Manila Trench Tsunami Source Modeling for West Kalimantan Nuclear Facility Mitigation

S Pribadi¹, Fauzi¹, T Kurniawan¹, Sunarko², H Suntoko², A Sudrajat¹, B S Prayitno¹ and N F Riama¹
¹Meteorological, Climatological and Geophysical Agency, Kemayoran, Jakarta, Indonesia
²National Atomic Energy Agency, Mampang Prapatan, Jakarta, Indonesia
Email: ¹sugengphd52@gmail.com

Abstract. Tsunami modeling with the Manila Trench earthquake source, the Philippines is very necessary as one of the mitigation measures for the prospective nuclear power plant (PLTN) facility in West Kalimantan. In this preliminary study, tsunami modeling using the COMCOT of non linear and the nesting grid method was carried out to obtain an estimate of the height and arrival time of the tsunami at the closest tidal initial points of a nuclear power plant. The Manila Trench is considered as the closed potential sources of earthquake threats to the prospective nuclear power plant site in Gosong Beach, West Kalimantan. The source is divided into 33 multiple segments and accumulated to magnitude 9.1 The results of this study can be used as material for risk assessment for nuclear power plant site development. The results obtained are that the estimated tsunami height at Gosong Beach is around 0.3 – 0.5 meters on the beach with an arrival time of about 550 minutes after the earthquake at its center.

1. Introduction

Kalimantan still lack electricity supply. Even though the infrastructure of a coal-fired Steam Power Plant (PLTU) as a commodity in Kalimantan has been established, the need for electricity as a source of community life is very much needed. Since been proposed as a candidate for the state capital (IKN) in the Paser area, North Penajem Regency, East Kalimantan since early 2020 become the strategic area [1]. Moreover, the existence of this nuclear power plant is estimated to be able to supply 35,000 Mega Watts of national electricity needs.

The Provinical Government of West Kalimantan, in this case the Bappeda of West Kalimantan Province, since 2012 has collaborated with the National Atomic Energy Agency (BATAN) to conduct a study on the selection of potential sites for nuclear power plants in West Kalimantan, in 2015. Then in 2019 BATAN again conducted a Ground Check Plan for the Site Evaluation of Nuclear Power Plants in West Kalimantan, including the Gosong Beach, Sungai Raya Village, Bengkayang Regency.

On March 11, 2011, a massive earthquake (magnitude 9.0) and accompanying tsunami hit the Tohoku region of eastern Japan. Since then, the Fukushima Daiichi Nuclear Power Plants have been facing a crisis due to the loss of all power that resulted from the meltdown accidents [7]. Then the earthquake triggered a tsunami that killed more than 18,000 people and flooded the reactor at the Fukushima nuclear power plant (NPP) caused a huge disaster [8][9]. Therefore, tsunami mitigation is a very important research to do, as the first step in determining the location and safe position of the nuclear power plant site development plan.

2. Far Source of Manila Trench

Even though Indonesia is an active country of the earthquake and tsunami disaster, but the province of Kalimantan, both are very rare based on data of the Tsunami Catalogue of WinITDB for 1559 to 2005.
Agency of Meteorology, Climatology, and Geophysics (BMKG) had listed earthquake inland Kalimantan from East to the West since year 2015 to 2019 under magnitude 6.1 and no caused tsunami.

The author tries to find a distant tsunami source that may be dangerous for the nuclear power plant site. The most likely threat is in the South China Sea (SCS) with a tsunami source in the Manila Trench area, Philippines. In this study, a probabilistic approach is used from the results of the previous author's studies where large tsunamis have been mapped and caused consistent hazards in the past. In this study, 33 multiple segments of Manila Trench, which accumulated as magnitude 9.1 were used with some modification treatments from [3]. See Figure 1, 2 and Table 1.

Figure 1. Scenario earthquake at the Manila Trench. Figure 2. Discrete model of 33 segments (right pane)
3. Data and Method

As a basis for making tsunami modeling, marine and land data are needed. First bathymetric and topographic maps starting from the initial layer or domain with a wide-scale ocean level with The General Bathymetric Chart of the Oceans (GEBCO) aims to provide the most authoritative and publicly available bathymetric data set for the world's oceans within 480 meter resolution. The second layer is National bathymetry (BATNAS) within 160 meter resolution and finally the National Topography (DEMNAS) within 11 meter resolution. Both are taken from the National Bathymetry from the Geospatial Information Agency (BIG). Land cover has been added from the Indonesian
Rupiah Bumi (RBI) by adopting the Manning roughness scale that distinguishes environments such as: settlements, swamps, groves, open land, and so on.

