sounding tracks set perpendicular to the coastline at 25-meter intervals. Cross-check tracks were established at distances of 100 meters, 200 meters, 600 meters, 800 meters, 1000 meters, and 1500 meters from the shoreline. An echosounder and GPS were installed on the boat, automatically recording depth data and position, including X, Y, and Z, every 20 meters as the boat moved. The depth data from the survey was corrected for tidal fluctuations, which were surveyed in parallel. The data is required as determining parameters for the layout.

3.4 Survey Result

Based on tidal observations every 15 minutes during the survey execution, the observation results can be seen in Table 2 and 3

Table 2. Tidal Observation During Bathymetric Survey

No.	Date and Time of Observation		Water Elevation (cm)		
			High	Low	Average
1	21-Aug-21	10:45:00	240.0	240.0	240.0
2	21-Aug-21	11:00:00	241.0	233.0	237.0
3	21-Aug-21	11:15:00	241.0	229.0	235.0
4	21-Aug-21	11:30:00	244.0	226.0	235.0
5	21-Aug-21	11:45:00	241.0	224.0	232.5
6	21-Aug-21	12:00:00	240.0	222.0	231.0
7	21-Aug-21	12:15:00	238.0	220.0	229.0
8	21-Aug-21	12:30:00	230.0	218.0	224.0
9	21-Aug-21	12:45:00	227.0	214.0	220.5
10	21-Aug-21	13:00:00	224.0	209.0	216.5
11	21-Aug-21	13:15:00	220.0	195.0	207.5
12	21-Aug-21	13:30:00	210.0	191.0	200.5
13	21-Aug-21	13:45:00	205.0	187.0	196.0
14	21-Aug-21	14:00:00	196.0	176.0	186.0
15	21-Aug-21	14:15:00	184.0	168.0	176.0
16	21-Aug-21	14:30:00	176.0	93.5	134.8

Source: Field Observations, 2022

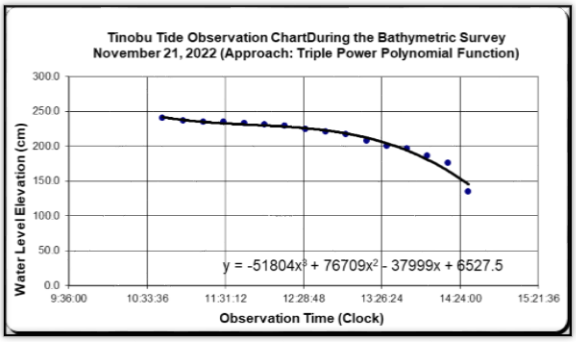

Fig 7. Tidal Observation Chart During Bathymetric Survey

Table 3. Results of Seabed Elevation Calculation

No.	Measurement Time x (Hours)	Water Elevation y (m)	z (m)	z + h (m)	Correction (kr) (m)	z_{kr} (m)
1	10:45:00	0.785	0.8	0.9	0.239	0.661
2	10:45:10	0.786	1.4	1.55	0.240	1.310
3	10:47:30	0.799	3.0	3.15	0.253	2.897
4	10:47:35	0.799	3.0	3.15	0.253	2.897
5	10:47:40	0.800	3.2	3.35	0.254	3.096
6	10:47:45	0.800	3.4	3.55	0.254	3.296
7	10:47:55	0.801	4.2	4.35	0.255	4.095
8	10:48:00	0.802	4.6	4.75	0.256	4.494
9	10:48:05	0.802	4.7	4.85	0.256	4.594
10	10:48:10	0.802	5.3	5.45	0.256	5.194
11	10:48:15	0.803	5.5	5.65	0.257	5.393
12	10:48:20	0.803	5.5	5.65	0.257	5.393
13	10:48:25	0.804	5.7	5.85	0.258	5.592
14	10:48:30	0.804	5.8	5.95	0.258	5.692
15	10:48:35	0.805	5.4	5.55	0.259	5.291
16	10:48:40	0.805	5.4	5.55	0.259	5.291
17	10:48:45	0.805	5.2	5.35	0.259	5.091
18	10:48:50	0.806	5.4	5.55	0.260	5.290
19	10:48:55	0.806	5.2	5.35	0.260	5.090
20	10:49:00	0.807	5.2	5.35	0.261	5.089

