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Economic Study of Design Engineering Analysis Pipeline and SPM Study from Survey Data Meteorology and Oceanography at Unit VI Balongan

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Abstract: The offshore facilities to be developed include a submarine pipeline (SPL) along with a Single Point Mooring (SPM) System located in the waters around the RU-VI Balongan special port consisting of a Single Point Mooring System (Buoy, hawser, floating hose, underbuoy, chain , anchor, PLEM etc.) which are used for loading and unloading of 2 (two) products, with coordinate location plans of 06o 15' 51.52" S and 108o 25' 13.04" E. and two parallel onshore pipeline lines along approximately 2.5 km (from the RU-VI refinery boundary to landfall), followed by 2 (two) parallel submarine pipeline lines of approximately 11 km (from landfall to the SPM location). With the general scope of survey work consisting of: 1) Carrying out preparations, including obtaining survey permits; 2) Building a network of control points to support topographical survey work; 3) Conducting bathymetric surveys, subbottom profiling, sonar and magnetic side scans covering the marine pipeline corridor and the SPM area; 4) Carry out meteorological and oceanographic research (met-ocean) consisting of wind observations, air temperature observations, air humidity, tide observations, current observations, sea water temperature and salinity measurements; 5) Soil investigations at sea and on land; 6) Pipe routing; and 7) Data processing and preparation of reports on survey results. In this study, we focus more on the use of meteorological and oceanographic (met-ocean) data in studying economic analysis in the engineering design plans for the Pipeline Study and SPM.

Keyword: Economics, Pipeline Design Engineering-SPM, Met-Ocean.

INTRODUCTION

Pertamina unit VI Balongan is a strategic facility that will always be developed, in this case Pertmina Engineering Center Directorate of Processing, PT.PERTAMINA (PERSERO) carries out Geophysical & Geotechnical Study Consultancy and Pipeline & SPM System Design Engineering Analysis, Avtur Supply Project for Soekarno-Hatta Airport from Refiney Unit VI Balongan, West Java. This consulting work is based on Contract of Work No 127/E20220/2010-SO between KSO and PERTAMINA.

The facilities to be built are onshore and offshore facilities. Onshore facilities include tanks, piping systems and others located in the Refinery Unit VI (RU-VI) refinery area.

Offshore facilities include the submarine pipeline (SPL) along with the Single Point Mooring (SPM) System which are located in the waters around the RU-VI Balongan special port which consists of :

1. Single Point Mooring System (Buoy, hawser, floating hose, underbuoy, chain, anchor, PLEM etc.) which is used for loading and unloading 2 (two) products, with planned location coordinates 06o 15' 51.52" S and 108o 25' 13.04" N.
2. Two parallel onshore pipeline lines of approximately 2.5 km (from the RU-VI refinery boundary to landfall), followed by 2 (two) parallel submarine pipeline lines of approximately 11 km (from landfall to SPM location)(Noya et al., 2017).

The purpose of carrying out this consulting work is for the KSO to collect soil, bathymetry and met-ocean data (Offshore Geophysical & Geotechnical Data) as reference material in preparing the design basis. Then the consultant also carried out Pipeline Route Selection and Engineering Design Analysis as well as SPM Mooring Design (Anchoring System) which will then be used for the preparation of the Front End Engineering Design (FEED) package by the Engineering Center, whereas in this study the researcher only focused on the results of the met-ocean survey meteorological and oceanographic data(Tbk., 2010)(Monitor Global Energy, n.d.).

The goal is that the engineering package (FEED Package) made meets pipeline design quality standards (onshore & offshore) that are optimal from technical aspects (including constructability), operations and costs. Meanwhile, the SPM specification is the fulfillment of all operational and technical requirements from Pertamina (client/user) to be used as a specification for making SPM by the SPM designer (vendor)(DNV, 2021).

RESEARCH METHODS

The research method here uses quantitative, deductive, hypothetical data, namely taking data directly from the field in the form of survey activities using meteorological observation equipment in the form of installing meteorological stations, as well as floating facilities in the form of boats for oceanographic observations consisting of observations, currents, CTD and tides(Balitbang et al., 2017)(Saputra & ., 2010).

Meteorological Observations (Wind, Temperature and Air Humidity)

Observations of wind, temperature and humidity were carried out at 1 (one) station known as the Pertamina Balongan Special Port (Pelsus), about 10 kilometers northwest of the city of Indramayu. Observations using the MET-26800 Weather Station tool. The wind observation station uses a 10-meter high triangle-tower. Wind observations were made from 23 May 2010 to 26 June 2010 or for 34 days(Fadholi, 2012).

The coordinates of the wind observation station are:

Table 1. Meteorological observation coordinate position

No	Name STS	Coordinate UTM		Description
		Easting	Northing	
1	Weather Station	211 218.86	9 296 317.02	Height 10m

Wind speed and direction are measured using a mechanical wind recorder (anemometer) mounted at the top of the mast approximately 12m above sea level. The wind speed is based on the number of rotations of the rotating propeller due to the wind. The number of rotations per minute is then converted into speed units and recorded in the data system in the form of numbers. The stronger the wind, the number of rotations will increase, and vice versa. The data record variations will be visible on the record graph. The wind direction is determined by the direction of the wind vane instrument, where this direction is influenced by the tail which is located at the back of the instrument.

Air temperature and humidity are measured using the MET-26800 Weather Station, which is designed as a system with a wind gauge which will record the data when downloaded as a file with wind speed and direction data.

Data on wind direction and speed, temperature and humidity are recorded automatically and continuously every 15 minute period which is the average of 1 minute readings (burst). Wind data is downloaded once every 3 days as a means of control and at the same time processing data in stages in the field(Sorensen, 2006).

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Current Measurement

Profile current measurement using a measuring device Nortek Aquadopp Acoustic Doppler Current Profiler (ADCP). To obtain optimal current data, the tool is mounted on the seabed using a concrete ballast of around 100kg, which is equipped with a pole to place the tool vertically. Flow measurements began on June 23 2010, until July 26 2010, or for 32 days.

Around the current station is known as an area of local fishermen's activities as well, so to protect the equipment from possible disturbances, the equipment is guarded using a boat with an anchor near the station. Current data is downloaded once every 1 (one) week, as well as for cleaning the tool. Before installation, the tool is calibrated against the compass and pressure sensor.

Current measuring stations are as follows(Noya et al., 2017):

Table 2. Current measurement coordinate position

No	Name STS	Coordinate UTM		Depth (m) (LWS)	KP
		Easting	Northing		
1	CM#1	214 457.19	9 306 706.38	16.5	00+190
2	CM#2	212 272.32	9 301 858.46	8.3	05+480
3	CM#3	211 108.82	9 297 879.58	3.8	09+620

The equipment is set to measure and record current direction and speed data (in the form of "North" and "East" vectors, and the magnetic direction of the device) automatically every 15 (fifteen) minutes, with each data recording (burst) time of 60 second). The current measurement layer (cell) is set every 1.0m, starting from the first cell 1.0m above sea level, vertical to sea level(Miftachurrozaq, 2017).

