Design of Sunda Straits automatic water level station network

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Abstract. The Sunda Strait is a region that has the potential for tsunamis due to tectonic and volcanic activities. Anak Krakatau landslide is one of the causes of Tsunamis that require accurate early detection by combining data from seismometers and other sensors. One of the instruments that can be implemented in the verification of early detection of Sunda Strait Tsunami waves is a network of automatic water levels that can measure changes in water level every one minute. The system is designed using ultrasonic water level sensors and rainfall sensors. The sensors are connected to a data logger for processing data with a solar power supply panel. The automatic water level network is installed in 3 locations around Anak Krakatau. Measurement data from sensors is sent to BMKG servers for further processing using 2G communication modules. The results of the system design show that the network of automatic water level works properly, where the pattern of water level patterns every minute from each station can be seen.

1. Introduction

The massive landslide of the Anak Krakatau eruption triggered a tsunami in the Sunda Strait on December 22, 2018. National Disaster Mitigation Agency (BNPB) had recorded at least 431 dead since the tsunami struck Sunda Straits coastal area [1]. The tsunami that occurred in the Sunda Strait was caused by a material avalanche of Mount Anak Krakatau which resulted in an increase in the height of the waves in the affected area.

Indonesia Agency for Meteorology, Climatology, and Geophysics (BMKG) has Tsunami Early Warning System, but the system did not process warning alert at that time because of the lack of a significant earthquake or massive volcanic eruption. So, the agency announces that the waves caused by high tide, instead tsunami waves. One effort in mitigating the occurrence of aftershocks in the Sunda Strait is to combine seismograph sensor data as a vibration detector with a verification system that can detect sea level anomalies. The tsunami forecasting method can utilize seawater level data as validation where a linear longwave model is used to generate a synthetic mareogram database [2]. Data processed using MATLAB to generate the tsunami height estimation after receiving the water level data. Those water level station information aids to predict the impacts of Tsunami in coastal areas [3].

In this study, we will discuss the design of an automatic water level station based on ultrasonic sensors for early verification of tsunamis in the Sunda Strait. The automatic water level station is designed using ultrasonic wave-based sensors, data loggers, power supply systems, and data communication modules. The resulting data is transmitted every one minute to the BMKG servers in Jakarta for subsequent post-processing. The design of the automatic water level will use ultrasonic sensors to monitor sea water levels using the radar principle, which can calculate the distance between
2. Automatic water level

One of the marine parameters used in science applications is sea level. Many types of sensors are used in water level measurements, both for measurements in marine and non-marine. Many scientific experiences related to the use of types of water level sensors, such as pressure sensors, radars, encoders, buoys, and acoustic sensors [4]. Water level station design must consider the characteristics of the structure and interaction between the structure and the water [5].

In this study, a network automatic water level stations will be designed to be installed in the Sunda Strait. The automatic water level is intended to determine the anomaly changes in the pattern of sea level in the Sunda Strait. The network consists of 3 automatic water levels installed around Anak Krakatau. The anomaly was then related to the volcanic activity data of Anak Krakatau.

Automatic water level station design adopts an Automatic Weather System (AWS) basic configuration, an instrument to observe weather changes and send the information automatically [6]. The system consists of sensors, data loggers, and a power supply system. Sensors measure the water level and send it to the data logger. Data from sensors are forwarded to a data logger for processing. The processing operation of the data logger is controlled by a microcomputer, which is tasked with supplying power to the sensor, collect and storing data at a certain sampling rate. A rechargeable battery is usually used as the main energy source for the system applied in Indonesia. Solar energy is usually used to charge batteries, using solar panels and power regulators.

3. System design

The automatic water level station consists of sensors, data loggers to process signals from sensors, power supply systems, and 2G modems. The enclosure is designed using ABS waterproof box with a length of 35 cm, a width of 25 cm, and a height of 15 cm which is equipped with input and output ports at the bottom of the enclosure.

Figure 1. Automatic water level station system diagram
The system diagram in Figure 1 shows the design of an automatic water level station. The station consists of input sensors, cellular modem, and a power supply, mounted on a stainless-steel monopole. The sensor used in the system is water level sensors and precipitation sensors. JUDD water level sensors use ultrasonic waves to measure changes in sea level, the value of water level comes from the distance of the sensor to the target; in this case, the sea level. Ultrasonic sensors work by measuring the reflection time needed by ultrasonic waves with a frequency of 50 kHz from being emitted until they are received again. The tipping bucket precipitation used to obtain rainfall data at the station, it uses reed switch and magnet. Rain collects on one side of the bucket after the amount of water matches the volume of the bucket it will move to do the tip action. Tip action will cause the magnet to close the reed switch circuit and generate pulses according to the number of tips.

