A Retrospective Study of Semi-Enclosed Bays Based on Short Core Samples in Surabaya and Bali, Indonesia

R Rositasari*, T Purbonegoro

1Research Center for Oceanography, Indonesian Institute of Sciences, Jl. Pasir Putih I, Ancol Timur, Jakarta Utara, 1440

*Corresponding author: rrositasari2016@gmail.com

Abstract. A retrospective study is one of the most critical aspects of paleoenvironmental studies on developmental planning and environmental monitoring from a geological perspective. The semi-enclosed bay of Lamong Bay, Surabaya, and Benoa Bay, Bali, was rapidly accelerated physics and ecological development on the national scope. The contrary semi-enclosed marine system is linked to large-scale anthropogenic disturbances. This study provides useful baseline information for stakeholders in preparing disaster mitigation plans. This study was aimed to determine past ecological changes based on the paleoenvironmental analysis in two bays with very different environmental development characteristics, i.e. Lamong Bay, Surabaya and Benoa Bay, Bali. Sampling was conducted in March 2017, including analysis of absolute age and sedimentation rate using the Pb210 isotope and foraminifera recent indexing from short core samples. The Ammonia-Elphidium index (A-E index) and the planktonic/benthic ratio (P/B) were used as a proxy of hypoxia and open ocean flow, respectively. Analysis of foraminifera characteristics showed that the study sites had experienced different ecological changes in the last few decades. Over the past 87 years, Lamong Bay has undergone ecological changes, from the aquatic environment strongly influenced by the open sea and supporting benthic life to shallow oligotrophic waters that cannot supports benthic life. In contrast, Benoa Bay has been shallow for the past 50 years and supports benthic life without the threat of hypoxia due to eutrophication.

1. Introduction

Enclosed bays are seas with a major-axis length to the entrance-width ratio of less than 4, while those with multiple entrances are defined as semi-enclosed bays [1]. A semi-enclosed marine system is linked to anthropogenic disturbances; the restricted flushing on this water system makes them vulnerable to land-based disturbances. The systems are affected by agricultural runoff, urbanization, and pollution [2]. Changes in freshwater runoff and precipitation, cloudiness, wind, and sedimentation, and erosion patterns can modify the productivity and health of these systems [2].

Reconstruction of sedimentation histories coupled with an accurate chronology may show major local and regional catchment events in aquatic systems [3]. Paleoenvironmental and bio-stratigraphical data were recorded on fine-grained organic sediment layers within the sequences through various biospecies, i.e., foraminifera, mollusks, pollen, etc. [4], since fine-grained organic sediment is a suitable habitat for meiobenthic organisms, such as foraminifera to feed, settle, and develop [5].

Sediment deposition in the coastal waters is originated from river streams and/or eroded materials from the surrounding area; therefore, the vertical distribution of sediments would record ecological proxy of the region from several decades to more than a century [6,7]. The semi-enclosed bay of
Lamong Bay, Surabaya, and Benoa Bay, Bali, was among the rapidly accelerated physics and economic development on the national scope. The contrary semi-enclosed marine system is linked to large-scale anthropogenic disturbances. Lamong Bay in Surabaya and Benoa Bay in Bali are semi-enclosed water bodies that are being developed for economic purposes, i.e., national seaports, transportation, and tourism [8]. Disaster mitigation studies, in this case for ecological disasters, are critical to be carried out by stakeholders from various perspectives to protect national assets. The purpose of this study is to determine past environmental changes in the two research locations as a reference for stakeholders in preparing disaster mitigation plans.

Benoa Bay is classified as shallow water. The depth ranges from 1.5 - 10 m and 50 m outside the bay. Benoa Bay is relatively flat and very shallow so that most of the seabed is exposed to water. The Benoa Bay area consists of three geological structures: 1) Volcanic rocks of the Buyan - Batur and Batur groups consisting of tuffs and lahars which formed in the Holocene Quaternary 2) The southern formation is in the form of surface sediment and rocks composed of coral limestone, local marl; and 3) surface sediment in the form of alluvium consists of the crust, gravel, sand, silt and clay as river and coastal sediment [9].