Tidal Observation

A tidal station was established at the PERTAMINA Special Port (Pelsus) pier. Tides are observed automatically using a tide gauge Tide Master for 30 days continuously. Tidal data is recorded every 15 minutes, where each data record is the average of 60 seconds of observation (burst). Tide data is effectively obtained for 33 days, starting from 24 May 2010, 13:00 to 26 June 2010.

The coordinates of the tidal stations are as follows:

Table 3. Tidal observation coordinate position

No	Name STS	Coordinat UTM		Description
		Easting	Northing	
1	Tide Station	211 381.75	9 296 336.28	Jetty Corner

Tidal data is downloaded every 2 (two) days to check the results of observations and the need to reduce the results of the bathymetric survey. Before being installed, the tool is calibrated first.

CTD Measurement (Conductivity, Temperature, Density, Depth)

Conductivity, Temperature and Depth (CTD) measurements are carried out once a week with a duration of 12 (twelve) hours at each station, using the Alec Compact CTD. When you have finished measuring at one station, the measurement is continued to the next station so that in one period, the total length of measurement is 36 hours.

CTD measurements were carried out at three stations as follows:

Table 4. CTD measurement coordinates position

No	Nama	Koordinat UTM		Kedalaman (LWS)	KP
		Easting	Northing		
1	CTD#1	214 457.19	9 306 706.38	16.5	00+190
1	CTD#2	212 272.32	9 301 858.46	8.3	05+480
1	CTD#3	211 108.82	9 297 879.58	3.8	09+620

CTD measurements are carried out in profile and automatically from the deck of a ship that is anchored at the measurement station. Nylon rope is prepared in advance on the ship, and tied to the tool. The water depth at the measuring station is known during the bathymetric survey.

The measurement time for each station is as follows:

Table 5. CTD measurement period

No	Nama STS	Measurement Period		Period
		From	Untill	
1	CTD#1	02 Juni 2010; 22:00 09 Juni 2010; 22:00 18 Juni 2010; 22:00	03 Juni 2010; 09:00 10 Juni 2010; 09:00 19 Juni 2010; 09:00	1 2 3
2	CTD#2	03 Juni 2010; 10:00 10 Juni 2010; 10:00 19 Juni 2010; 10:00	03 Juni 2010; 21:00 10 Juni 2010; 21:00 10 Juni 2010; 21:00	1 2 3
3	CTD#3	02 Juni 2010; 10:00 09 Juni 2010; 10:00 18 Juni 2010; 10:00	02 Juni 2010; 21:00 09 Juni 2010; 21:00 18 Juni 2010; 21:00	1 2 3

Measurements are made by slowly lowering the tool using a nylon rope with manual control, at the same time the CTD tool records data continuously. The lowering of the rope stops when the device reaches approximately 1.0m above the seabed as indicated by the length of the rope. The tool is then pulled back slowly up to sea level. This process is carried out once every 1.0 hours, for 12 hours for one CTD station.

After completing CTD observations at one station, the boat then moves to the next stations, until all stations are fully observed. Observation procedures at other stations are the same as the previous station.

Secondary Data Collection

Meteorological secondary data collection includes: Wind Speed and Direction, Air Temperature, Air Humidity and Rainfall, for 10 years (period 1999 – 2008). Secondary data collection was taken from the Cirebon BMKG station (the closest station to Balongan).

The wind data analyzed is the daily maximum wind speed and direction magnitude. Data processing is carried out in a statistical manner to calculate the number and percentage of events against the classification of direction and maximum wind speed every month, every season and the whole time in that time interval(Tbk., 2010)(Pertamina engineering center, 2010).

Wind directions are classified into eight cardinal directions, namely North, Northeast, East, Southeast, South, Southwest, West and Northwest. Based on this classification, the frequency distribution of each particular wind speed and direction is calculated and then tabulated in a table and depicted in the form of a wind rose, as shown in tables and figures.

Equipment Calibration and Validation

1. Automatic weather Station

   Measurements of wind direction and speed, temperature, pressure and humidity were observed using the MET-26800 Automatic Weather Station. Each tool sensor has been calibrated by the factory. In order to function optimally, the tool is installed in an open area, with a minimum wind sensor height of 10m from the ground.
2. Current profiler

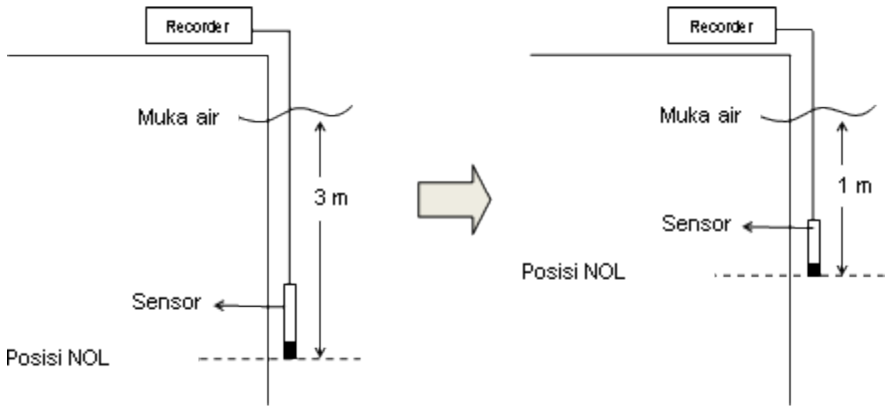
   Profile current measurements were carried out using a Nortek Aquadopp 600kHz Acoustic Doppler Current Profiler (ADCP). Calibration of the tool is carried out on the pressure sensor and magnetic compass.

   When carrying out the calibration of the pressure sensor, the device is lowered into the water using a rope at a known depth. Previously the tool was connected to a computer and operated in "real-time". The depth reading is then adjusted to the depth of the tool (the length of the rope from sea level). After being set, then validation is carried out in the same way, and compared with depth readings.

   The tool will be installed on the seabed (seabed mounted) using concrete moorings. Compass calibration is carried out with the instrument mounted on its mooring and by ensuring that the instrument is protected from the possibility of any equipment containing magnetic material. Calibration is carried out by rotating the device connected to the computer, 360 degrees clockwise, and slowly. When finished, angle correction is set in the tool; Now the tool has been calibrated.

   Still in a position connected to the computer, the tool is run in "real-time", then the tool is directed parallel to the ship's bow to compare its direction. The tool is then rotated perpendicular to the bow of the ship, and the direction of the tool read on the computer also shows the same change.
3. Tide Gauge

   Tidal observations were made using the Valeport TideMaster Automatic Tidegauge tool. Equipment calibration is carried out through the "Site Calibration" facility in the Tidelog software. The calibration implementation diagram is as follows:



Picture 1. Valeport 740 Tide Gauge Calibration Stages

Validasi atas hasil kalibrasi dilakukan dengan menempatkan sensor tekanan pada kedalaman tertentu, kemudian membandingkan hasil pembacaan dengan kedalaman sebenarnya.

