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Sediment Characteristic of Pagai Strait, Mentawai

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Abstract. The marine sediment is important indicator of the seafloor. The characteristics of marine sediments can be seen from grain size, type and Total Dissolved Solid (TDS). Sediments derived from organic and non-organic particles are carried by the sea currents, waves, streams and tidal process in the coastal areas. At very high levels, sediments can cause pollution or vulnerability such as decreasing of dissolved oxygen, coral bleaching, and increased the eurotrification processes. Pagai Strait is located between North Pagai Island and South Pagai. This strait has enormous potential and it is used by the surrounding community for various activities such as port and sea transportation, fishery, marine aquaculture and tourism. This study aims to determine the characteristics of sediment in Pagai Strait. The field survey was conducted in September 2016 for waves, currents, water quality and sediment samples with purposive sampling method. The results showed that the average of sediments in Pagai Strait is D35 sized 0.155 mm; D50 sized 0.273 mm; and D90 sized 1.574 mm with specific gravity 2.665 gr/cm3 and dominated by sand 66.88%. TDS between 51.6 to 55.0 mg/L, appropriate for port and mangrove. Scale of sediment, A = 0.119 and sediment velocity is 0.002 m/s. Sediment transport approximately is 0.389 m3/day.

Keywords : Sediment transport, grain size, TDS.

INTRODUCTION

The Pagai Strait is located between North Pagai Island and South Pagai Island, Mentawai Islands Regency. This area is located on the Indonesian Ocean and subduction path of active tectonic plates which are prone to earthquake and tsunami. Various activities and impacts of the Tsunami in 2010 (7.7 Mw) caused certain characteristics in sediment. Sediment is formed by organic and non-organic materials. CEM (2002) classified sediments in two major classes: clay (ϕ<0.0039 mm) and sand (ϕ~0.0625 - 2.0 mm) [1]. The sediment in Pagai Strait is combination between muddy sand and nummulite limestone. The depth of the strait is between 3m to 55m. Most of the sediment is dominated by sand. The volume of sediment at the strait is influenced by the location also. This strait is estuary of eight rivers. The research aims to determine the type, grain size and sediment transport and also the distribution of parameters, including Total Dissolved Solid (TDS). TDS was used to indicate the water quality status. Figure 1 shows the location of Pagai Strait and Figure 2 shows the location of sediment samples.