Based on the Bermelen physiographic map (1949), Surabaya coastal plain is the alluvial plain of the major river in East Java. The upstream of the Lamong River is located in a limestone mountain on the border of Bojonegoro and Lamongan Regencies as long as 131 km, passing through several sub-districts of Surabaya. It empties into the Java Sea of the Gresik region. There is a unique tidal phenomenon along the west and east coast of Surabaya, a tide difference of more than one meter. This condition was caused by resonance and convergence of coastal geometries, which increased the amplitude of the tides compared to the open sea tides [10].

Paleoecology and paleoceanography use various proxies to obtain retrospective data from the past. In addition to modeling that uses current information to predict the future, archived records in sediments are widely used to read natural and/or anthropogenic trends in the future. The concept of sedimentary depositional facies provides a fundamental concept for reconstructing aqueous paleoenvironments based on the geological record [8], which contains many assumptions regarding the physics, chemistry, and biology the environmental deposition. It spans multiple temporal and spatial scales [9,10]. Biological and geochemical proxies obtained in core samples have been used to reconstruct eutrophication and hypoxia over specific periods [11]. Using organisms as proxies for reconstructing paleoecology and paleoceanography for specific environmental parameters such as benthic foraminifera is very interesting since the proxy reveals both chemical and biological data [12].

The use of single-celled organisms such as foraminifera in coastal monitoring activities is very efficient. In recent years benthic foraminifera has been used to provide general environmental interpretations as a proxy to quantify specific selected parameters, mostly dissolved oxygen and the flux of organic carbon [13,14,15]. The increase in industrialization and modernized agriculture in developing countries has caused eutrophication [16]. Ammonia and Elphidium are benthic foraminifera that is well adapted to coastal waters [13,17]. Ammonia is better at tolerating prolonged oxygen depletion than Elphidium [18]. Gupta and Platon [18] reported that the Ammonia-Elphidium (A-E) index from the southeastern and eastern coastal waters of the U.S. was an excellent tracker of coastal paleo-hypoxia on a decadal scale when an undisturbed, continuous record of sedimentation was available and when the effects of possible co-varying factors (e.g., salinity) were minimal. Another index that has been widely used in depositional environments is the planktonic and benthic ratio (P/B). The P/B (Planktonic/Benthic) ratio expresses the amount of the planktonic foraminifera in the system due to the distance from the mainland and the decrease in turbidity, which enables the primary production to increase [19].

2. Methods and Materials
Samples were collected in the semi-enclosed waters of Lamong Bay, Surabaya, and Benoa Bay, Bali, Indonesia, in March 2017 (Figure 1). The position of the Benoa Bay core station was -8.744372874 South Latitude and 115.1859185 East Longitude, and Lamong Bay was -7.22469544 South Latitude
and 112.686023 East Longitude. Sediment samples were taken using a simple core made of PVC pipe that was two inches in diameter. Single-core samples were taken from each location by planting PVC pipes from the boat into the bottom sediments of protected waters, such as near mangrove areas. Protected waters are the preferred sites for core sampling due to the delicate sediment layers that have been entirely deposited without any disturbances at the location. Core samples consisting of fine fractions (silt and/or clay) contain many data/information for further observations, including the absolute age using the affordable isotope, $^{210}$Pb. The core sample was cut into a 5 cm interval. Every 5 cm divided for three different analyses: dating, grain size, and foraminifera analysis. Previous studies by Rositasari and Suyarso [20] on the coast of Jakarta Bay and Minhat et al. [21] in the Malacca Strait used a 5 cm subsample interval on core samples and have provided useful chronological and ecological information (based on foraminifera indices).

The cores were stored in a freezer for further analysis. The number of subsamples of each core was highly dependent on the consolidation of the bottom sediment at the core site, which 100 cm core sample was obtained from Lamong bay and 35 cm from Benoa Bay. The more consolidated the bottom sediment was, the more difficult it was to execute cores manually. Ten subsamples from core at Lamong Bay and five subsamples from Benoa Bay were analyzed on dating, grain size, and foraminifera analysis.

![Figure 1. Sampling Site in Lamong Bay, Surabaya and Benoa Bay, Bali](image)

The chronological measurements of the sediment deposition were carried out based on the calculation of the $^{210}$Pb isotope (with a half-life of 22.3 years) at the National Nuclear Energy Agency of Indonesia. The methods were useful in measuring 150-200 years of chronological age. Several researchers have widely used research using the single-core sample method to observe paleoceanography. Lynts [22] used a single-core sample to perform a planktonic foraminifera analysis in Tongue of the Ocean, Bahamas. Strauss et al. [23] studied the benthic foraminiferal history on the
inner Texas shelf for 100 years using a single-core sample without repetition. Minhat et al. [21] have also used a single core sample to reveal the composition and distribution of benthic foraminifera during the Holocene period in the Malacca Strait.