4. CTD

Conductivity, Temperature Density and Depth (CTD) measurements using the Alec Compact CTD tool. The tool consists of conductivity, temperature and pressure sensors, where each tool sensor has been calibrated by the factory. The measurement activities in the field were not calibrated.

FINDINGS AND DISCUSSION

Processing and analysis of meteorological data is intended to obtain summary and descriptive statistics within the available data range. Wind speed and direction are processed to provide total monthly wind speed and direction and their frequency distribution. With this aim, the objective of getting an overview of the character of the meteorological conditions in the survey area can be fulfilled.

Current data processing can be calculated from ADCP measurement tools and then analyzed by combining tidal data(Michael E. McCormick, Ph.D., Sc.D., 1973)(Indonesia, 2009)

.Wave data processing using the above formulation can calculate the height and period of the waves. The results of calculating the height and period of these waves are then arranged according to the percentage of the frequency of their occurrence in the 8 cardinal directions. Tables of the percentage of frequency of occurrence of wave height and the percentage of frequency of occurrence of wave periods and their pictures are presented in the attachment(Pranowo, 2016).

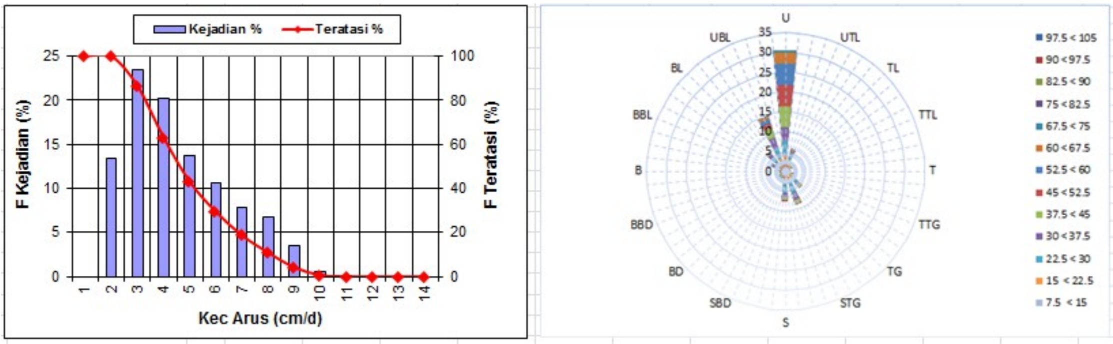
Current Profile

1. Current Station CM-1

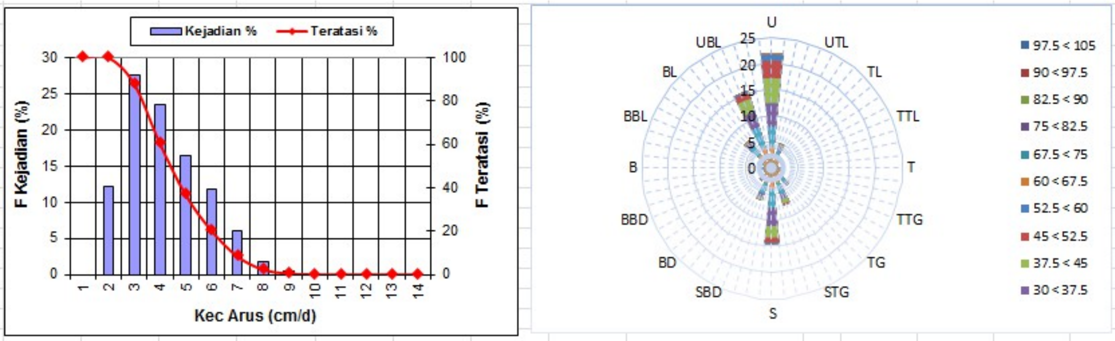
Table 6. Current Statistic Analysis-CM-1

Current Speed (cm/s)	CURRENT DEPTH		
	Bottom (2.5m)	**Middle (9m)**	**Surface (15m)**
Maximum Speed	45,0	56,3	67,6
Statistic Speed :			
90%	25,5	36,3	45,7
80%	22	32	42,94
70%	19,5	27,5	35,8
60%	17	23,5	28,88
50%	14,8	19,6	22,1
40%	12,7	16,1	17
30%	10,5	13,04	12,94
20%	8,1	10	9

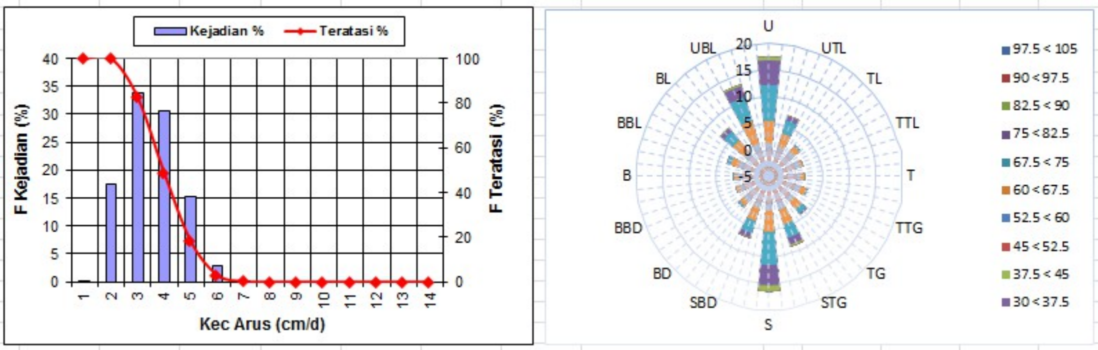
10%	5,3	6,8	5,68
Mean Speed	15,3	21,2	25,4
Minimum Speed	0,0	0,1	0,2



Picture 2. Scater Current Rose-CM-1 Surface



Picture 3. Scater Current Rose-CM-1 Midlle



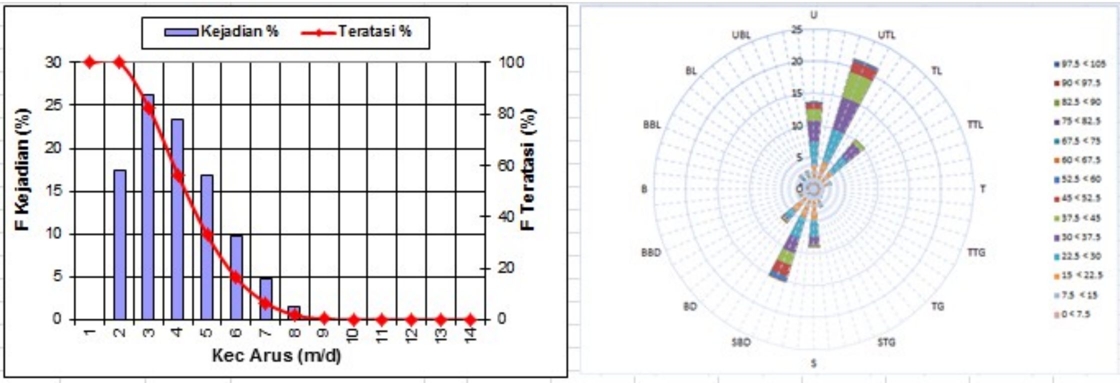
Picture 4. Scater Current Rose-CM-1 Bottom