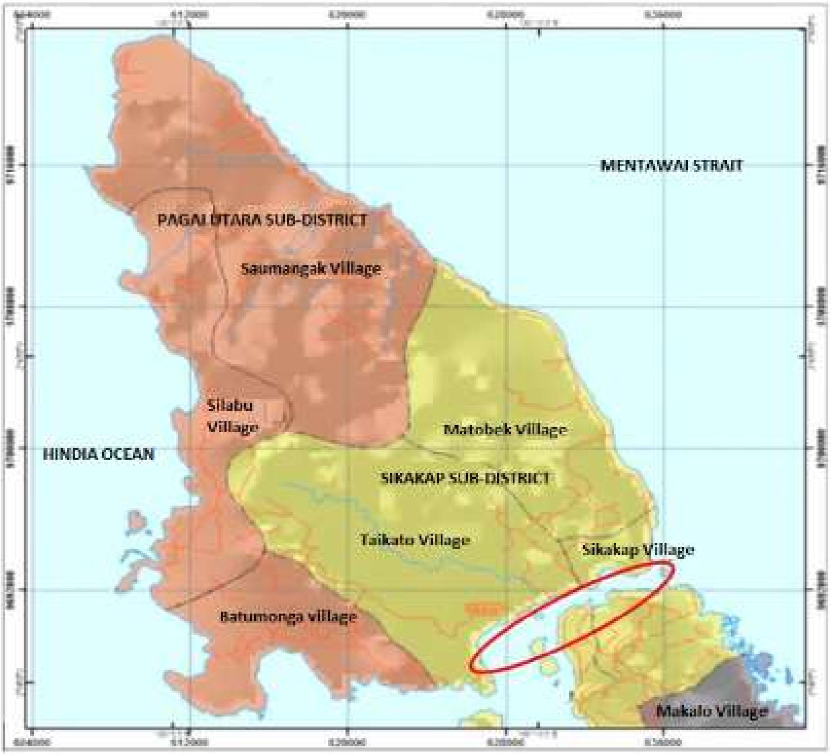


FIGURE 1. The Location of the Pagai Strait

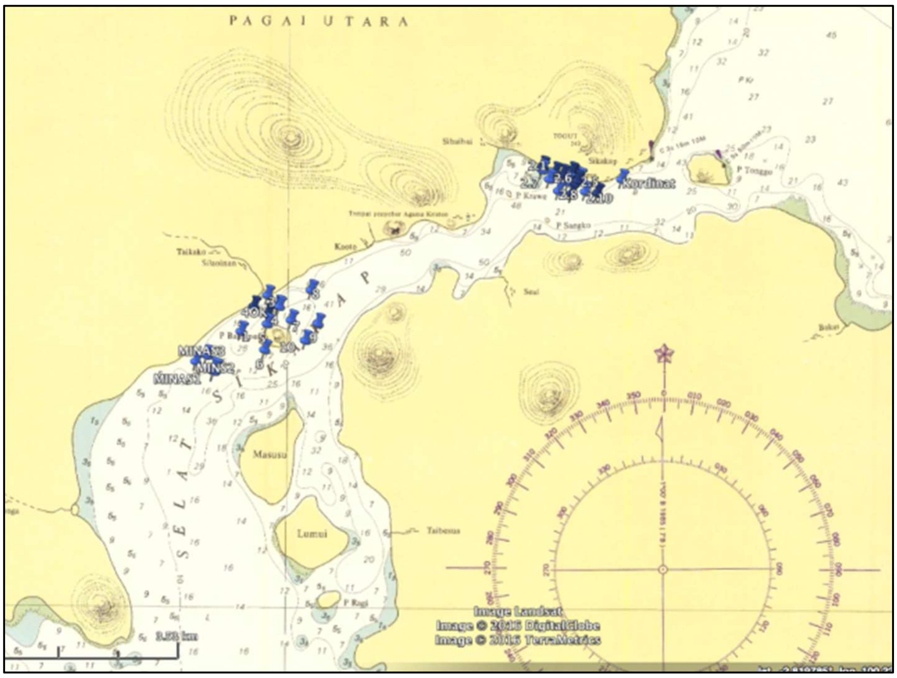


FIGURE 2. The Location of Sediment Samples

METHODOLOGY

The survey of sediment characteristic in Pagai Strait was conducted on September 2016, on 23 sample points by purposive sampling using sediment grab, WQC TOAA and ADCP. The current was measured by ADCP, TDS by WQC TOAA and sediment grab for sediment samples. Grain size of soil particles and density/specific gravity were tested in soil mechanic laboratory at Civil Engineering Lab of Andalas University using soil sieve distribution analysis. With this method, it it could be find the value of D_{35}, D_{50} and D_{90} in ASTM method. Distribution of soil particles diameter then were mapped using Ocean Data View (ODV).

DISCUSSION

Mechanism of sediment budget is a complex process of sediment. Sediment on rivers, ocean currents, tidal waves, storms, and any materials from the land is brought by the winds [2]. Complexity of coastal sediment is shown as Figure 3. In normal and balanced condition, the beach can gain and loss the sediment at the same periodical time. Mostly, the currents and waves trigger the phenomenon of sediment transport. Winds and storm contributed on the surface distribution of sediment. Sediment in Pagai Strait is a type of long-shore sediment because the currents direction is similar along the strait.

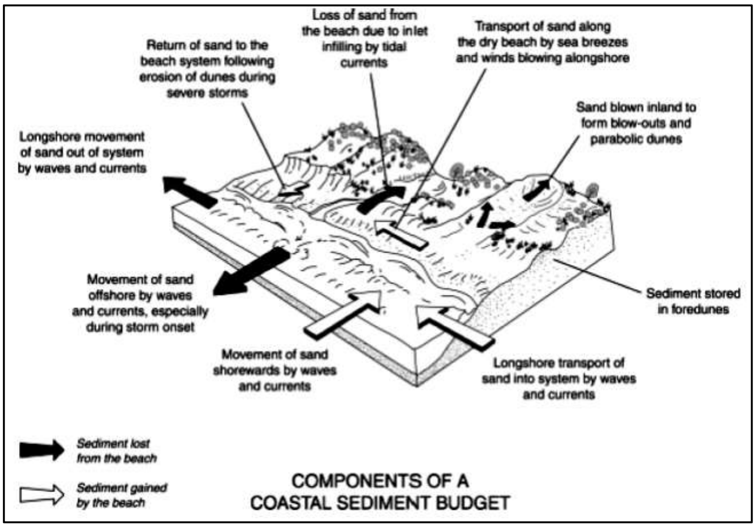


FIGURE 3. Mechanism of Coastal Sediment Budget [2]

