IDSL (Inexpensive Device for Sea Level) performance analysis for tews (Tsunami Early Warning System) in Sadeng fisheries port

Dian Novianto1*, Semeidi Husrin1, Dwiyoga Nugroho1, Rikha Bramawanto1, Agus Setiawan1, Sofiyan M. Permana1, Agus Suhyan1, Daud SA. Sianturi1, Donal Daniel1, Ifan Ridlo Suhelmi1 and Syarifah Fauzah2

1Marine Research Centre - Ministry of Marine Affairs and Fisheries (MMAF), Jakarta - Indonesia
2Oceanography Program, Bandung Institute of Technology - Bandung - Indonesia

Email: dian.novianto@kkp.go.id

Abstract. Inexpensive Device for Sea Level Monitoring or IDSL is one of TEWS devices operating in Indonesia for more than two years, monitoring real-time on a 24/7 sea level and providing email, SMS alerts, CCTV images, and information about a potential event of a tsunami. This paper aims to analyze the device’s performance at Sadeng Fisheries Port based on critical parameters for tsunami early warning systems such as data quality, latency time, the quality of CCTV images, and the release of warning capabilities. The results show that the tidal range at spring tide is about 3.19 m, in line with BIG tidal station data. These data also indicate that the minimum tide height is 0.06 m and the maximum tide height is 3.25 m. Performance results show a total data gap of 1717 data gaps with a minimum gap of 10 seconds and a maximum gap for two days of 9 hours, with latency intervals dominated by values less than 30 seconds. However, consist eight extreme latencies in the observation period are associated with internet quotas and technical interference. For the quality of CCTV cameras, good quality images contributed to about 84,85%. Although there are many interferences from GSM signals and vessel activity below the sensors, the overall performance of this device has shown high reliability to strengthen the existing tsunami early warning system in the South of Java and Indonesia.

1. Introduction
Indonesia is a country that is very prone to tsunamis, especially local tsunamis. Indonesia’s geographic location is located between the confluence of plates that are generally the source of tsunami generation, such as the Eurasian, Indo-Australian, and Pacific Plates. Based on geographic and geological morphology, many areas in Indonesia are known as areas prone to disasters, particularly earthquakes and tsunamis. Therefore, disaster mitigation programs must be prepared intensively and carefully by the authorities and all stakeholders. The leading cause of tsunamis in Indonesia is tectonic earthquakes (the majority globally) [1].

Nevertheless, specifically for the tsunami in Palu and the Sunda Strait, the cause of the tsunami was caused by submarine landslides [2–5] and by the submarine landslides due to flank collapsed during the eruption of Mount Anak Krakatau [6–8]. Indonesia has 127 volcanoes, and some of them can cause tsunami waves, so a comprehensive Tsunami Early Warning System is needed to reduce the impact
caused by a tsunami. Tsunamis caused by non-tectonic events such as submarine landslides and submarine volcanic eruptions can be detected by observing sea-level changes, so a sea-level measuring instrument is recommended as TEWS.

The concept of using a tide gauge network for TEWS is not new and has already been applied to the ina-TEWS system [9]. However, the current system still has weaknesses related to providing real-time sea-level change alerts that are not yet available [10]. In order to strengthen and minimize the impact of tsunami generated by submarine landslides and underwater volcanic eruptions, a collaborative initiative between The Joint Research Center (JRC), the Indonesian Tsunami Society (IATsI), the Marine Research Center of the Ministry of Marine Affairs, and Fisheries and the Meteorological, Climatological, and Geophysical Agency of Indonesia (BMKG) to design and implement the new Emergency System namely Inexpensive Device for Sea Level Monitoring or IDSL for the real-time fast Tsunami instruments. The device works 24/7 to monitor in real-time the sea level, provides email, SMS alerts, CCTV images, and information about a potential tsunami event [10]. The objectives of this study were to analyze the performance of the IDSL in measuring and analyzing changes in sea level to achieve a fast and accurate early warning system.

2. Data and methods
The performance of the IDSL tool analyzed is located at the Sadeng fisheries port, Songbanyu Village, Girisubo Sub-district, Gunung Kidul District, Yogyakarta. IDSL was installed here on October 26, 2019. Figure 1 shows the installation location of IDSL at Sadeng Port.

![Figure 1. Research location of device installation IDSL-306.](image)

The data taken is the raw data from the IDSL tide gauge via the website https://webcritech.jrc.ec.europa.eu/TAD_server. The length of data analysis was reviewed for six months, from March 1, 2020, to August 31, 2020. The parameters used as benchmarks in assessing IDSL performance include sea-level elevation (tides), data gaps, alert systems, webcam analysis, and latency values. The sea level elevation value is the essential condition to monitor. The elevation value is measured with intervals in seconds and analyzed by the server so that it becomes a benchmark in providing alert signals which is the main essence of this instrument. To analyze the IDSL instrument's accuracy, the first thing to do is to validate the IDSL tide data with other tide gauge instruments.