2. Current Station CM-2

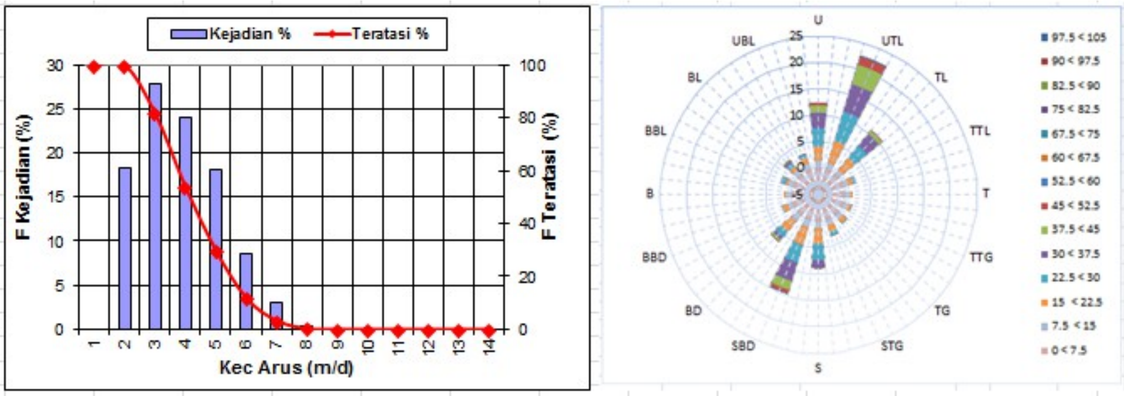
Table 7. Current Statistic Analysis-CM-2

Current Speed (cm/s)	CURRENT DEPTH		
	Bottom (2.5m)	**Middle (4.5m)**	**Surface (7m)**
Maximum Speed	379,6	50,1	57,7
Statistic Speed :			
90%	24,7	30,9	34
80%	21	24,6	26,9
70%	18,4	20,7	22,5
60%	16,3	17,6	18,98
50%	14,3	14,9	15,9
40%	12,1	12,3	13
30%	10,1	9,9	10,3
20%	8	7,5	7,6
10%	5,4	4,9	4,8

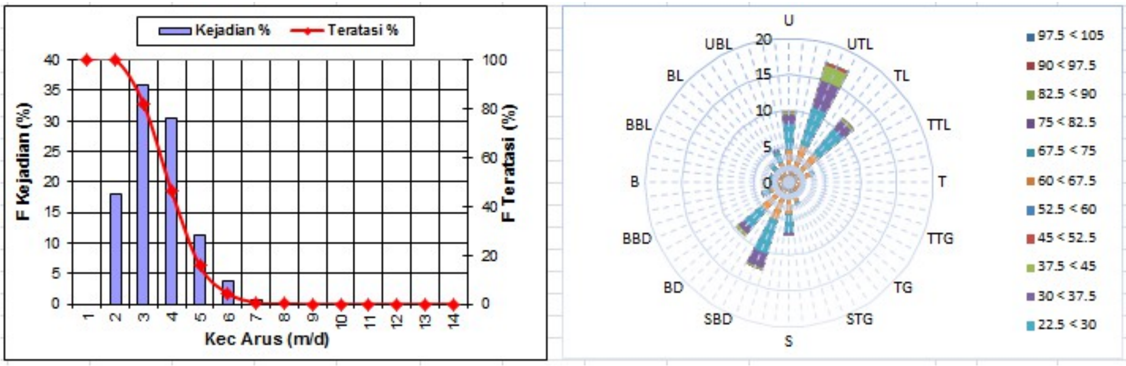
Mean Speed	15,0	16,2	17,9
Minimum Speed	0,1	0,2	0,2



Picture 5. Scater Current Rose-CM-2 Surface



Picture 6. Scater Current Rose-CM-2 Midlle



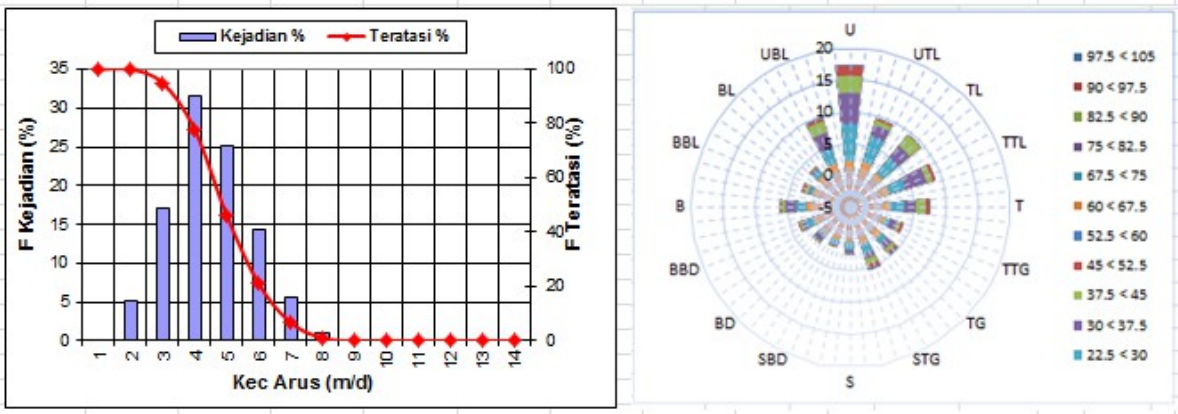
Picture 7. Scater Current Rose-CM-2 Bottom

