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Sedimentation Management Strategy in River Estuary for Control the Water Damage in Downstream of Ayung River

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***Abstract*— The Ayung River Basin is the largest watershed on Bali Island. Ayung River flows from Lake Batur and empties into Padanggalak beach. River estuary is an area of sediment material deposition that will form an alluvial formation. The deposition of sediment at the river estuary is due to the influence of river flow, tidal, and wave action on the beach. Sediments that settle at the river estuary can obstruct water flow to the sea, which can cause backwater and flooding to the mainland. The strategy of controlling sediment deposition in the river estuary is essential to reduce the water damage in the downstream area, which is usually used as a tourism area. Ayung River Estuary is one of the estuaries that experienced a massive deposition; on the other hand, the Ayung River Estuary is widely used as a tourism area. The data used are primary and secondary—primary data obtained by a survey to the location and secondary data obtained from supporting data for analysis. Sedimentation occurs in the Ayung river estuary. It is due to soil type, topography, and hydro oceanographic condition. Besides, changes in the regional functions, such as temple construction, also affect the sedimentation process in the estuary. Sedimentation management strategies that can be carried out for the Ayung River estuary are the first is with the jetty construction method, which begins with the normalization of the downstream river, and the second is maintenance dredging, which is carried out through cooperation between the government and the community. Besides being used as sediment control, the jetty that was built can be developed as a tourist location around the estuary area.**

***Keywords*—river estuary; sedimentation; management strategy; downstream; water damage.**

I. INTRODUCTION

Watershed is an area that is limited by ridges where the rainwater that falls on the area will be accommodated by the ridge of the mountain and will be flowed through small rivers to the main river [1]. Estuaries are complex, dynamic environments with many interacting processes, and they vary both spatially and temporally [2]. River Estuary worldwide are very dynamic complexes where both ocean and land events are important drivers; any modifications in either of these will have an impact on the coastal water body [3]. The stability of the coastline is impacted by water and sediment volume, changing the course of the estuary reach and ocean dynamics. The coastline across the estuary develops due to the deposition of river sediment [4]. Sediment sources and sinks must be identified to calculate the sediment budget for a coastal area accurately. A sediment budget refers to the total amount of sediment added to and removed from a coastal system and indicates if accretion or erosion is expected in a particular location. Gaps in knowledge on either side of the budget will prevent reliable estimates about how much sediment is accreting or eroding from a coastline each year [5]. In the estuary, the velocity of the wave propagation is higher than the speed of the river flow from upstream. It induces the tidal bore generation [6]. The stream bed sediments are mainly originating from the physical erosion of the soils, even if the bank erosion could contribute to supply some sediments to the river loads, and their subsequent transport into the hydrographic network by the different rivers draining the upper parts of the catchment [7].

The rivers that flow in Bali Province are the Bali Penida River Region Unit, which consists of 391 River Watersheds [8]. The Ayung River Basin is the largest watershed on Bali Island. Ayung River flows from Lake Batur and empties into Padanggalak beach. River estuary is an area of sediment material deposition, which is thought to produce alluvial formations that are either building the surface of the estuary base (aggradation) or lowering the surface of the estuary base (degradation) [9].

Ayung River estuary is widely used as a tourism area, such as Padanggalak beach, which is visited by many people, both domestic and non-domestic. Besides Padang Galak

beach, which offers beautiful natural scenery in the Ayung river estuary, there is also a temple called Campuhan Windhu Segara Temple, which is used as a religious location that visited by many people around there. Even though it has promising tourism potential, but there is a sedimentation problem at the Ayung River estuary, which has a negative impact on the area around the estuary.

The problem that occurs at Ayung River estuary is sedimentation. The process of sediment and river mouth sediment transport is the process of sedimentation, erosion of the bottom of the estuary, and transportation of sediments on the surface of the earth [10]. Erosion and transport of unconsolidated sediments match energetic forcing. Rocks and soil breakdown results from physical weathering due to heat, water, frost, and pressure, and to chemical weathering, then particles are eroded, i.e., removed, and transported. While rainfall and surface runoff are driving soil erosion, the fluvial stream (characterized by bottom shear and turbulence level) is driving stream erosion. It is the main transport agent for all collected material [11]. According to Foster and Meyer [12], erosion is the cause of sedimentation caused by water, especially covering the process of detachment, transportation, and deposition of soil particles that occur due to collisions of rainwater and water flow. Sediment is preferably retained within these systems, as extraction would weaken their resilience to sea-level rise [13].

Sedimentation that occurs in Ayung River estuary is the form of sand covering the river estuary; this deposition occurs because of the influence of the dominant waves originating from the east, southeast, and south as well as eroded sediments from the river headwaters.