In this analysis, a comparison of tidal elevation measurements from IDSL will be carried out with The Geospatial Information Agency (BIG) prediction data obtained on the http://tides.big.go.id/ page. BIG tide predictions are generated from the assimilation of permanent tide station data and altimetry satellites. Validation calculations will use the Correlation Coefficient (CC), Root Mean Square Error (RMSE), and Mean Average Percentage Error (MAPE) method [11,12]. Each validation method can be calculated by the following formula:
\[
CC = \frac{\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{N}(x_i - \bar{x})^2 \sum_{i=1}^{N}(y_i - \bar{y})^2}}
\]

(1)

\[
RMSE = \sqrt{\frac{\sum_{i=1}^{N}(y_i - x_i)^2}{N}}
\]

(2)

\[
MAPE = \frac{1}{N} \sum_{i=1}^{N} \left| \frac{y_i - x_i}{y_i} \right| \times 100\%
\]

(3)

where,

\( n \): the amount of data

\( i \): data order

\( x_i \): model data

\( y_i \): observation data

\( \bar{x} \): model data average

\( \bar{y} \): observation data average

Data gap analysis is carried out by looking at empty data through the TAD server website, which can be accessed at https://webcritech.jrc.ec.europa.eu/TAD_server/Device/484. Then descriptive statistics from the data gap are calculated, such as; the number of gaps, total gap duration, mode, median, average, minimum, maximum, and range of existing data gaps.

The alert system is seen by matching the alert data contained in the raw data with incoming SMS or emails, validating with webcam catches, and seeing the results of elevation measurements (whether there is a surge in elevation indicating a tsunami or not). Then the image analysis is carried out by calculating the percentage of images with good quality (bright, apparent sea level elevation), Mid-Quality (unclear, sea-level elevation is still visible), bad quality (dark/blurry, sea level not visible). The latency data will be analyzed by looking at the interactive plot graph on the website and looking at the descriptive statistics of the existing latency values.

3. Results and discussion

Observation data from March to August 2020 at Sadeng Fisheries Port (Figure 2) shows that the tidal range at spring tide is about 3.19 m, in line with BIG tidal station data. These data also indicate that the minimum tide height is 0.06 m and the maximum tide height is 3.25 m, with an average sea level of 1.37 m. Assessing the Correlation Coefficient value between the IDSL and BIG data is 0.93. The RMSE calculation value of the two raw data is 0.08 m, and the MAPE calculation result is 14%. The overlay of BIG data with IDSL data can be seen in Figure 3.

![Figure 2. Tidal levels from IDSL measurements, Sadeng Fisheries Port.](image-url)
3.1 Data gaps analysis

Figure 4 shows a histogram graph of the data gap (left) and descriptive statistics (right) from the IDSL data during March-August 2020. It can be seen that during that period, there was a total data gap of 1717 data gaps with a minimum interval of 10 seconds and a maximum gap for two days of 9 hours, and The entire duration of gaps is 11 days 17 hours. The most data gap interval is in the range of one to three minutes, totaling 774 gaps. For a span of three to five minutes, there are 310 data gaps. This range of three to five minutes is a particularly vulnerable drawback considering that this tool will be intended as a TEWS. Generally, gaps in the range of 10 minutes and below are gaps caused by communication network (GSM) disturbances. Then some data gaps show quite a long interval, around a few hours to several days, internet quotas and technical interference generally cause this condition. The causes of the gap that rose in IDSL at the Sadeng Fisheries Port were delays in internet quota payments and disruption of communication networks. The data gap caused by these two causes is a technical problem sought for a solution. Although communication network disturbances dominate the cause of data gaps (based on the number of gaps that appear), data gaps due to delays in internet quota payments have a very long duration of data gaps (the number of data gaps tends to be fewer).

3.2 Latency time

Latency time measures the time it takes for data to travel from the instrument measurement devices to processing software. The greater the latency value, the slower the response is given. The latency value can be used as an indicator of the quality of the tool. Long latency will take time between measurement and processing which will cause warnings to be significantly delayed [13]. The value of latency at Sadeng Fisheries Port during March-August 2020 is shown in Figure 5. There are eight extreme latencies in the observation period, and this is related to technical problems referred to in the data gap section.
Figure 6 shown the latency value for each month to see with a better resolution. The average latency value in March is relatively high, which is in the range of 15 to 30 seconds compared to other months, which is in three to ten seconds. The latency data at Sadeng Fisheries Port is considered quite good because latency values dominate it in seconds, which means that the faster data is transmitted for immediate processing, and early warning will be delivered faster.

There are still drawbacks in operating IDSL in Indonesia; the GSM network plays a vital role in data transfer available to the server and local operator's skills in maintaining and repairing the equipment when needed. Knowledge and understanding of local communities about the real threat of a tsunami disaster an expected to jointly preserve the existence of this tool so that the threat of vandalism can be minimized.