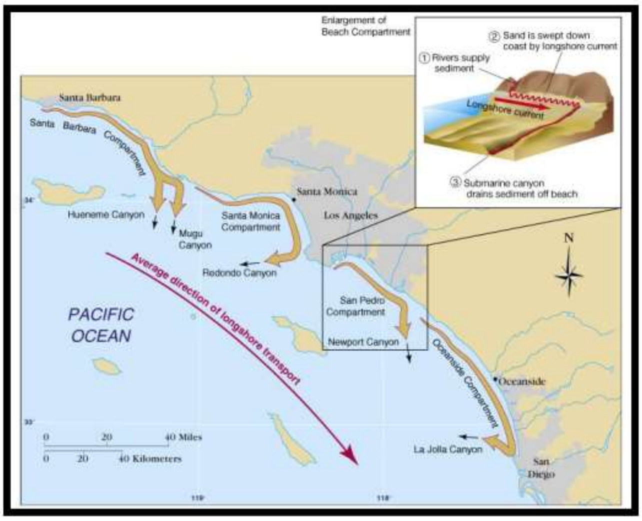


FIGURE 4. Ilustration of Longshore Sediment at Pacific Coastal [3]

People use the Pagai Strait in many ways such as fisheries, ports or transportation, tourism, aquaculture, domestic or daily needs, etc. Figure 4 below shows the population and activities along the Pagai Strait. Figure 5 shows the history of earthquake and tsunami at west water of Sumatera.