3. Current Station CM-3

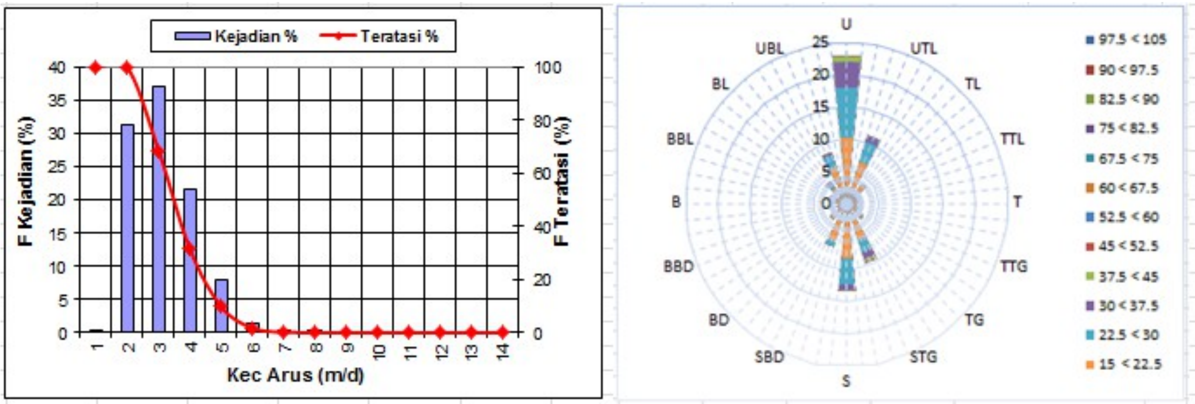
Table 8. Current Statistic Analysis-CM-3

Current Speed (cm/s)	CURRENT DEPTH	
	Bottom (2m)	Surface (3m)
Maximum Speed	51,6	52,2
Statistic Speed :		
90%	21,2	27,1
80%	16,9	19,14
70%	13,9	12,3
60%	11,4	0,5
50%	9,1	0,5
40%	6,86	0,5
30%	4,6	0,5

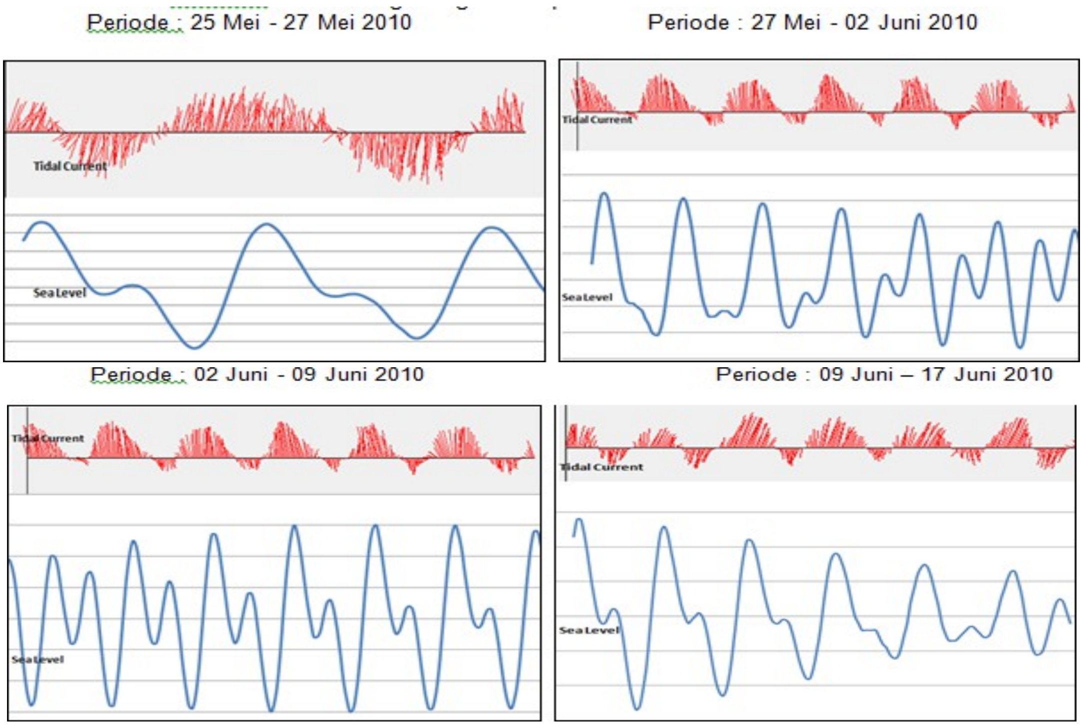
20%	1,88	0,5
10%	0,5	0,5
Mean Speed	10,1	7,9
Minimum Speed	0,0	0,5

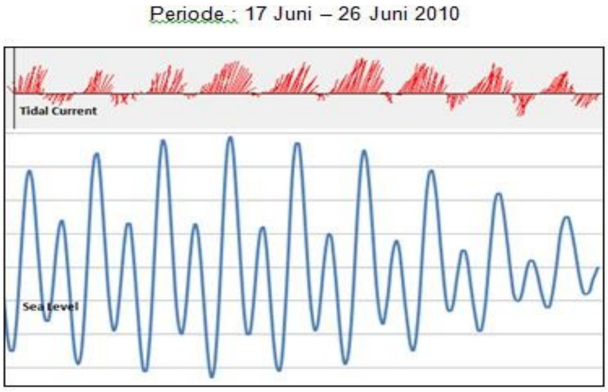


Picture 8. Scater Current Rose-CM-3 Surface



Picture 9. Scater Current Rose-CM-3 Bottom



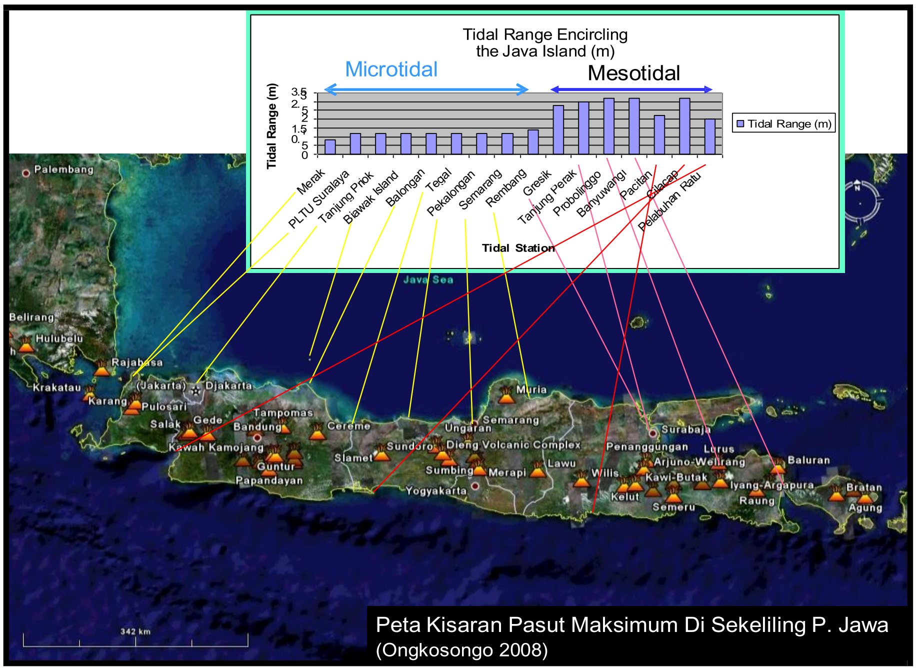


Picture 10. Correlation of currents and tides during observations

Tide Tidal

The general condition of the tides in the coastal waters of West Java, the phenomenon of the tides in the waters of Indramayu-Balongan also shows the characteristics of the tides in shallow water, namely the influence of the dominant factor of the oscillating tidal waves in their distribution. Throughout its propagation, wave oscillations are affected by the depth of the ocean, so these waves are called shallow water tides(Clay et al., 1978).