Sand sediments that cover the river mouths cause the accumulation of mud sediments originating from river flow. This can cause blockage of water discharge into the sea so that it can result in overflowing of water when the discharges in the river are more significant than the usual. It causes the inundation of the area around the Ayung river downstream, wherein the downstream area is located some tourism sites, such as Campuhan Windhu Segara Temple and Tangtu Beach. These sites are the location for recreational tourism and for religious events for the surrounding community. The overflow that ever occurred in the Ayung River estuary in 2013 that can be seen in Fig. 1.

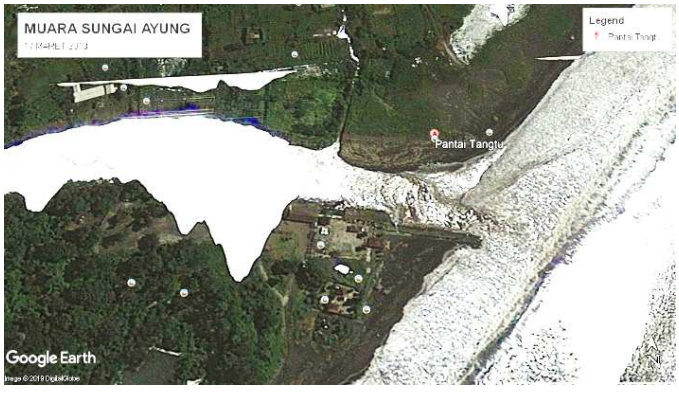

Fig. 1 The overflow that ever occurred in the Ayung River Estuary in 2013

For overcome this problem, it is necessary management of sedimentation in Ayung river estuary as a preventive measure of the impact caused by water damage around the Ayung river estuary and surrounding areas.

II. MATERIAL AND METHODS

A. Research Location

This research took place in the downstream area of the Ayung River in Denpasar City. The Ayung River Basin is a continuous river flow throughout the year, and land use is dominated by wetland agriculture. The river conditions in this area have high cliffs with long grooves, where the level of vertical erosion in all rivers is quite high.


Fig. 2 Research Location in Ayung River Estuary

B. Research Material

The research material used is primary and secondary data. Primary data obtained from surveys directly to the location to see the sedimentation occurs. Secondary data obtained from supporting data in the form of photos of Google Earth, maps of soil types, and topographic maps.

C. Data Analysis Technique

This research will be done by analyzing the characteristics of sedimentation in the estuary, observe the changes of sedimentation form that occurred from 2003-2018, find the factors that causing sedimentation and determining the strategy to manage sedimentation in the Ayung River Estuary. This strategy is expected to reduce the impact of water damage that can harm the area around the downstream of the Ayung River.

III. RESULT AND DISCUSSION

A. Estuary

An estuary is a partially enclosed coastal water body where freshwater from rivers and streams mixes with saltwater from the ocean. Estuaries, and their surrounding lands, are places of transition from land to sea. Although influenced by the tides, they are protected from the full force of ocean waves, winds, and storms by landforms such as barrier islands or peninsulas.

Estuarine environments are among the most productive on earth, creating more organic matter each year than comparably-sized areas of forest, grassland, or agricultural land. The sheltered waters of estuaries also support unique communities of plants and animals specially adapted for life at the margin of the sea.

Estuaries provide us with a suite of resources, benefits, and services. Some of these can be measured in dollars and cents, while others cannot. Estuaries provide places for recreational activities, scientific study, and aesthetic enjoyment. Estuaries are an irreplaceable natural resource that must be managed carefully for the mutual benefit of all who enjoy and depend on them. [14].

B. Ayung River Estuary

The Ayung River Basin is the largest watershed in the Bali Penida River Basin, with an area of 306,149 km^2 with a river length of 71,791 km. This watershed through 6 districts/cities, that are Tabanan Regency (4,901 km^2), Buleleng Regency (10,734 km^2), Denpasar City (18,141 km^2), Gianyar Regency (49,875 km^2), Bangli Regency (95,076 km^2), and Badung Regency (127,421 km^2) [15]. Ayung River Estuary is located between Padang Galak Beach and Tangtu Beach. In this area, there are some tourism activities and a religious activity. In the high intensity of the rainfall, around this area, the water from the river will be overflowed.

C. Sedimentation in Estuary

Sedimentation in estuaries is a natural process that can be accelerated by changes in land use or land management within the catchment, or by the development of structures within the estuary. Accelerated sedimentation rates can impact on the amenity values of an estuary by infilling channels and making sediments muddier. Increased suspended sediment in the water column, and deposition of sediment on tidal flats, can affect benthic communities (i.e., plants such as seagrass, and animals such as shellfish and worms that live on or in the estuary sediment), with knock-on effects to fish and shorebirds. The amount of sedimentation can be influenced by rainfall, waves, and tidal currents and varies at different locations within an estuary and seasonally with changes in weather patterns. This variation means that monitoring sedimentation is complex, and it can be challenging to measure accurately [16].