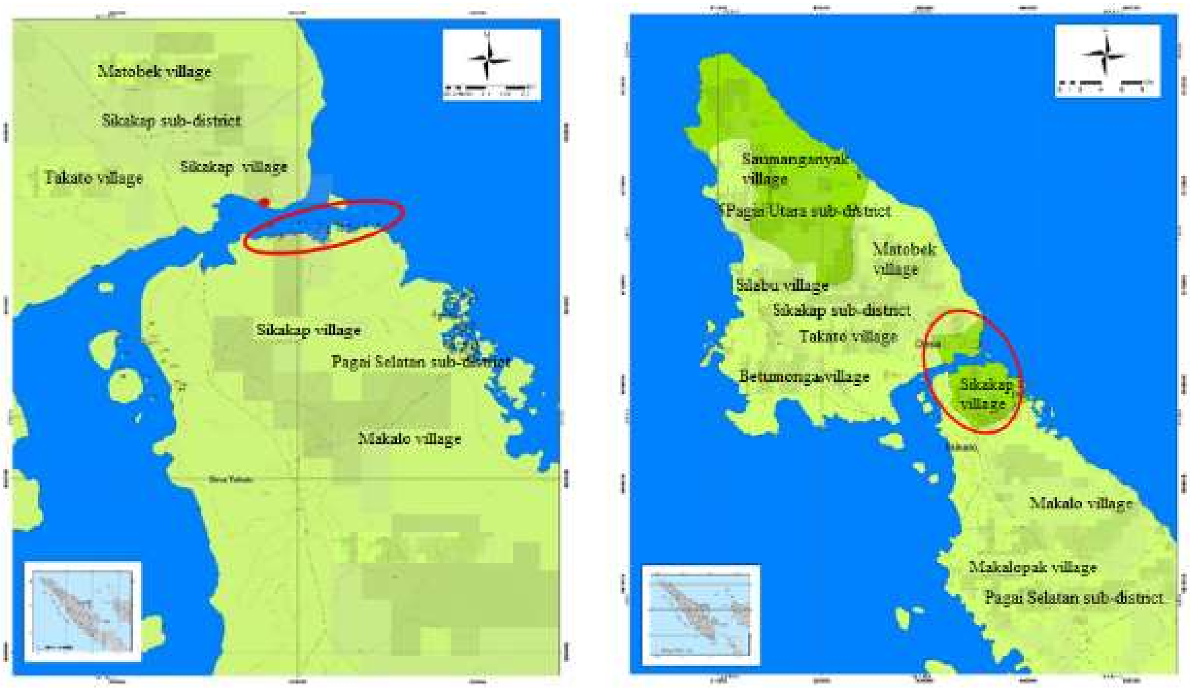


FIGURE 5. Activities and Population in around The Pagai Strait

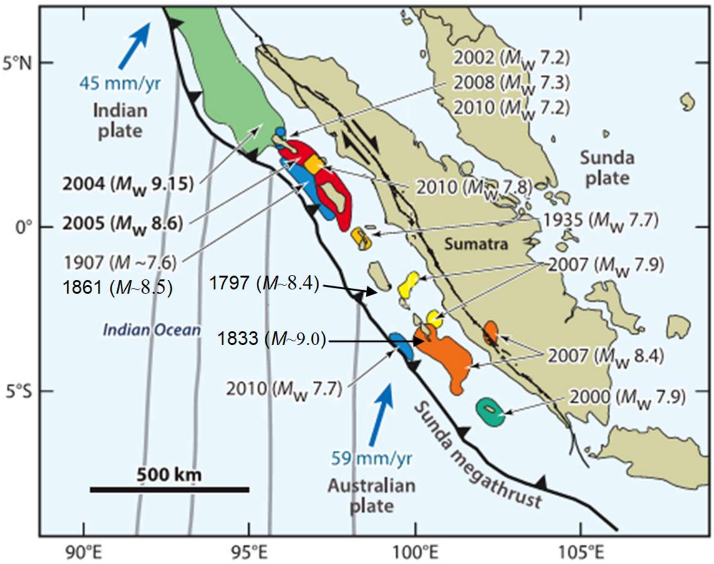


FIGURE 5. Map of the history of earthquake and tsunami at West Sumatera waters from [4], [5], [6] and [7]

On figure 5, as we can see, The Pagai Strait was hit by tsunami at least three times at year 1833 (9.0 Mw), 2007 (7.9 Mw and 8.4 Mw) and 2010 (7.7 Mw). The bathymetry around The North Pagai Island is between 3 m to 55 m. The Figure 6 below shows the bathymetry around The North Pagai Island and The Pagai Strait.

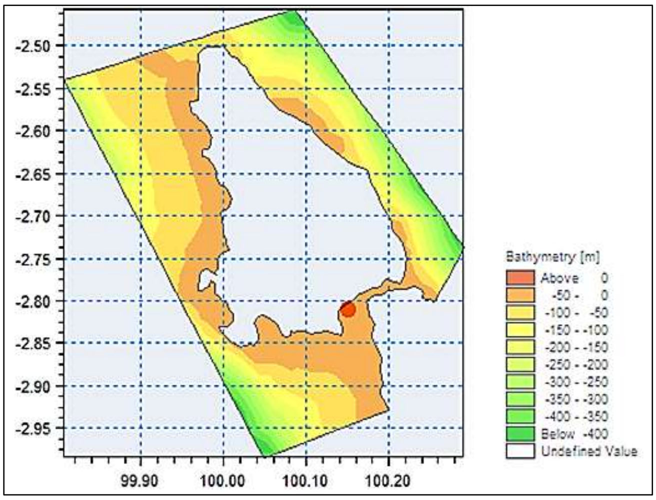


FIGURE 6. Bathymetry around The North Pagai Island and The Pagai Strait Strait [8]

The maximum current velocity is 0.13 m/s and type of tidal is mixed tide prevailing semi diurnal tide (F = 0.537).

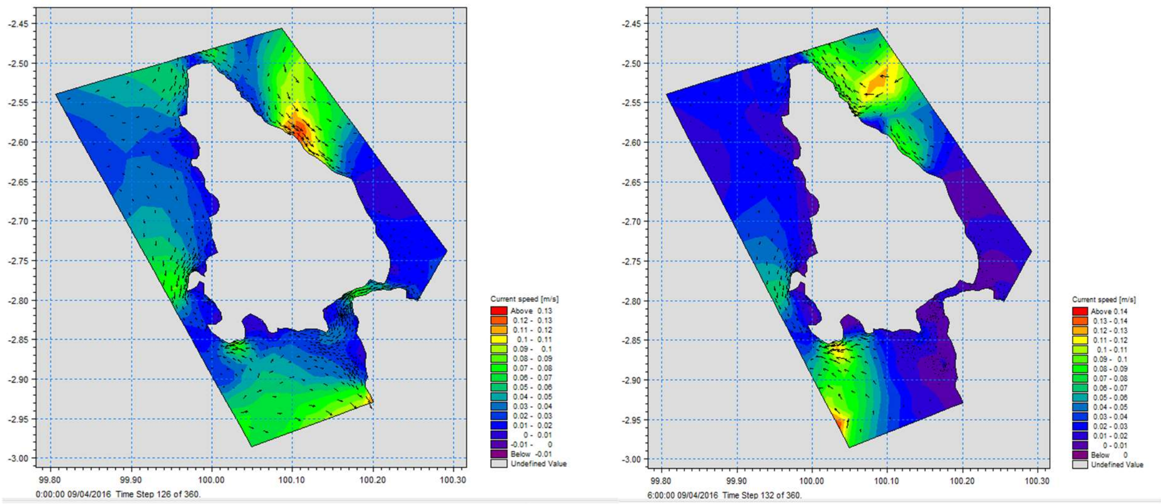


FIGURE 7. Direction and Velocity of Current around The North Pagai Island and The Pagai Strait [8]