To determine the characteristics of the tides in Indramayu-Balongan waters, a tide analysis is performed to calculate the harmonic constants, namely calculating the amplitude and phase lag of each tidal constant. The purpose of the tidal analysis is to obtain some useful information needed to predict sea level variations in the survey area and its surroundings. Tidal information will be very useful in determining design criteria for pipeline plans.



Picture 11. Map of Maximum Tidal Range around Java Island.

The maximum tidal range in Balongan is only less than 1.4 m, so the waves hitting the beach are relatively small.

The tidal wave factor in the waters is influenced by the moon, the sun and the gravity of other celestial bodies, which is called the astronomical factor, and along the propagation the spread is influenced by the topography of the seabed and the morphology of the coast as well as meteorological conditions. Tidal elevation is the sum of the tidal components and meteorological factors which are assumed to be constants, as shown in the following equation:

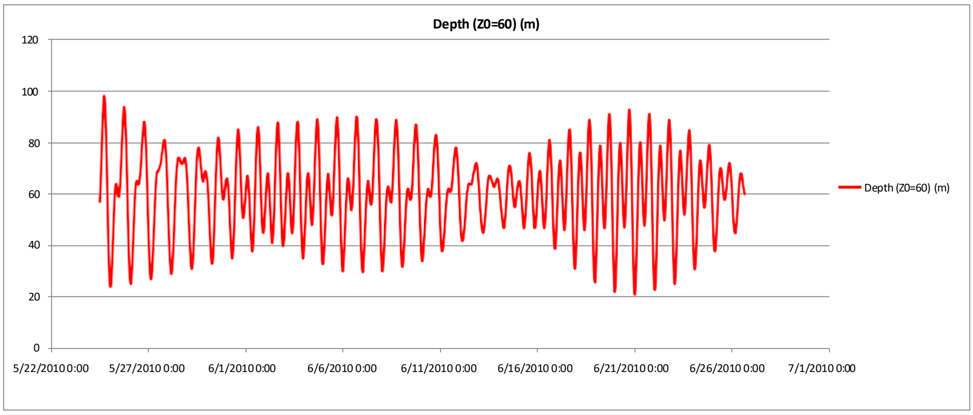
$$\eta(t) = S_0 + SS_0 + \sum_{i=1}^{N} A_i \cos(\omega_i t - P_i) \qquad (1\text{-}1)$$

Table 9. Tidal Constants of Balongan PELSUS Station

Konstanta	S0	M2	S2	N2	K2	K1	O1	P1	M4	MS4	Z0
Amplitudo H (cm)	1.90	0.14	0.09	0.04	0.03	0.19	0.06	0.12	0.002	0.004	0.60*
Phase g (°)	-	320	143	267	101	17	138	174	36	240	-

Table 10. Tidal Harmonic Analysis

DESCRIPTION		DEPTH (cm)
HAT	Highest Astronomical Tide	62
MHWS	Mean High Water Spring	50
MHWN	Mean High Water Neap	30
MSL	Mean Sea Level	0
MLWN	Mean Low Water Neap	-32
MLWS	Mean Low Water Spring	-51
Z0/CD/LWS	Chart Datum/Lowest Astronomical Tide	-60



Picture 12. Tidal Curve

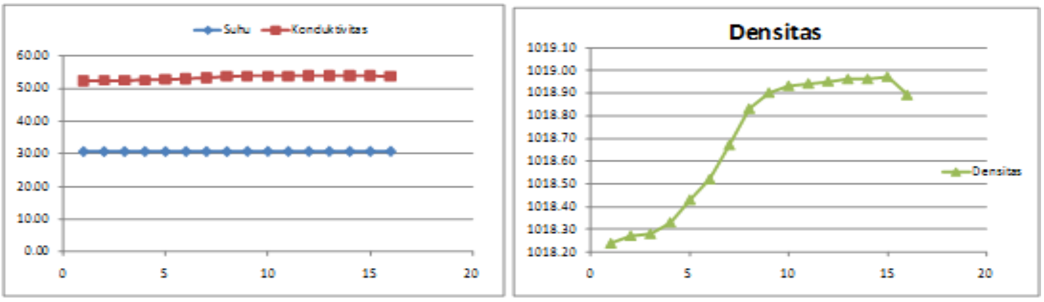
CTD

The CTD data recorded in the tool's memory is downloaded and then displayed in graphical and tabular form. A summary of the results is as follows:

Table 11. Average CTD observations for each depth layer

Sea Depth (m)	CTD OBSERVATION			
	Water Temperature (°C)	Salinity (ppm)	Conductivity (mS/cm)	Density (kg/m^3)
0-1	30.61	30.61	52.37	1018.24
1-2	30.62	30.65	52.45	1018.27
2-3	30.62	30.66	52.46	1018.28
3-4	30.63	30.73	52.57	1018.33
4-5	30.63	30.86	52.77	1018.43
5-6	30.65	30.98	52.97	1018.52
6-7	30.62	30.66	53.29	1018.67
7-8	30.62	30.68	53.65	1018.83
8-9	30.68	31.48	53.77	1021.52
9-10	30.68	31.52	53.83	1018.93
10-11	30.68	31.53	53.85	1018.94
11-12	30.68	31.54	53.87	1018.95
12-13	30.68	31.55	53.87	1018.96
13-14	30.68	31.55	53.88	1021.60

14-15	30.68	31.54	53.87	1018.97
15-16	30.68	31.43	53.69	1018.89
MAXIMUM	30.68	31.55	53.88	1021.60
MEAN	30.65	31.12	53.32	1019.02
MINIMUM	30.61	30.61	52.37	1018.24



Picture 13. Graph of Temperature, Conductivity and Density CTD measurement results

The average temperature in Balongan waters is 30.65°C, the temperature range as shown in the table above looks a bit high for coastal waters (LIPI Oceanographic Environment, 1993). The high maximum temperature which reached 30.68°C is almost significant with the average water temperature value, made possible because the research area is located close to the river water outlet around the survey area, where in the outlet area there is turbulence (mixing of water) from the river to sea water which results in underwater temperature is rather high so that it affects the temperature of the surrounding area.