Source: Field Observations, 2022

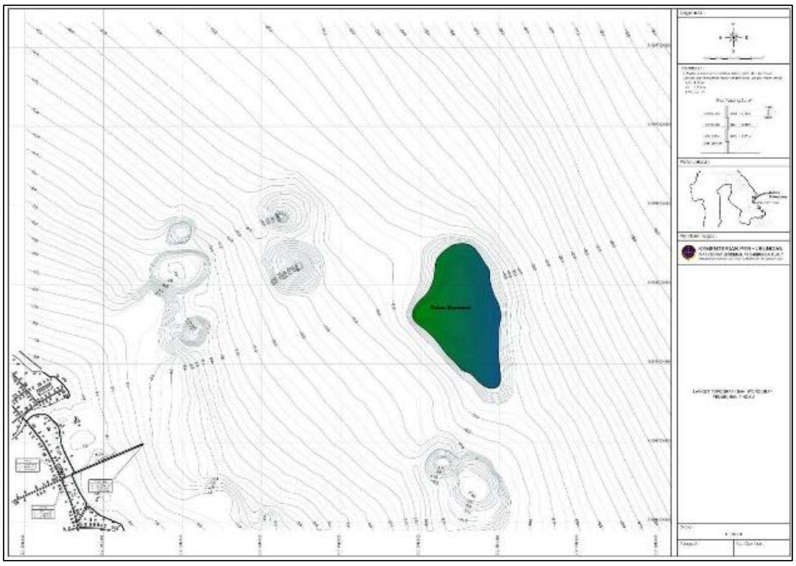

Fig 8. Map of the Bathymetric Survey Results for Tinobu Port

4 Topographic Survey

Topographic mapping is a process to obtain an overview of the ground surface, allowing us to understand the terrain's shape and perform cut and fill volume calculations. Topographic mapping is crucial for construction activities. In construction projects, a good topographic survey is essential to assess the environmental conditions, calculate materials, and plan the design.

Fig 9. The Types of Topographic Equipment Used in the Tinobu Port Survey

Fig 10. Coastal Shoreline Measurement

Fig 11. Detail Measurement of the Causeway

Fig 12. Cross Section Measurement

Topographic survey is a survey conducted to determine the condition or contour of a land area on the ground. The topographic measurements carried out at Tinobu Port were performed using a Total Station device, specifically the Topcon GM55 series. The output from this device is digital data that can be directly copied to a flash drive and processed on a computer using AutoCAD software. The data from the topographic survey at Tinobu Port can be found in Table 4

Table 4. Topographic Survey Data for Tinobu Port

Point (P)	North (Y)	East (X)	Elevation (Z)	Code (CD)	Ket
1	9595680.5518	416266.9704	2.8700	STN	*Topo*
2	9595690.7888	416302.6404	-0.2730	ACPeilschaal	*Topo*
3	9595690.7888	416302.6394	-0.2730	ACPeilschaal	*Topo*
4	9595678.0108	416269.9954	3.0730	DC	*Topo*
5	9595678.1298	416269.8354	3.0660	DC	*Topo*
6	9595682.1838	416269.2324	3.0880	DC	*Topo*
7	9595682.3128	416269.0024	3.0930	DC	*Topo*
8	9595682.4678	416268.6594	2.7810	DC	*Topo*
9	9595680.1988	416268.3054	2.8760	CD	*Topo*
10	9595678.8908	416266.2424	2.8520	CD	*Topo*
11	9595678.9078	416260.3034	2.8080	CD	*Topo*
12	9595679.1598	416261.5624	3.1200	CD	*Topo*
13	9595678.9368	416261.5584	3.1050	CD	*Topo*
14	9595675.6038	416263.9074	3.0850	CD	*Topo*
15	9595675.5208	416264.1464	3.0970	CD	*Topo*
16	9595683.2768	416266.6094	0.6100	CD	*Topo*
17	9595643.7488	416180.7084	3.0550	BD	*Topo*
18	9595645.7888	416182.9014	2.9200	CD	*Topo*
19	9595645.4288	416182.5784	3.1870	CD	*Topo*
20	9595645.4788	416183.1944	3.1870	CD	*Topo*