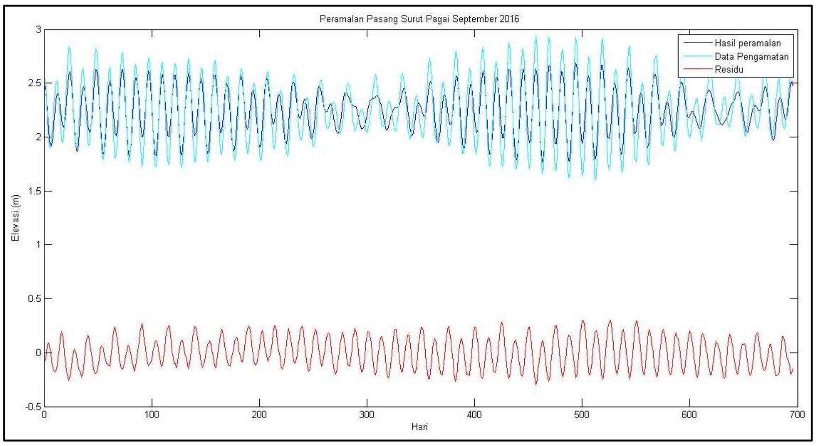


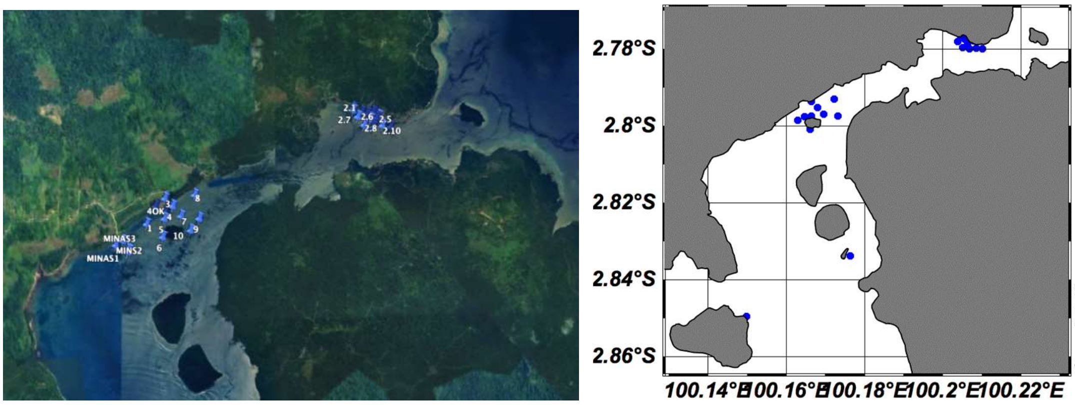
FIGURE 8. Type of Tidal in The Pagai Strait [8]

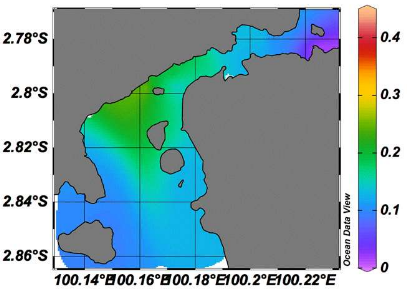
TABEL 1. Distribution of TDS and Sediment based on diameter, type and specific gravity