Foraminiferal contain in approximately 100 cm³ dry sediments were analyzed at the laboratory of Research Center for Oceanography, Indonesian Institute of Sciences (LIPI). Identification and calculation of foraminiferal abundance were carried out using a Nikon Labophot low-power microscope. The granulometry method was used for grain size analysis.

2.1. The Ammonia-Elphidium Index
The abundance of Ammonia and Elphidium (Foraminifera) was used to calculate the Ammonia–Elphidium (A–E) Index [18].

\[
A - E \text{ Index} = \frac{NA}{NA + NE} \times 100
\]  
\[(1)\]

NA = The abundance of Ammonia in the sediment sample  
NE = The abundance of Elphidium in the sediment sample

2.2. The plankton/benthic (P/B) ratio
P/B ratio was used to express the percentage of planktonic foraminifera in the total foraminiferal community [24].

\[
P/B \text{ ratio} = \left( \frac{P}{P + B} \right) \times 100\%
\]  
\[(2)\]

P = Individual number of planktonic foraminifera  
B = Individual number of benthic foraminifera  
P/B ratio was used as a proxy of water depth, paleoenvironment, paleoecology, water mass distribution, and flow intensity [25,26,27].

3. Results and Discussion

3.1 Physical Properties and Sedimentation Rate

3.1.1 Lamong Bay, Surabaya. The absolute age and sediment rate of nine subsample cores from the Lamong Bay site were identified (Table 1). The absolute age of the oldest segment was unidentified using \(^{210}\)Pb and was described as before 1927 in the 45-53 cm layer. The layer was identified as sandy mud sediment in the range of 54.4-68.2% mud content. The grain fraction in the 40-45 cm layer was deposited in 1927 and consisted of a higher mud content range of 92.6-99.3%. The vertical distribution of mud at the study site shows that fine sediment deposits have increased over the last several decades. Sedimentation rates from 1998 to 2005 were almost triple those in the 1927 to 1986 period (Table 1). Based on the East Java regional government’s documentation, there was a flood in the Kali Lamong watershed in 2004 [28], which caused a drastic increase of sediment rate in 2005 (Table 1). The sedimentation rate in coastal waters is closely related to natural and anthropogenic processes along the river basin. Kali Lamong is located in the active physiographic route of the alluvial plain of East Java [29], so changes in land use along the river plain have caused flooding along the Kali Lamong River Basin area. The threat of flooding from Kali Lamong has caused huge losses to residents around Mojokerto, Sidoarjo, Gresik, and Surabaya since the late 1980s [28].
3.1.2 Benoa Bay, Bali. The oldest layer of the Benoa Bay core sample was deposited in 1961, and the youngest layer was deposited in 2011. The core sediment’s grain size consisted of 46-76% mud and 24-54% sand fractions. Sedimentation rates were approximately three times higher in 2011 than in 1961 (Table 2), which coincided with the Ngurah Rai Airport development. The development period of phase I to phase II of the airport construction was finished in the late 2000s, and phase III was completed within the last two decades [30]. As a point of comparison, the highest sedimentation on the west coast of Jakarta Bay occurred in the late 1970s, when there was massive land clearing during the early development period of the Sukarno-Hatta International Airport. On the east coast of Jakarta Bay, the highest sedimentation occurred in the 1980s during the initial expansion of housing developments in several areas around Bekasi [20].

Table 1. The absolute age of the sediment layers and sedimentation rate of Lamong Bay, Surabaya.