Source: Field Observations, 2022

Topographic mapping or surveying is a crucial element in the construction of a port. The elevation data obtained from topographic surveys significantly impacts the planning of a port. This data plays a pivotal role in the development of the onshore area and also influences the elevation of the port's wharf.

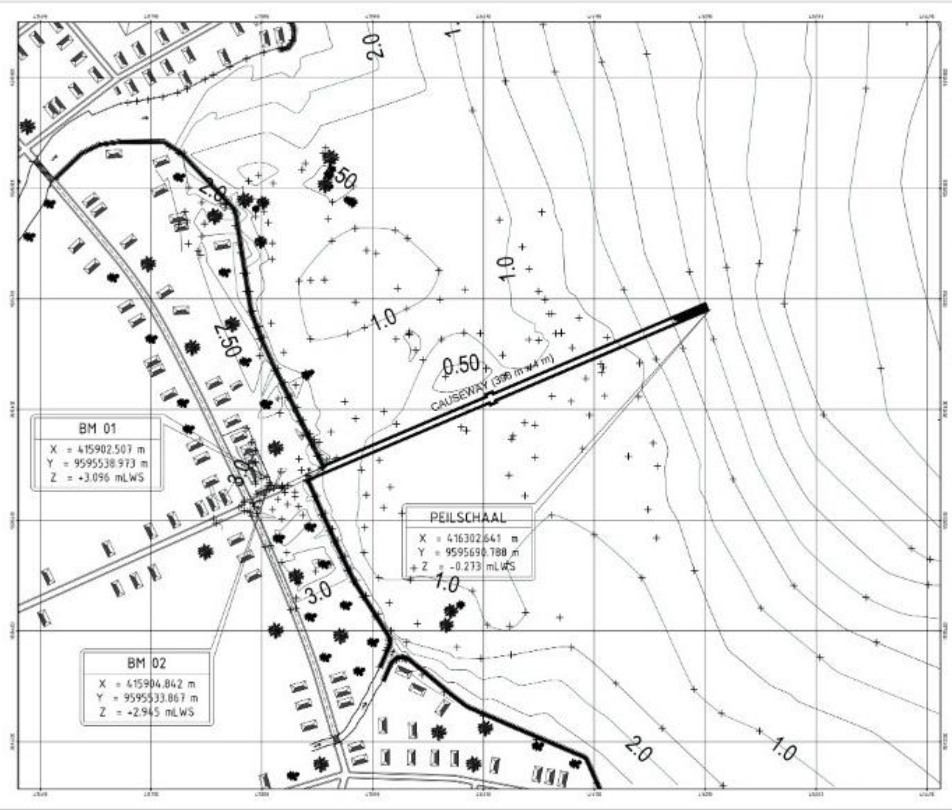

Figure 13. Map of the Topographic Survey Results for Tinobu Port

5 Tides

The tidal conditions in the study area will significantly influence the characteristics of waves, currents, and the planned sea level elevations, which will, in turn, determine the stability analysis of coastal structures and the determination of peak elevations. In connection with this, a study and analysis of tidal data have been conducted for each month over several years, and a summary of the results is provided in the attached Table. This study and analysis are based on tidal data at the location. To understand the variations in tidal characteristics along the coast, an analysis of tidal characteristics has also been carried out.