The tsunami modeling method used is COMCOT (Cornell Multi-grid Couple Tsunami) Power from the Institute of Geological & Nuclear Science (GNS Science) of New Zealand [4]. Other supporting applications in this tsunami modeling are Matlab, Arc Map, Global Mapper, Surfer, Octave, QGIS, and GMT. COMCOT is based on non-linear empirical models and nesting grids so that it can be run in shallow water modeling as described in this formula.

\[
\frac{\partial \eta}{\partial t} + \frac{1}{R \cos \psi} \left( \frac{\partial P}{\partial \psi} + \frac{\partial}{\partial \phi} (\cos \phi Q) \right) = -\frac{\partial h}{\partial t}
\]  

Where \( \eta \) stands for the water surface fluctuation; \((P, Q)\) denote the volume flux components in the \( x \) (East) and \( y \) (North) directions, respectively; \((\psi)\) denote the longitude of the Earth; \( R \) is the radius of the Earth; and \( h \) the water depth. The term \(-\partial h/\partial t\), reflecting the effect of bathymetry variation, can be used to model tsunami generated by transient seafloor motions such as slow rupturing processes or submarine landslides. \( f \) represents the Coriolis force coefficient due to the rotation of the Earth and where \((P, Q)\) denote the volume fluxes in \( x \) direction and \( y \) direction, respectively, and both are products of velocity and water depth, i.e., \( P = hu \) and \( Q = hv \).

4. Results and Discussions

An estimated tsunami source model from the Manila trench, showing areas in the west, so that the tsunami strength is stronger towards the wide-spreading South China Sea. There is a recent paper of Qiu et al and J P Terry et al, that examines the manila trench, but makes these fault segments separately so that it does not provide an energy accumulation of magnitude 9.1 so the author does not take this paper as a reference. Besides, our original goal was to obtain the worst-case outcome as mentioned by D M Ha et al and K Megawati et al.

The area closest to the tsunami hit is the waters of China and the farthest is the waters around West Kalimantan. The tsunami wave was split by the chain of the Spratly Islands but entered the shallow sea west of Sarawak so that the tsunami height increased again. The strength of the tsunami decreased when it entered the waters of the Riau Islands with a large size so that the tsunami entered from the cracks with the remaining energy. Lack of local bathymetric data around Gosong Beach makes it difficult to analyze tsunami data in this area.

The simulation results for the Gosong Beach area are obtained after 10 hours from the time of the earthquake's rupture from the source. The maximum amplitude of tsunami from the source to the depicted area in Figure 3. The results of the tsunami propagation from the source to the affected area and the arrival time and change in the broad to narrow layer and the initial tsunami gauge distribution of stations 1 to 9 are shown in Figure 4.
Figure 3. The maximum amplitude of tsunami from the source to the depicted area.

Figure 4. The broad layer to the narrow layer within distribution of initial gauge.

The selection of the arrival time and tsunami height is based on the provisions of the international tsunami warning where the Estimated Time of Arrival (ETA) for the arrival of a tsunami is taken from an indication of a sea level rise of 0.2 meters, the presence of the first tsunami wave at a sea rise of 0.5 meters, and a height of 0.5 meters. Maximum tsunami at the peak measured after the Estimated Wave Height (EWH) of 0.5 meters.

The arrival time and height of a tsunami are closely related to distance. Sequentially from highest to lowest values can be seen from stations 1 to 5. Stations that are closer to the source of the tsunami have a faster tsunami arrival time (1-4 hours) and a higher tsunami height (0.7-1.2 meters). The farthest station number 4 and 5 have a longer arrival time (7-9 hours) and the lowest tsunami height (0.3 meters).

Station 6 is relatively close to the source so it has a fairly fast tsunami arrival time (almost 7 hours) but there is a refractive effect on the islands around Sambas that it passes through so that it gives amplification of the tsunami height (1.2 meters). Stations around Gosong Beach, Bengkayang (stations 7, 8, 9) have low tsunami heights (0.3–0.5 meters) and longer arrival times (7-10 hours) because they are far from the source and blocked by islands near Sambas. See Figure 5, 6 and 7.
Figure 5. Marigrams from the initial gauge with the lowest to highest serial numbers (1-9) arranged from top to bottom and to the right side.

Figure 6. Estimated time of arrival (ETA)

5. Conclusions
The tsunami hazard map in West Kalimantan is based on tsunami modeling with an earthquake scenario in the Manila Trench. The results of tsunami modeling at artificial tidal measurement points around Gosong Beach showed low results because small islands were blocked so that the tsunami arrival time slowed down. Unlike those that are not blocked by islands or off the coast of the South China Sea, the tsunami height is high, and the arrival time is faster.

It is very important to conduct surveys of bathymetric data and field topography spread out, as a reference in conducting topographic data processing to combine elevation contours that have small
correction values to satellite data, as well as for bathymetric data, especially the range limit of tens of meters along the coastline.

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