No	Sta	TDS (mg/L)	Gs (gr/cm^3)	D_{35} (mm)	D_{50} (mm)	D_{90} (mm)	Gravel (%)	Sand (%)	Clay (%)
1	Sta 2.1	54.3	2.657	0.28	0.395	2.800	5.294	87.206	7.50
2	Sta 2.2	51.6	2.665				0	1.25	98.75
3	Sta 2.3	54.5	2.667	0.073	0.110	0.290	0	63.60	36.40
4	Sta 2.4	54.4	2.658	0.19	0.605	4.300	6.40	72.50	21.10
5	Sta 2.5	54.4	2.663	0.058	0.090	0.400	1	56.033	42.967
6	Sta 2.6	54.4	2.666	0.088	0.120	0.315	0	77.632	22.368
7	Sta 2.7	54.6	2.671	0.025	0.067	0.250	0	77.632	22.368
8	Sta 2.8	54.6	2.653	0.33	0.697	6.400	16.767	64.967	18.267
9	Sta 2.9	54.6	2.674	0.008	0.019	0.150	0	16.567	83.433
10	Sta 2.10	54.6	2.679	0.05	0.016	0.067	0	6.200	93.80
11	Sta 2.11	54.6	2.658			0.150	0	25.250	74.75
12	BBI		2.668		0.13	1.40	0	55.429	44.571
13	P. Ragi		2.670	0.125	0.14	0.34	0	91.867	8.133

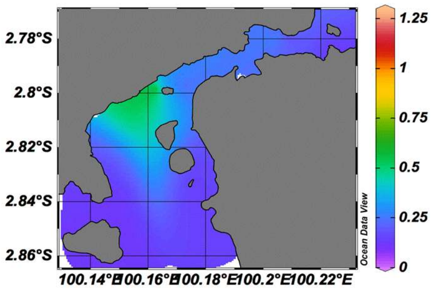
14	P. Siruso		2.669	0.096	0.12	0.38	0	85.235	14.765
15	Ttk.1	52.4	2.656	0.407	1.270	6.830	18.3	77.533	4.167
16	Ttk.2	54.1	2.656	0.200	0.240	0.385	0	97.133	2.867
17	Ttk.3	53.2	2.668	0.213	0.271	0.522	0	95.90	4.10
18	Ttk.4	54.2	2.669	0.205	0.247	0.400	0.267	97.433	2.30
19	Ttk.5	54.1	2.666	0.200	0.246	0.392	0	97.467	2.533
20	Ttk.6	55.0	2.657	0.150	0.380	6.900	19.167	55.967	24.867
21	Ttk.7	53.3	2.679	0.091	0.120	0.310	0	77.771	20.229
22	Ttk.8	54.6	2.661	0.240	0.350	1.100	4	91.30	4.70
23	Ttk.9	54.6	2.67	0.076	0.160	0.540	1.024	64.314	34.661
	Average		2.665	0.155	0.273	1.573	3.139	66.877	29.982

The grain size analysis shows that average diameter of sediment is D_{90} size 1.57 mm (Gs=2.665 gr/cm^3) and dominated by the sand about 66.88%. TDS about 51.6 to 55.0 (mg/L). According to Environmental Ministry Decree No.51 year 2004, the TDS appropriate for ports (80 mg/L) and mangrove (80 mg/L) but not for coral dan seagrass (20 mg/L). The distribution of sediment based on grain size (diameter) as shown in figure 9 and the type of sediment as shown in figure 10 below.

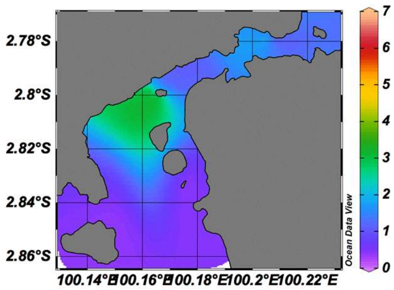




(a) Sediment D_{35}



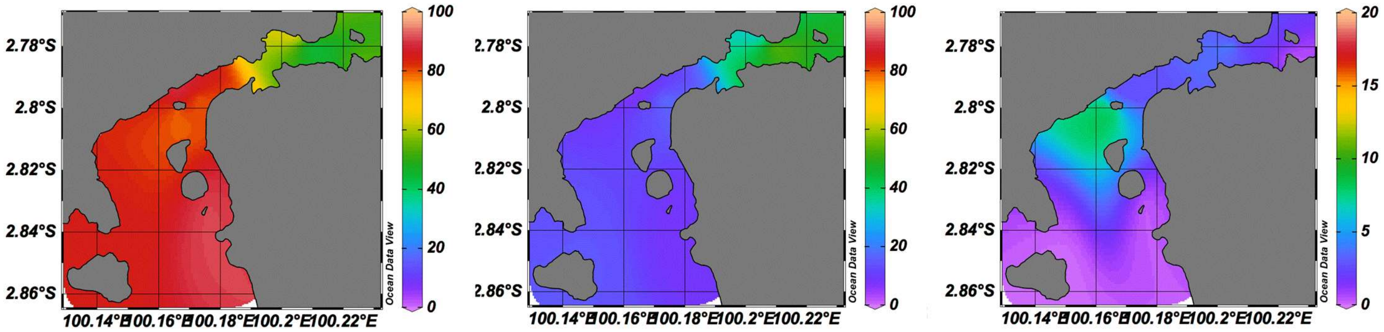
(b) Sediment D_{50}



(c) Sediment D_{90}

FIGURE 9. Distribution of Diameter Sediment at the Pagai Strait (D_{35}, D_{50} and D_{90})