| No | Sample code | Depth (cm) | Estimated Year | Sedimentation rate ± Uncertainty (cm/y) | Mud content (% weight) |
|----|-------------|------------|----------------|---------------------------------|-----------------------|
| 1  | ST-9A       | 0-5        | 2014           | 1.72±0.10                      | 99.8                  |
| 2  | ST-9B       | 5-10       | 2011           | 1.52±0.09                      | 98                    |
| 3  | ST-9C       | 10-15      | 2007           | 1.33±0.08                      | 97.5                  |
| 4  | ST-9D       | 15-20      | 2005           | 2.59±0.13                      | 96.8                  |
| 5  | ST-9E       | 20-25      | 1998           | 0.71±0.04                      | 96                    |
| 6  | ST-9F       | 25-30      | 1986           | 0.43±0.02                      | 97.8                  |
| 7  | ST-9G       | 30-35      | 1979           | 0.70±0.04                      | 92                    |
| 8  | ST-9H       | 35-40      | 1961           | 0.28±0.02                      | 88                    |
| 9  | ST-9I       | 40-45      | 1927           | 0.14±0.01                      | 90                    |

Table 2. The absolute age of the sediment layers and sedimentation rate of Benoa Bay, Bali.

| No | Sample code | Depth (cm) | Estimated Year | Sedimentation rate ± Uncertainty (cm/y) | A-E index |
|----|-------------|------------|----------------|---------------------------------|----------|
| 1  | ST12-A      | 0-5        | 2011           | 0.84±0.05                      | 5.5      |
| 2  | ST12-B      | 5-10       | 1996           | 0.33±0.01                      | 17       |
| 3  | ST12-C      | 10-15      | 1984           | 0.43±0.02                      | 16.5     |
| 4  | ST12-D      | 15-20      | 1961           | 0.22±0.01                      | 18       |

3.2 Foraminiferal Distribution

The specimens, both benthic and planktonic species in the subsurface layer of Lamong Bay, were classified as very poor, except in layers of 45 - 53 cm, which had the highest species richness and abundance (Table 3). The 45-53cm layer was deposited before 1927 and consisted of eight benthic species and five planktonic species, in the range of 1-58 individuals per species. The decrease in foraminiferal diversity and abundance between 1927 and 1986, and the disappearance of all life forms from 2005 to 2014, would indicate that there has been an ecological change in the coastal water in Lamong Bay. This phenomenon is closely related to the flow intensity from the open shore, which can be traced through the P/B ratio as a proxy [25,26].

The P/B ratio in the coastal water of Lamong Bay before 1927 was 53%, and by 1927 it had decreased to 44%. Since 1961 the ratio has dropped to <20%, and the specimens of both planktonic and benthic foraminifera have been absent since 2005. Based on [23], the P/B ratio of <20% indicates the inner-shelf water condition, while the ratio of 20-60% is middle shelf, and a ratio of 40-70% is the outer shelf. The retrospective study based on the P/B ratio shows that before 1927, Lamong Bay was
favorable for benthic and planktonic foraminifera. During that period, water circulation at the bottom was strongly influenced by the oceanic water of the Madura Strait. By 1927, the influence of the open shore had begun to diminish, and by 2005, the shallow marine layer was also disrupted, that neither benthic nor planktonic foraminifera could inhabit this area.

Table 3. Species list of Foraminifera in Lamong Bay core sample

| Species               | 0 - 05 cm | 5 - 10 cm | 10 - 15 cm | 15 - 20 cm | 20 - 25 cm | 25 - 30 cm | 30 - 35 cm | 35 - 40 cm | 40 - 45 cm | 45 - 53 cm |
|-----------------------|-----------|-----------|------------|------------|------------|------------|------------|------------|------------|------------|
| **Benthic**           |           |           |            |            |            |            |            |            |            |            |
| *Ammonia beccarii*    | -         | -         | -          | -          | -          | -          | 1          | -          | -          | -          |
| *Balaminina marginata*| -         | -         | -          | -          | -          | -          | -          | -          | -          | -          |
| *Cibicides*           | -         | -         | -          | -          | -          | -          | -          | -          | -          | -          |
| *pseudoegerianus*     | -         | -         | -          | -          | -          | -          | -          | -          | -          | 1          |
| *Elphidium crispum*   | -         | -         | -          | 1          | 1          | -          | -          | -          | -          | -          |
| *E. craticulatum*     | -         | -         | -          | -          | -          | -          | -          | -          | -          | -          |
| *E. lessonii*         | -         | -         | -          | -          | -          | -          | -          | -          | 1          | 1          |
| *Strebelus schroeterianus* | -       | -         | -          | -          | -          | -          | -          | -          | 2          | 21         |
| **Planktonic**        |           |           |            |            |            |            |            |            |            |            |
| *Globigerinoides rubra*| -         | -         | -          | -          | -          | 1          | 3          | -          | -          | 25         |
| *Globigerina bulloides*| -         | -         | -          | -          | -          | -          | 2          | 6          | 50         |
| *Globorotalia menardii*| -         | -         | -          | -          | -          | -          | -          | 2          | 18         |
| *Orbulina*            | -         | -         | -          | -          | -          | -          | -          | -          | 17         |
| *Sphaeoidina bulloides*| -         | -         | -          | -          | -          | -          | -          | -          | 4          |