Fig 14. The Assembly Process of the Tidal Information Board at Tinobu Port

Fig 15. The Condition of the Tidal Information Board at High Tide

Tidal observations have been conducted for 15 days at the planned location. It is assumed that a 15-day or 1-month observation period is sufficient, as it is based on the concept that tidal occurrences are primarily driven by the gravitational interactions between the moon, Earth, and the sun. Tidal observations were conducted at the outer end of the causeway, specifically at coordinates UTM = 416312.821; 9595666.628. The observations began on Sunday, August 22, 2021, and continued until Sunday, September 5, 2021, spanning 15 days of continuous 24-hour observations.

Fig 16. Daytime Tidal Observations

Based on the graph of tidal observations, it can be seen that the tidal pattern at the location is a mixed semi-diurnal tide. To confirm the exact tidal type at the location, calculations are necessary using commonly used formulas. The field observation data for tidal measurements is presented in Table 3.11, and Figure 3.18 depicts the results of the tidal calculation.

Table 5. Table of Tidal Observation Results Over 15 Days

No	Date			Reading On Hour Scale																								Number of Readings	Readings
				00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23		Ave/day
1	22	August	2021	221	212	203	194	185	176	167	158	170	173	191.5	223.5	227	237.5	223	191.5	162.5	113	84	58	69	96.5	132.5	174.5	4043.00	168 46
2	23	August	2015	201	232	241	235	216	194	160	146	1305	152.5	172	2185	226	248	238	225	194	156	109	78	70	82	108	146	4178.50	174.10
3	24	August	2015	169	218	238	248	235	196	173	150	127	121.5	130	172	201	230	245	240	218	182	151	97	88	83	115	126	4153.50	173.06
4	25	August	2015	165	179	190	247	262.5	240	188	168	123	117	126	147	166	189	236	246	227	204	188	178	82	93	98	117	4176.50	174.02
5	26	August	2015	154	192	198	207	216	220	206	196	187	179	103	118	130	138	147	156	166	155	146	142	112	108	114	128	3818.00	159.08
6	27	August	2015	139	148	156	169	177	199	188	176	118	120	106	100	156	169	181	187	199	219	226	207.5	98	109	115	132	3794.50	158.10
7	28	August	2015	148	156	166	176	187	178	178	169	159	147	138	128	122	126	139	130	140	149	156	161	169	156	148	138	3664.00	152.67
8	29	August	2015	126	136	147	160	166	176	187	166	157	148	137	110	96	102	109	116	124	130	140	137	138	127	121	115	3271.00	136.29
9	30	August	2015	116	123	128	136	144	152	160	166	157	146	136	127	117	108	157	167	179	187	197	189	187	177	167	159	3682.00	153.42
10	31	August	2015	146	140	131	139	150	157	160	164	166	157	152	138	126	117	129	137	147	162	171	167	182	192	187	176	3693.00	153.88
11	1	September	2015	167	173	177	182	169	191	187	177	169	157	147	138	126	121	117	125	132	142	151	156	165	171	179	187	3806.00	158.58
12	2	September	2015	177	167	163	149	157	152	136	144	153	158	166	159	147	137	127	119	107	113	119	125	130	139	145	151	3440.00	143.33
13	3	September	2015	187	183	171	159	147	143	149	157	169	176	184	179	170	161	151	136	127	116	127	136	147	156	167	176	3774.00	157.25
14	4	September	2015	197	186	177	147	153	165	167	179	191	178	171	157	165	151	145	133	121	111	101	157	170	179	187	197	3885.00	161.88
15	5	September	2015	206	197	186	179	188	194	176	168	181	186	197	206	218	214	183	168	117	113	107	112	117	123	130	140	4006.00	166.92