Based on figure 9, the composition of sediment is D90 (1,573 mm), D50 (0,273 mm) and D35 (0,155 mm) and figure 10 shows the distribution of sand (66,878%), clay (29,982%) and gravel (3,139%).



(a) Sand (b) Clay (c) Gravel

FIGURE 11. Distribution of Sediment Type at the Pagai Strait (Sand, Clay and Gravel)

Sediment Transport at The Pagai Strait

1. Velocity of Particles, USACE (2000) :
   Median sediment size $D_{50} = 0.273$ mm. Figure 11, we get sediment scale for D_{50}, A = 0.119. Therefore, the velocity of sediment particle wf =0.2 cm/ second or 0.002 m/second (figure 12).

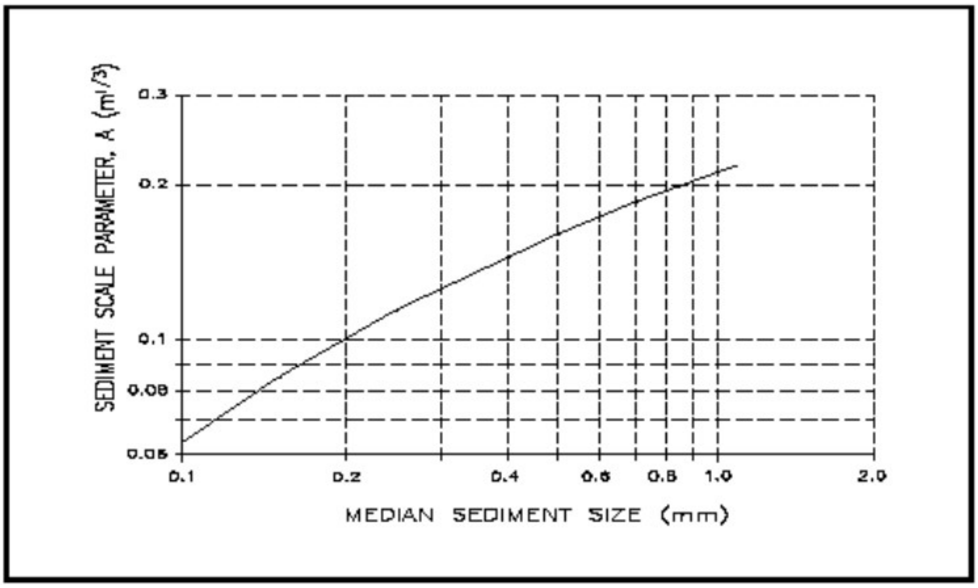


FIGURE 12. The Relation between Sediment Scale Parameter (A) with Median Sediment Size (D_{50}) [9]

Table III-3-3
Summary of Recommended *A* Values (Units of *A* Parameter are $m^{1/3}$)

D(mm)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.1	0.063	0.0672	0.0714	0.0756	0.0798	0.084	0.0872	0.0904	0.0936	0.0968
0.2	0.100	0.103	0.106	0.109	0.112	0.115	0.117	0.119	0.121	0.123
0.3	0.125	0.127	0.129	0.131	0.133	0.135	0.137	0.139	0.141	0.143
0.4	0.145	0.1466	0.1482	0.1498	0.1514	0.153	0.1546	0.1562	0.1578	0.1594
0.5	0.161	0.1622	0.1634	0.1646	0.1658	0.167	0.1682	0.1694	0.1706	0.1718
0.6	0.173	0.1742	0.1754	0.1766	0.1778	0.179	0.1802	0.1814	0.1826	0.1838
0.7	0.185	0.1859	0.1868	0.1877	0.1886	0.1895	0.1904	0.1913	0.1922	0.1931
0.8	0.194	0.1948	0.1956	0.1964	0.1972	0.198	0.1988	0.1996	0.2004	0.2012
0.9	0.202	0.2028	0.2036	0.2044	0.2052	0.206	0.2068	0.2076	0.2084	0.2092
1.0	0.210	0.2108	0.2116	0.2124	0.2132	0.2140	0.2148	0.2156	0.2164	0.2172

Notes:
(1) The *A* values above, some to four places, are not intended to suggest that they are known to that accuracy, but rather are presented for consistency and sensitivity tests of the effects of variation in grain size.
(2) As an example of use of the values in the table, the *A* value for a median sand size of 0.24 mm is: $A = 0.112\ m^{1/3}$. To convert *A* values to feet units, multiply by 1.5.