JUDD water level sensor and tipping bucket sensor are connected to the Campbell CR1000 data logger for calculation. CR1000 datalogger models commonly used for environmental monitoring research and long-term meteorological observation stations. It is used because it has a 16 channel of single-ended input which is used as a meteorological sensor-sensor interface with a 13 Bit Analog to Digital Converter (ADC). Pulse counters on the CR1000 can also be used for interfaces with rain gauge sensor. The automatic water level station uses the power supply from solar panels. The power supply system uses a 20 Wp solar panel connected to a solar charge regulator to a 12 V Valve Regulated Lead Acid (VRLA) battery. The power supply system is connected directly to the power data logger input to provide working voltage to the automatic water level. Data transmission uses Sierra FXT 009 modem which is equipped with a Machine to Machine (M2M) card that can be operated in a GSM/GPSR/2G frequency channel.

![Figure 2. Automatic water level station system flow chart](image-url)
Figure 2 shows the flow chart of the automatic water level system. The automatic water level station program setting uses LoggerNet 4.5 from Campbell Scientific, which provides basic Quality Control functionality on streaming data. Logger Net 4.5 has been built-in with the CRBasic application, which is a data logger management program with syntax similar to the BASIC programming language [7].

The sensors will initialize after connecting to the data logger. The water level data information during a tsunami event must have very little latency, so the system sampling rate set to 1 second. Tsunami warning efficiency improves with real-time data, while archived data is not a requirement [8]. After data is collected from the sensor, the data logger will average the data to produce 1-minute average data. The processed result is sent using FTP and TCP/IP to the BMKG servers. The system will reset the data logger every 00.00 UTC to reset the accumulation of daily rainfall.

4. Implementation

4.1. Installation

There are three installation locations in the automatic water level station network to monitor changes in the water level surrounding the Anak Krakatau. Labuan's automatic water level installation location is at the Labuan power plant. The sensor is installed on the edge of the channel water supply Labuan power plant with coordinates 105° 49'33.6" E and 6° 23'29.5" S. The choice of installation location is based on a concrete structure for installation and security of automatic water level. Labuan automatic water level location under the coordination of the BMKG Headquarter and PT. Indonesia Power for the security of automatic water level equipment. Sebesi Island is located in the north of Anak Krakatau. The automatic water level station is installed at the end of the Sebesi Island platform dock with coordinates 105° 30'46.0" E and 5° 56'09.0" S. The selection of the installation location is based on the material structure of the pier.

Figure 3. Automatic water level station at Tamanjaya

Tamanjaya Village is a village located in Sumur Sub-district, one of the most severely affected areas of Tsunami landslide Anak Krakatau on December 21, 2018. Figure 3 showed that the automatic water level is installed at the end of the Tamanjaya pier with coordinates 105° 30'09.4" E and 6° 46'52.1" S.

Each installation station is equipped with a tide height chart. Installation of the tide height chart is intended to ensure the accuracy of the sensor readings with a chart measuring scale. Accuracy testing assumes that sea level observation data from tide height charts as correct data and tidal data using ultrasonic sensors are assumed to be measurement data that have errors. Installation of a tide height chart is also used as a reference point for the reconstruction of the sensor installation location when the sensor is moved or destroyed.
4.2. Data monitoring

Data sent from the automatic water level station can be observed every minute on the BMKG website. The automatic water level station will show a color indicator that indicates the operational status of the station. When the system is off, it will change to the red icon. Data received from the station displayed in the water level pattern every minute. The example data obtained from Tamanjaya station shown in Figure 4.

![12-hour data](image1)

![24-hour data](image2)

![7 days data](image3)

**Figure 4.** Data example obtained from Tamanjaya station

The image shows a graph of the water level pattern every minute. Graph (a) shows the pattern of water level every 12 hours on June 14, graph (b) shows the daily pattern of water level in the Tamanjaya station, and graph (c) shows a weekly pattern.
5. Conclusion
The conclusion obtained from this study is that an automatic water level station network has been installed at three points around Anak Krakatau. The sensor can produce water level and rainfall data every minute. Data from the automatic water level station location sent to the BMKG servers to verify the potential for tsunamis in the Sunda Strait. An example of monitoring data on 12 June 2019 until 18 June 2019 at Tamanjaya station can be seen as a pattern of water changes recorded by the system every minute.

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