Core samples from Benoa Bay revealed a different retrospective compared to Lamong Bay since *Ammonia beccarii* was found in abundance in larger morphological sizes than the average size of Jakarta Bay specimens [20], indicating that Benoa Bay waters were more favorable for those species. *Ammonia beccarii* and its various subspecies are cosmopolitan species found in shallow coastal waters worldwide [13]. Benoa Bay was healthy shallow water from 1961 to 2011 (Table 2). The highest abundance of benthic foraminifera in Benoa Bay was *Elphidium*, consisting of 131 individuals in sedimentary layers of 0-5cm deposited of 2011. A different trend was indicated on the east coast of Jakarta Bay, where *Elphidium* was abundant in the early 1900s, and its numbers decreased rapidly within nine decades [20]. The abundance of *Elphidium* indicates the presence of anthropogenic flow from agricultural activities that trigger nutrient enrichment and phytoplankton blooming [21]. Elphidium is herbivorous species that is not able to adapt easily to hypoxic conditions [18,32].

The A-E index in the sedimentary layer of 2011 decreased to the lowest value since 1961 (Table 2), which indicated no threat of hypoxia on the coast of Benoa Bay, Bali, in recent decades. The decline of A-E index began in 2011, which indicates that oxygen levels necessary for life at the bottom of the water are not threatened by development in this region. This phenomenon can also be caused by the shallowness of the water and the accommodative circulation in the area, specifically at the core sampling location around the mangrove belt in Benoa Bay. Water circulation in Benoa is dominated by tidal currents, [33] reported that current conditions inside the bay (at the core sampling location) at neap tide were higher than in other parts of the bay, ranging from 0.36-0.4 m/s. Similarly, the current at spring tide was also higher than it was in the rest of the bay and ranged between 0.6 and 0.66 m/s. Different results were revealed in the west and east Jakarta Bay core samples, which increased the A-E index in the last five decades [34]. The increase in the A-E index in Jakarta Bay implies that the threat of hypoxia has risen in recent decades, particularly in the nearby coastal plain.

4. Conclusion

The characteristics of foraminifera in Lamong Bay, Surabaya, and Benoa Bay, Bali, show that both sites have experienced different ecological changes in the last few decades. Over the past 87 years, Lamong Bay has undergone ecological changes, from a strongly influenced system by the open sea supporting benthic life to shallow oligotrophic water that cannot support benthic life. In contrast, Benoa Bay has been a surface water system supporting benthic life for 50 years without hypoxia. This
study implies that the threat to Lamong Bay over more than eight decades was sporadic alluvial deposition through such a long history of flooding to its coastal system worsened by accelerated development on the coastal plains. In contrast, Benoa Bay has had a low sedimentation rate for the past five decades and supported benthic life without any significant threat to change these waters’ ecological conditions.

Acknowledgments
This study was supported financially by the DIPA Research Center for Oceanography, the Indonesian Institution of Sciences (LIPI).