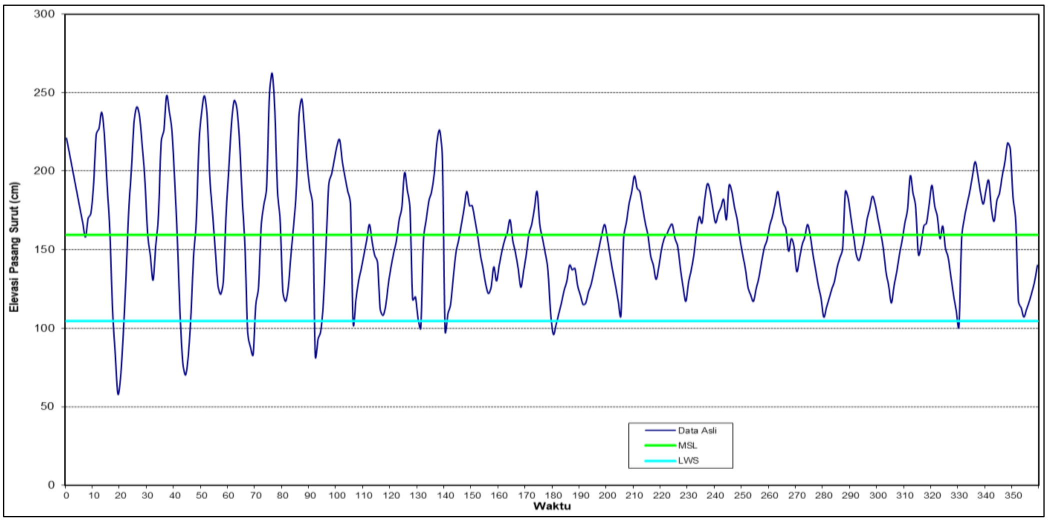

Fig 17. Graph of Tidal Calculation Results

Over the course of 15 days at Tinobu Port, observations of tides were made. To determine the type of tide, calculations were performed using the Formazalh formula to analyze the tidal components. Based on these calculations:

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

$$= \frac{15 + 9}{41 + 14} = 0.43$$

Based on the Formzhal value, the tidal criteria are:
Double daily mixed type tide (Mixed Tide Prevailingsemidiurnal)

The calculation yielded an F (Formashal) value >0.25, which means that the tide at the location is categorized as a mixed tide with a tendency towards semi-diurnal doubling (mixed tide prevailing semi-diurnal). This obtained tidal type aligns well with the common classification of tidal patterns in Indonesia, where other parts of Eastern Indonesia also fall under the mixed tide category with a tendency towards semi-diurnal doubling (refer to the tide classification map of Indonesian regions)

Fig 18. Map of Tidal Pattern Locations

Using the mentioned parameters, tidal forecasts for a period of 18.6 years have been generated. The forecast results indicate the important elevation levels around the planned construction site of Tinobu Port as follows.

Table 6. Important Elevation in Location Waters Refers to Lowest Low Water Level (LLWL)

Highest High Water Level	HHWL	:	109.3 cm
Mean Highest Water Level	MHWL	:	82.2 cm
Mean Sea Level	MSL	:	54.6 cm
Mean Lowest Water Level	MLWL	:	27.1 cm
Lowest Low Water Level	LLWL	:	0 cm

6. Wave

6.1 Wave Obeservations

To obtain the planned waves, the results of observations and measurements of waves directly on the beach are needed using simple measurements using eye observation, a measuring tank and a stop watch which requires up to four people as well as reading the level of the rise and fall of the waves, a time reader and note takers of the readings who read them simultaneously. endlessly intensive and second to second because the wave period is only in the range of 2 to 5 seconds per wave, up to tens of minutes per observation and in one day several observations are required which are also synchronized with tidal conditions, and these observations require several days length for each season. Therefore, such observations will not be consistent and accurate and will not be able to produce sufficient results for detailed planning or a planning system that can be relied upon as part of a long-term plan.

Taking wave or other oceanographic data for several days in certain months in certain seasons of the year will only be of academic benefit as additional knowledge of the conditions of oceanographic phenomena at that time and time will be used as a basis for planning or decision-making regarding actions that should be taken. carried out on major problems that must be addressed in the coastal/marine environment, it needs to be supported by additional/secondary data that is broader, more comprehensive, and detailed which contains key parameters that can indirectly replace the need for primary data. long and more detailed, while the results of direct observations obtained over a period of several days are only a complement to strengthening an assumption within certain limits.