Figure 5. Latency time, March-August 2020.
Figure 6. Graph of the latency value of Sadeng Fisheries Port in March-August 2020.

### 3.3. Alert system

In the IDSL instrument, the alert value is calculated on the data logger using a methodology that calculates the difference between a signal and a wave with a Kalman filter \[8\]. When this difference exceeds the standard deviation of the signal several times, the warning value is increased by one unit (value 10 is the maximum alert level). An SMS / email will be sent if the warning value exceeds two units. If the detected anomaly is still ongoing and the value continues to increase, the SMS / email will return after five minutes. This warning will be sent to a particular list, including BMKG, which will later be the lever of the ongoing phenomenon. The alert mechanism can be seen in Figure 7 below.

![Alert mechanism](image)

Figure 7. Alert mechanism \[8\].

Total alerts at Sadeng Fisheries Port during March-August 2020 occurred three times with details as in Table 1. No maximum warning signal reaches 10. It means there are no emergencies that need to be further verified. It is indicated that the alert signal that appears is caused by sea-level disturbances from ships sailing near the instrument sensors.
Table 1. The appearance of an alert signal in March-August, 2020

| Time (UTC)            | Alert | Elevation (m) |
|-----------------------|-------|---------------|
| 20/03/2020 02:52:51   | 4     | 1.40          |
| 13/04/2020 14:01:09   | 1     | 1.14          |
| 19/06/2020 11:56:03   | 1     | 1.38          |

Many tsunami incidents in Indonesia claimed many lives because the TEWS function was not optimal. With about 75% of Indonesia’s coastline threatened by a tsunami [14], an accurate early warning system for Indonesian coastal communities is urgently needed. The tsunami arrival time in Indonesia is generally between 10-60 minutes, with the estimated time of the tsunami waves to reach the coast is 30 minutes after the earthquake [15]. The golden time is estimated to be around 25 minutes if the tsunami event validation process takes five minutes. The travel time for the route to reach the safe point of the evacuation site in Gunung Kidul is between 46 -61 minutes [16,17]. This condition can threaten the safety of the coastal communities of Gunung Kidul if they have to anticipate the arrival of tsunami waves. Socialization and collaboration between stakeholders are expected to create new alternative evacuation routes to reduce travel time to safe assembly points.

3.4. CCTV image

The main objective of the CCTV images is to detect the water lines visually as the sign for the tsunami event. The CCTV working system on the IDSL device takes pictures every 15 minutes during normal conditions and will take pictures every two minutes after a change in the alerts system occurs. The addition of CCTV to IDSL is beneficial in validating surrounding conditions regarding the appearance of alerts, such as those caused by bad weather, strong wind, and the presence of boats under the sensor.

The percentage of CCTV image quality during observation can be seen in Table 2. Bad Quality Images (5.62%) usually occur at night or sometimes in stormy conditions with heavy rain. In this condition, it is difficult to identify the sea level line. In comparison, good-quality images (84.85%) always occur during the day. The rest are mid-quality (9.53%) images that look blurry or indistinct, but waterline identification can still be seen. This condition usually occurs at dusk and dawn. CCTV image quality classification is shown in Figure 8.

Table 2. Percentage of image quality CCTV from IDSL Sadeng fisheries port.

| Month | Good quality | Mid-Quality | Bad Quality |
|-------|--------------|-------------|-------------|
| March | 91.30        | 2.18        | 6.52        |
| April | 86.15        | 0.31        | 13.54       |
| May   | 86.55        | 11.72       | 1.73        |
| Juni  | 75.62        | 21.74       | 2.64        |
| July  | 76.29        | 17.19       | 6.51        |
| August| 93.23        | 4.00        | 2.77        |
| Total | **84.85**    | **9.53**    | **5.62**    |
4. Conclusions
The IDSL elevation data correlates very well with the BIG prediction data. The average frequency of existing data gaps is recorded in the range of three to five minutes, and this predominantly occurs due to signal or communication network interference. Quite long data gap intervals (in the order of hours to days) usually occur due to technical errors. The IDSL latency value is considered quite good with a value of 3 – 10 seconds, followed by a range of 5 – 30 seconds which is still within the tolerance for data transmission for early warning. The alert system on IDSL is good enough to provide early warning of wave anomalies, but often this alert system is interrupted by local events such as ripples from ships validated with CCTV images. Based on the above discussion, it can be concluded that the overall performance of this device has shown high reliability to strengthen the existing tsunami early warning system in the South of Java and Indonesia.

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Authorship contribution statement
DN. Conceptualization, writing, data investigation, statistical and formatting. SF. Data collections, Statistical and formatting. SH, ASet, IRS, DNu. Reviewed and edited the manuscript. RB, SMP, ASuf, DSA, DD. data collections

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