References
[1] Healy T and Harada K 1991 Mar. Pol. Bull. 23 639 – 644.
[2] MacCracken M, Escobar-Briones E, Gilbert D, Korotaev G, Naqvi W, Perillo G M E, Rixen T, Staney E, Sundby B, Thomas H, Unger D, and Urban E R 2009 Watersheds, bays, and bounded seas, ed E R Urban, B Sundby, P Malanotte-Rizzoli and J M Melillo (Washington: Island Press) pp 9 – 29
[3] Douglas B G, Kuhnen M, Radke L C, Hancock G, Brooke B, Palmer M J, Pietsch T and Ford P W 2010 Environ. Chem. 7 190 – 206
[4] Laoupi A 2007 https://www.researchgate.net/publication/332710818 (Accessed on June, 11 2020)
[5] Châtelet, E A, Gebhardt K and Langer M R 2011 Geol. Paläont. Abh. 262 (1) 91 – 116
[6] Strauss J, Grossman E L, Carlin J A and Dellapenna T M 2012 Continental Shelf Research 38 89 – 97
[7] Tsujimoto A, Yasuhara M, Nomura R, Yamazaki, Hideo S, Yoshikazu, Hirose, Kotaro and Yoshikawa S 2008 Mar. Micropal. 69 225 – 239
[8] Tanto T A, Putra A, Kusumah G, Farhan A R, Pranowo W S, Husrin S and Ilham 2017 Jurnal Kelautan Nasional 12 (3) 101 – 107
[9] Tanto T A, Putra A, Husrin S, Pranowo W S 2018 Reklamasi Di Perairan Teluk Benoa Bali (Aspek Fisik Perairan, Ekosistem, Dan Potensi Kerentanan Pesisir). A MaFRa D Press.
[10] Hasanuddin, Kusmanto E and Setiawan W B 2016 Jurnal Oseanologi dan Limnologi di Indonesia 1 (3) 69 – 80
[11] Gooday A J, Jorissen F, Levin L A, Middelburg J J, Naqvi S W A, Rabalais N N, Scranton M, and Zhang J 2009 Biogeosciences 6 1707 – 45
[12] Murray J W 2000 Marine Micropaleontology https://core.ac.uk/download/pdf/33747.pdf
[13] Murray J 2006 Ecology and application of benthic foraminifera (Cambridge: Cambridge University press) p 426
[14] Sousa SHM, Yamashita C, Semensatto DL and Turra A 2020 Jour. Sedimen. Enviro. 5 257 - 265
[15] Bouchet VMP, Deldicq N, Baux N and Mear Y 2020 Ecol. Indicator 117 106607
[16] Rabais N N, Turner R E, Sen Gupta B K, Platon E and Parsons M 2007 Ecol. Appl. 17 (5) S129-143
[17] Samir A M. 2000 Jour. Foram. Res. 30 (2) 83-91
[18] Sen Gupta B K and Platon E 2006 Jour. Coast. Resc., Spec. issue 39 1351-55
[19] Pezelj D and Drobnjak L 2019 Journal of the Croatian Geological Survey and the Croatian Geological Society, 72 (2) 93 –100
[20] Rositasari R dan Suyarso 2014 Oseanologi dan Limnologi di Indonesia. 40 (3) 295-309
[21] Minhat F I, Husain ML and Sulaiman A 2019 Data in brief 24 104214
[22] Lynts G W 1971 Micropaleontology 17 (2) 152 – 166
[23] Strauss J, Grossman E L, Carlin J A and Dellapenna T M 2012 Continental Shelf Research 38 89 – 97
[24] Murray J W 1991 Ecology and palaeoecology of benthic foraminifera (Harlow: Longman) p
397

[25] Van Der Zwaan G J, Jorissen F J and De Stigter H C 1990 Mar. Geol. 95 1–16 doi: 10.1016/0025-3227(90)90016-D

[26] Van der Zwaan G J, Dujinstee I A P, Den Dulk M, Ernst S R, Jannink N T and Kouwenhoven T J 1999 Earth Scien. Rev. 46 213–236

[27] Jurnaliah L, Winantris, Fauzielly L 2017 Bulletin Sci. Constri. 15 (3) 211 – 216

[28] Bappeda Jatim http://bappeda.jatimprov.go.id/2011/02/17/761/ (Accessed on Dec, 9 2020)

[29] ESDM Jatim http://esdm.jatimprov.go.id/esdm/attachments/article/38/Data%20Geologi.pdf (Accessed on Dec 9 2020)

[30] Balipedia 2020 Sejarah Bandara Internasional Ngurah Rai Bali. https://balipedia.id/sejarah-bandara-internasional-ngurah-rai-bali/

[31] Thomas E, Abramson I, Varekamp J C and Buchholtzten Brink M R 2004 Proceedings 6th Biennial Long Island Sound Meeting 87 – 91.

[32] Platon E and Gupta B S 2001 Coastal and Estuarine Studies 58 147-163

[33] Tanto T A, Kusumah U J W G, Pranowo W S, Husrin S, Ilham and Putra A 2017 Jurnal Ilmiah Geomatika 23 (1) 37-48

[34] Rositasari R, Puspitasari R, Suratno and Purbonegoro T 2019 AIP Conference Proceedings 2175 020043