Meteorology

1. Wind Speed-Gust Direction

Table 12. Analisa wind speed-wind gust maksimum dan dominan

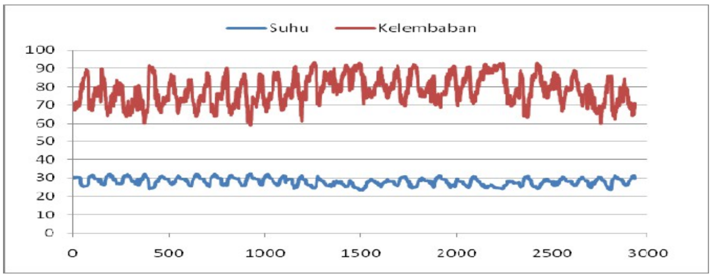
PARAMETER	Wind Speed		Wind Gust	
	(knot)	(m/d)	(knot)	(m/d)
Maximum Speed	20,10	10,34	33,17	17,06
0,9	9,10	4,68	15,02	7,72
0,8	7,70	3,96	12,71	6,54
0,7	6,20	3,19	10,23	5,26
0,6	5,50	2,83	9,08	4,67
0,5	4,00	2,06	6,60	3,40
0,4	4,00	2,06	6,60	3,40
0,3	3,30	1,70	5,45	2,80
0,2	2,60	1,34	4,29	2,21
0,1	1,80	0,93	2,97	1,53
Minimum Speed	0,00	0,00	0,00	0,00
Mean Speed	4,92	2,53	8,11	4,17
Std Deviasi	2,95	1,52	4,87	2,51
Total Data / F	2933,00	2933,00	2933,00	2933,00
SQRT	54,16	27,86	54,16	27,86
Std Error	0,05	0,05	0,09	0,09
CI-95%	0,11	0,11	0,18	0,18
Orientation Dominant Speed and Direction:				
Dominant Wind Speed	20,10	10,34	33,17	17,06
Mean Dominant Speed	5,69	2,93	9,39	4,83
Mean Dominant Direction	111,00	111,00	111,00	111,00

Picture 14. Wind speed and wind gust rose

2. Temperature and Humidity

Table 13. Air temperature-humidity analysis

PARAMETER	Air Temperature °C	Humidity (%)
Maximum	32,60	93,10
0,9	30,40	89,10
0,8	29,80	85,60
0,7	29,20	83,00
0,6	28,70	80,00
0,5	28,10	77,90
0,4	27,50	75,70
0,3	26,70	73,40
0,2	26,00	71,10
0,1	25,30	68,30
Minimum	23,70	59,20
Mean	27,96	78,24
Mean Dominant	28,10	77,90
Std Deviation	1,93	7,56
Total Data / F	2933	2933
SQRT	54,16	54,16
Std Error	0,04	0,14
CI-95%	0,07	0,27



Picture 15. Observation Data of Temperature vs Humidity

Wave

1. Prediksi Gelombang Data Pengamatan Kecepatan Angin

   Prediksi gelombang juga dilakukan terhadap data hasil pengamatan selama 1 (satu) bulan (pengamatan AWS), yaitu dari 23 Mei 2010 sampai dengan 24 Juni 2010(Tbk., 2010)(Hemsley, 2001)(Hasselmann et al., 1976).

Table 14. Analisa gelombang berdasarkan data kecepatan angin

Category		Wave Heights		
		Significant (Hs)	Maximum (Hmax)	Significant Storm (Hstorm)
Maximum (m)		1.11	2.06	2.84
Percentile (m) :	90%	0.52	1.14	2.11
	80%	0.47	1.00	1.68

70%	0.44	0.89	1.33
60%	0.41	0.80	1.22
50%	0.38	0.71	1.05
40%	0.33	0.61	0.94
30%	0.30	0.51	0.82
20%	0.22	0.41	0.67
10%	0.11	0.27	0.44
Minimum (m)	0.01	0.02	0.12
Mean (m)	0.39	0.77	1.20
Standard Error of mean (m)	0.0007	0.0014	0.002
Standard Deviation (m)	0.19	0.36	0.46
Zero Crossing Wave Period (Tz)			
Maximum Tz (sec)	3.00	3.50	4.30
Percentile Tz (sec) : 90%	2.10	3.10	4.30
80%	2.00	2.80	4.30
70%	1.90	2.60	4.30
60%	1.80	2.40	4.30
50%	1.80	2.30	4.30
40%	1.70	2.20	4.30
30%	1.60	2.10	4.30
20%	1.40	2.00	4.30
10%	1.00	1.80	4.30
Minimum Tz (sec)	0.30	0.30	0.20
Mean Tz (sec)	1.70	2.40	4.30
Standard Error of mean (sec)	0.01	0.01	0.01
Standard Deviation (sec)	1.30	1.80	1.70
Peak Wave Period (Tp)			
Maximum Tp (sec)	4.00	4.40	4.72
Percentile Tp (sec) : 90%	2.70	3.40	4.72
80%	2.60	3.20	4.72
70%	2.50	3.10	4.72
60%	2.40	3.00	4.72
50%	2.30	2.80	4.72
40%	2.20	2.60	4.72
30%	2.10	2.50	4.72
20%	1.80	2.30	4.72
10%	1.30	1.90	4.72
Minimum Tp (sec)	0.40	0.40	0.40
Mean Tp (sec)	2.30	2.80	4.72
Standard Error of mean (sec)	0.01	0.01	0.01
Standard Deviation (sec)	1.70	2.10	1.50

2. Secondari Data Wave

Maximum and Significant Wave Height as well as dominant wave period and direction in Balongan Waters based on 10 year wind data forecast (1999 – 2008)(Rijn, 1993)(Tbk., 2010)(Endeco, 1984)(Hasselmann et al., 1976).

Table 15. Analysis of maximum and significant wave height and period in Balongan waters based on Bretschneider analysis

BRETSCHNEIDER WAVE	SIGNIFICANT	MAXIMUM	STORM	UNIT
Wind Above 10 m	10.5	10.5	10.5	m/s
Depth	18	18	18	m
Fetch	200	200	200	Km
Storm Duration	120	120	120	Hour

Wave Length (m)	19.58	27.23	33.98	m
Wave Height (m)	1.19	2.08	2.71	m
Wave Period (sec)	3.7	4.2	4.8	s
Zero Crossing Periode (s)	2.8	3.2	4.1	s
Wind Speed (Beufort Scale)	5	5	6	BFT