FIGURE 13. Recommendation of A value Based on Grain Size D50 [9]

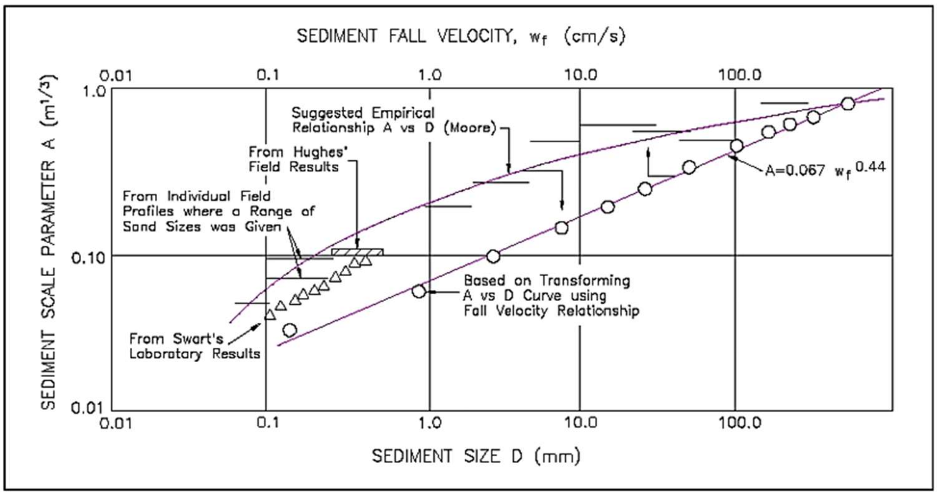


FIGURE 14. The Relation Parameters between A, wf and D_{50} [9]

2. Profile of balanced coastal, Dean (1977) :

$$h = f(A^n)\ldots\ldots\ldots(3)$$

$$h = f(A)^{\frac{2}{3}} = \left(\frac{24}{5}\frac{D}{\rho g K^2\sqrt{g}}\right)^{\frac{2}{3}}\ldots\ldots\ldots(4)$$

and $K = 1{,}4e^{(-2{,}5\ D_{50})}$
If A is a function of wf, then:

$$h = 2.25\left(\frac{wf^2}{g}\right)^{\frac{1}{3}}\ldots\ldots\ldots\ldots(5)$$

with:
h = profile of balanced coastal (m)
A = Parameter of sediment scale, function of D50
n = 2/3

$$h = 2{,}25\left(\frac{0{,}00119^2}{9{,}18}\right)^{\frac{1}{3}}$$
$$h = 0{,}113872 \text{ m}$$

3. Volume of sediment transport, CERC and CEM (2002) :

$$Qs = 0{,}014\, x\, Hs^2\, x\, co\, x\, kr^2 x\, \sin\alpha\ x\ \cos\alpha \ldots\ldots\ldots (7)$$

with:
Qs = volume sediment transport (m3/second)
Hs = height of significant waves (m)
co = velocity of wave (m/ second)
kr = refraction coefficient
α = angle of break wave
Data (RICRV, 2016):
Hs = 2,06 m
= 0,032716°
Sin α = 0,000571
Cos α = 1
Kr = 0,999985
co = 0,132 m/ second

$$Qs = 0{,}014\, x\, Hs^2\, x\, co\, x\, kr^2 x\, \sin\alpha\ x\ \cos\alpha$$
$$Qs = 0{,}014\, x\, 2{,}06^2\, x\, 0{,}1327894\, x\, 0{,}999985^2 x\, 0{,}000571\, x\, 1 = 0{,}000004505$$

Qs = 0,000004505 m^3/ second x 24 x 60 x 60
Qs = 0.389 m^3/day

CONCLUSION

The result shows that the characteristics of sediment is mostly D_{90} with size 1.57 mm; specific gravity 2.665 gr/cm^3; and dominated by sand 66.88%. TDS about 51.6 to 55.0 (mg/L) appropriate for port and mangrove. The velocity of sediment particles is 0.002 m/s and the volume of sediment transport is 0.389 m^3/day approximately.

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