If the planner considers that the data in a few days has become the basic primary data to be extrapolated to a larger scale so that it seems as if it can represent a random population whose time span covers decades without the support of other broader key secondary data, then the basis The validity of this idea needs to be further questioned unless the aim is to generate a further effort in academic exploration.

In connection with these considerations, the consultant has taken certain approaches related to wave observations and other parts of oceanography, which are required in accordance with the availability of funds and the desired planning target results. In this case, apart from field data, the survey results are also supported by wave conditions from wave forecasting results.

6.2 Wave Forecasting

6.2.1 Wind

Monthly wind data, information regarding its direction is needed as input in wave forecasting to obtain a wave plan. The wind data held by the consultant is monthly wind data from the Betoambari Meteorological Station, Bau-Bau City for the last 5 (five) years between 2018-2022. The monthly maximum Wind Event Speeds for the five years from 2018-2022 are shown below.

Table 7. Wind Events in 2018

Month	Maximum Speed	Direction	
		(…°)	Points of the Compass
January	9	280	W
February	7	270	W
March	7	272	W
April	7	162	S
Mey	7	283	W
Juny	6	100	E
July	8	100	E
August	8	100	E
September	8	270	W
October	7	275	W
November	7	270	W
December	7	274	W

Source: BMKG Betoambari Bau-Bau Station

Table 8. Wind Events in 2019

Month	Maximum Speed	Direction	
		(…°)	Point of the Compass
January	8	270	W
February	9	270	W
March	7	275	W
April	6	230	SW
Mey	5	65	NE
Juny	5	100	E
July	6	235	SW
August	7	90	E
September	7	90	E
Ovtober	7	240	SW
November	6	245	SW
December	7	230	SW

Source: BMKG Betoambari Bau-Bau Station

Table 9. Wind Events in 2020

Month	Maximum Speed	Direction	
		(……°)	Point of the Compass
January	6	312	NW
February	8	230	SW
March	7	241	SW
April	7	100	E
Mey	6	95	E
Juny	6	92	E
July	8	90	E
August	9	100	E
September	8	95	E
October	10	235	SW
November	7	230	SW
December	8	270	W

Source: BMKG Betoambari Bau-Bau Station

Table 10. Wind Events in 2021

Month	Maximum Speed	Direction	
		(……°)	Points of the Compass
January	8	270	W
February	7	220	SW
March	7	230	SW
April	6	100	E
Mey	7	225	SW
Juny	8	80	E
July	11	80	E
August	13	100	E
September	12	100	E
October	0	0	CALM
November	12	181	S
December	9	180	S

Source: BMKG Betoambari Bau-Bau Station

Table 11. Wind Events in 2022

Month	Maximum Speed	Direction	
		(……°)	Points of the Compass
Januari	7	170	S
Februari	7	270	W
Maret	8	180	S
April	6	98	E
Mei	8	150	SE
Juni	7	100	E
Juli	9	100	E
Agustus	10	90	E
September	9	80	E
Oktober	9	100	E
Nopember	9	160	S
Desember	8	270	W

Source: BMKG Betoambari Bau-Bau Station

The magnitude of wind speed and direction are presented visually in a windrose diagram. The dominant speed and direction comes from the west.

Fig 18. Wind rose year of occurrence 2018-2022

However, considering the condition of the planned location of Tinobu Port which is on the east coast, the representative wind direction and incidence are winds originating from the northeast, east and southeast. Then, an analysis will be made of the three wind directions that influence the condition of the port location to determine the wave height over the next 2-50 years.

7 Fetch

Fetch for the area around Tinobu Harbor reaches three cardinal directions, namely from the northeast, east and southeast. This is due to the fact that the planned position of the port is located on the east coast of Southeast Sulawesi, so that automatically the direction of the waves due to the push of the wind comes from the three cardinal directions.