Table 16. Meteorological and oceanographic analysis of return periods

SUMMARY OF MET-OCEAN INFORMATION					
Metocean Parameter			**Return Period (Years)**		
Item	**Notation**	**Unit**	**1**	**10**	**100**
Wind Speed					
60-minute mean	U_{60}	m/s	10.42	10.89	11.72
1-minute mean	U_1	m/s	10.94	11.44	12.31
3-second gust	U_{gust}	m/s	17.14	17.61	18.44
Wave Height					
Significant wave height	H_s	meters	1.27	1.74	2.57
Significant wave period	T_s	s	3.78	4.25	5.08
Significant wave length	L_s	meters	19.66	20.13	20.96
Maximum individual wave height	H_{max}	meters	2.16	2.63	3.46
Maximum individual wave period	T_{max}	s	4.28	4.75	5.58
Maximum individual wave length	L_{max}	meters	27.31	27.78	28.61
Wave Steepness					
Significant wave steepness	$(H/L)_s$		0.065	0.087	0.123
Maximum individual wave steepness	$(H/L)_{max}$		0.079	0.095	0.121
Water Level					
Astronomical tide:					
• Highest (above MSL)	HHWL	meters	0.62		
• Lowest (below MSL	LLWL	meters	0.60		
Storm surge (above MSL)	η	meters	TBA		

CONCLUSION

Wind Analysis

In general, wind patterns in Balongan and its surroundings can be divided into 4 patterns based on the season(AVISO, n.d.)(BMKG, n.d.), namely:

1. West season (December, January, February)

   In December, January and February the dominant wind direction is from the west (42.61%), northwest (23.77%), southwest (11.24%) and north (11.14%) with a dominant speed of 5-7 m/s (38.24%), 3-5 m/s (28.87%) and 7-9 m/s(19.30%). This happens because of the influence of the northeastern trade winds where the wind comes from the high pressure area at 30o latitude to the low pressure area at the equator.

2. Transitional season 1 (March, April, May)

   The influence of the sun's movement from south to north in March, April and May causes a transition to change the direction the wind blows. In the Balongan area, during the first transitional season, the dominance of the west monsoon began to decrease, although it remained dominant with the composition of the wind direction, namely northeast (18.93%), west (16.71%), north (14.24%) and east (12.90%).

   Meanwhile, in terms of wind speed, transition season 1 also shows a reduction from the west season where the percentage of wind blowing at speeds of more than 11 m/s decreases from 4.87% to 0.97%, besides that, the percentage of wind speed ranges from 3-5 m/sec increased to 42.72% and the 5-7 m/s range increased to 41.20%, while the wind speed range of 7-9 m/s decreased to 2.93%. Dominant speed in the range of 3-5 m/s is 42.72%.

3. East season (June, July, August)

Changes in the pattern of wind blowing direction from the west season and transition 1 are seen in this east season, where the dominance of the wind direction comes from the northeast (27.69%), east (22.68), southeast (150.24%) and south (14.05%) exceeding the percentage of wind that coming from high latitudes, this is due to the influence of the southeastern trade winds where a high pressure area is formed at 30o LS. The wind speed also decreased during this east season, namely in the range of 3-5 m/s (46.21%), the range of 7-9 m/s decreased to 9.03% and the range of 9-11 m/s decreased to 1.41%.

4. Transitional season 2 (September, October, November).

   The influence of the sun's movement from north to south in September, October and November causes a transition to change the direction the wind blows. In the Balongan area, during the second transitional season, the dominance of the east monsoon begins to decrease, although it remains dominant with the composition of the wind direction, namely south (19.96%), north (19.86%) and northeast wind (19.26%). Dominant wind speed does not show significant changes. As in the east monsoon, where the dominant wind speed is in the range of 3-5 m/s (45.89%) and 5-7 m/s (40.08%).

   The annual Windrose pattern for total wind data for 10 years shows that the East wind is the dominant wind with an occurrence frequency of 17.99%. Followed by the second dominance from the northeast with an incident frequency of 16.90%. While the north and south winds have a frequency of 14.15% and 12.62%, respectively. Dominant speed in the range of 3-5 m/s and 5-7 m/s with a frequency of 40.76% and 40.27% respectively. So that the wind speed in the range above only occurs with a relatively small frequency, for example in the range of 9-11 m/s the frequency is only 3.60%(Pertamina engineering center, 2010)(Boyun Guo, PhD, Shanhong Song, Ph.D., Ali Ghalambor, PhD, Tian Ran Lin, PhD, 2005).

Wave Analysis

Secondary Data Forecasting 10 years.Wind speed and direction are used to estimate areas most potentially affected by coastal erosion, as well as those that disrupt operations in marine waters. Estimated using the 1952 Sverdrup, Munk, and Bretschneider (SMB) nomogram(Tbk., 2010)(Boyun Guo, PhD, Shanhong Song, Ph.D., Ali Ghalambor, PhD, Tian Ran Lin, PhD, 2005).

The location of Balongan Beach is a beach facing the open sea in the north, relatively open in the east, while in the west it is protected by (Cape Berakit). The position of the selected review point is 108.5 ◦East Longitude, 6.2 ◦North Latitude,(Puspitorini, 2017)

In general, wave patterns on Balongan Beach and its surroundings can be divided into 4 patterns based on the season, namely:

1. West season (December, January, February)

   In December, January and February the dominant wind direction is from the west (42.61%), northwest (23.77%) and southwest (11.24%) with a dominant speed of 5-7 m/s (38.24%), 3-5 m /sec (28.87%) and 7-9 m/sec (19.30%). With fetch lengths from the northwest (115953.71 m), north (119443.07 m) and northeast (95030.09 m), the waves from the west dominate with the number of occurrences reaching 42.59%, followed by waves from the northwest with a percentage of 23.76%. The dominant wave heights are between 0.6-1.0 m (23.06%), 1.0-1.4 m (19.87%) and 0.2-0.6 m (14.33%). The dominant wave period is 7-9 sec (41.17%) and 5-7 sec (21.98%), the wave height in the west season is the largest compared to the wave heights in other seasons, with the highest occurrence of waves with a height of more than 2.2 m, namely 6.24%.

2. Transitional season 1 (March, April, May)

   The influence of the shifting direction and wind speed during transition season 1 causes the direction of the waves to change and there is almost no domination of the direction, namely northeast (18.93%), west (16.71%), north (14.24%) east (12.82%) and northwest (9.49%). While the dominant wave height is still relatively the same, namely between 0.6-1.0 m (23.64%) and 1.0-1.4 m (20.66%), 0.2-0.6 m (19.25%). Dominant wave period 7-9 sec (35.81%), 5-7 sec (27.57%) and 9-11 sec (5.84%).

3. East season (June, July, August)

   In the east monsoon the dominant wave directions are northeast (27.68%), east (22.43%) and north (11.69%). With the dominant wave height in the range of 0.6–1.0 m (23%), followed by the range of 0.2-0.6 m (20.10%) and 1.0-1.4 m (19.77%). The dominant wave period occurs in the range of 5-7 m/s (30.17%) and 7-9 m/s (29.29%).

4. Transitional season 2 (September, October, November).

   It can be seen again the strengthening of the waves, where the dominant wave height is between 1.0-1.4 m (22.82%) and 0.6-1.0 m (19.53%). The dominant wave period is 7-9 sec (35.12%) and 5-7 sec (20.04%). The direction of the dominant wave comes from the north (19.86%) and northeast (19.26%)(Pertamina engineering center, 2010).

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