Table 12. Effective fetch of Tinobu Port

α	cos α	X_i	X_i . Cos α
72	0.3090	8.5050	2.6282
66	0.4067	7.7180	3.1392
60	0.5000	8.1110	4.0555
54	0.5878	11.7600	6.9124
48	0.6691	12.3280	8.2490
42	0.7431	13.3990	9.9574
36	0.8090	1.9450	1.5735
30	0.8660	1.7420	1.5086
24	0.9135	1.7630	1.6106
18	0.9511	2.0840	1.9820
12	0.9781	83.9250	82.0910
6	0.9945	94.8940	94.3742
0	1.0000	1.1800	1.1800
6	0.9945	1.2140	1.2073
12	0.9781	1.1760	1.1503
18	0.9511	70.9210	67.4499
24	0.9135	5.0210	4.5869
30	0.8660	4.6520	4.0288
36	0.8090	4.0920	3.3105
42	0.7431	3.4080	2.5326
48	0.6691	2.7570	1.8448
54	0.5878	2.1720	1.2767
60	0.5000	1.7290	0.8645
66	0.4067	1.4490	0.5894
72	0.3090	1.2590	0.3891
	18.4563		308.4923

Source: Analysis Results
With Average Fecth Length = 16.71 km

To get a prediction of wave height, the fetch value is first determined using a formula:

$$F_{eff} = \frac{\sum X_i \cos\alpha}{\sum \cos\alpha}$$

From measuring the fetch length on the map, the value Feff = 16.71 km is obtained. For more details, see the following image.

Fig 19. Tinobu Harbor fetch length map

After getting the wind and fetch data, we can then determine the wave height and period using the wind speed and fetch data (see attachment) to obtain the Wave Height and Period. The prediction results for wave height and wave period from 2016 - 2020 are shown in the following table. Based on the wind direction, the dominant wave direction is East. The results of wave height calculations from wind speed data show that the wave height is significant.

8 Wave Height Analysis and Prediction

Waves that occur very often in the sea and are quite important are waves generated by the wind. Waves are generated by wind due to the transfer of energy from the wind to the sea surface due to fluctuations in air pressure on the sea surface. This generation process occurs in an area called the area where the wind speed increases, the ripples become larger and eventually currents (waves) will form. The longer and stronger the wind blows, the bigger the waves that form. The height and period of the waves formed depend on the wind speed, the length of the wind gusts and the wave generation distance (fetch).

In this study, wave height and period were predicted from the maximum wind speed over a period of 5 consecutive years and the maximum significant wave height obtained. Wave height predictions based on monthly maximum wind data recorded for 5 years are as follows.

Calculation of wave height (Ho) is calculated using the Wilson Method formula (Kiyoshi Horikawa p. 40, 1997), with the following equation:

$$\frac{g\,H_{1/3}}{{U_{10}}^2} = 0{,}3\left[1 - \left\{1 + 0{,}004\left(\frac{g\,F_L}{{U_{10}}^2}\right)^{1/2}\right\}^{-2}\right]$$

Table 13. Number of Waves based on Height Distribution on the East Coast (according to monthly maximum wind data) for 2018

Month	Wave Height		Direction
	H_s (m)	(...º)	Point of the compass
January	0.458	280	West
February	0.329	270	West
March	0.329	272	West
April	0.329	162	South
Mey	0.329	283	West
Juny	0.266	100	East
July	0.393	100	East
August	0.393	100	East
September	0.393	270	West
October	0.329	275	W
November	0.329	270	W
December	0.329	274	W

Sources : Analysis Result

Table 14. Number of Waves based on Height Distribution on the East Coast (according to monthly maximum wind data) for 2019

Month	Wave Heigth		Direction
	H_s (m)	(...º)	Point of the compass
January	0.393	270	W
February	0.458	270	W
March	0.329	275	W
April	0.266	230	SW
Mey	0.206	65	NE
Juny	0.206	100	E
July	0.266	235	SW
August	0.329	90	E
September	0.329	90	E
October	0.329	240	SW
November	0.266	245	SW
December	0.329	230	SW

Sources: Analysis Result

Table 15. Number of Waves based on Height Distribution on the East Coast (according to monthly maximum wind data) for 2020

Month	Wave Heigth H_s (m)	Direction (...°)	Point of the Compass
January	0.266	312	NW
February	0.393	230	SW
March	0.329	241	SW
April	0.329	100	E
Mey	0.266	95	E
Juny	0.266	92	E
July	0.393	90	E
August	0.458	100	E
September	0.393	95	E
October	0.524	235	SW
November	0.329	230	SW
December	0.393	270	W

Sources: Analysis Result

Table 16. Number of Waves based on Height Distribution on the East Coast (according to monthly maximum wind data) for 2021

Month	Wave Heigth H_s (m)	Direction (...°)	Point of the Compass
January	0.393	270	W
February	0.329	220	SW
March	0.329	230	SW
April	0.266	100	E
Mey	0.329	225	SW
Juny	0.393	80	E
July	0.590	80	E
August	0.725	100	E
September	0.658	100	E
October	0	0	CALM
November	0.658	181	S
December	0.458	180	S

Sources: Analysis Result

Table 17. Number of Waves based on Height Distribution on the East Coast (according to monthly maximum wind data) for 2022

Month	Wave Heigth H_s (m)	Direction (...°)	Point of the Compass
January	0.329	170	S
February	0.329	270	W
March	0.393	180	S
April	0.266	98	E
Mey	0.393	150	SE
Juny	0.329	100	E
July	0.458	100	E
August	0.524	90	E
September	0.458	80	E
October	0.458	100	E
November	0.458	160	S
December	0.393	270	W

Sources: Analysis Result

Table 18. Wave height and wave direction are based on a return period of up to 50 years

Direction of the incoming wave	Return Period (thn)				
	2	5	10	25	50
	Wave Height (m)				
Northeast Direction	0.046	0.075	0.094	0.118	0.14
East Direction	0.467	0.367	0.301	0.217	0.15
Southeast Direction	0.097	0.202	0.271	0.359	0.42

Sources: Analysis Result

The wave height obtained from the wave forecasting results is a plan wave that represents each year, considering that the port structure being built has a certain construction age, the wave height used is the return period wave height. To obtain the wave height for a certain return period, the Fisher - Tippett Type I distribution method is used. The results of calculating the wave height for the return period are as follows:

For construction purposes, a wave height with a return period of 50 years is used.

Fig 20. Rose diagram wave year of occurrence 2018-2022

Conclusion

Conclusions from the results of the research carried out by the author will provide several outputs or final results from this research process regarding the condition of the waters around Tinobu Harbor, including:

1. The existing conditions at Tinobu Port, especially the causeway, which is more than 30 years old, has experienced a lot of damage, so the facilities and functions at the Port should be developed.
2. The results of the bathymetric survey carried out around the waters of Tinobu Harbor have produced a map, which displays the water conditions and depth contours, where the depth of the waters of Tinobu Harbor to the front of the sacred island is between 1-17 meters from MSL.
3. The results of the topographic survey have also produced a topographic survey map which contains the land conditions of the Tinobu Port area as well as the elevation of the land and water contours which have been explained and limited by the elevation of the water contours through tidal calculations.
4. Based on the results of tidal observations that have been carried out at the research location, important elevations have been issued that will be used in determining the elevations of land and water buildings at Tinobu Port.
5. Based on wind data obtained from the BMKG Betoambari station, Bau-Bau Regency, the dominant speed and direction comes from the west, however, considering the condition of the planned Tinobu Port location on the east coast, the wind direction and occurrence that is used as representative is wind originating from the northeast, east and southeast. Then, from the three wind directions that influence port conditions, an

analysis will be made to determine the height of underwater waves in the next 2-50 years.

6. Wind data that is processed and analyzed to determine the size/height and direction of waves that are likely to impact Tinobu Harbor, will still be in safe condition for the next 50 years.

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