D. Geological State of Ayung River Basin

The Ayung watershed is dominated by reddish-brown latosol and litosol soils as much as 47.91% of the Ayung watershed area. Whereas specifically for the downstream area of the Ayung River, the regosol is dominated by yellowish-brown and yellowish-brown latosol.

Latosol soil is soil that has advanced weathering with acidic pH characteristics, low organic matter, and nutrient content [17]. Latosol soil is a type of soil that developed or formed by the horizon differentiation, clay texture, brown, red to yellow, scattered in wet climates, rainfall more than 3000 mm/year, and altitude ranges between 300-1000 meters above sea level. It is easy to absorb water and moderate organic matter content. It has a pH of 6-7 (neutral to acid) and phosphate substance that is easily compounded with iron and aluminum; humus levels are easily decreased. Latosol soil is suitable for rice, crops, coconut, rubber, coffee, palm oil, and fruits.

Regosol soil is soil formed by weathering rocks containing volcanic ash, beach sand, and naphtha. Spread on flat topography, the base material of this soil are volcanic material and beach sand [18]. Regosol soil is a type of soil that still young, has not experienced the differentiation of the horizon, is fertile, coarse-grained, gray in color, rich in nutrients, pH 6-7, tends to lose, high water-absorbing ability, and easily eroded—widely used for agricultural land. Regosol soil is also suitable for crops, tobacco, and fruits. This land is also of moderate temperature because it is part of the volcanic soil of moderate temperature.

From the characteristics of the soil and the existing conditions in the research location, the downstream area of the Ayung River is indeed an area with high rainfall with an easily eroded soil type. This condition causes the sedimentation and flooding downstream of the Ayung River to have great potential to occur.

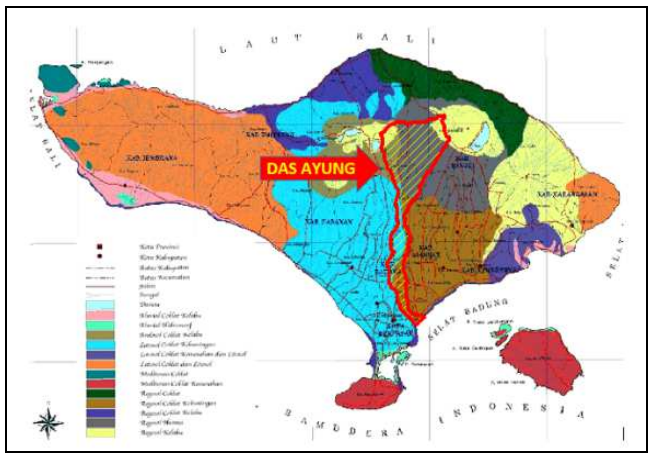

Fig. 3 Ayung River Basin Soil Type

E. Topography of the Ayung River Basin

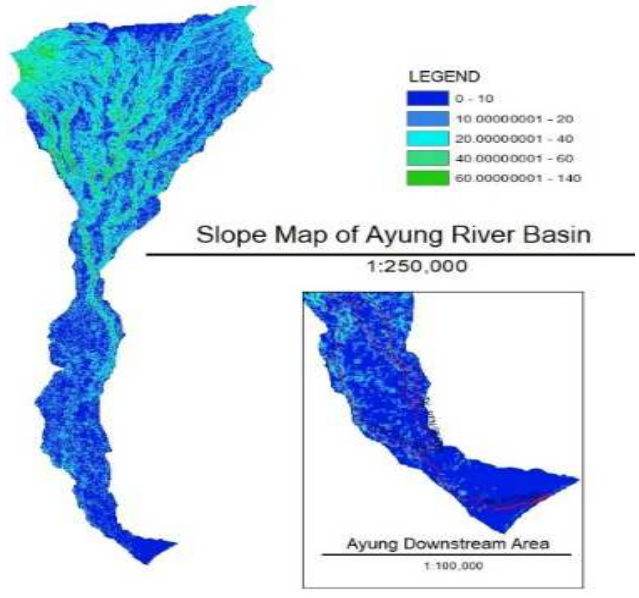

Fig. 4 Topography of the Ayung River Basin

In general, the height of the Ayung River Basin ranges from 0-2000 m with the dominant height ranging from 1000-1500 m at 36% of the Ayung River Basin area. The slope gradient as a topography factor also plays an essential role in

impacting soil erosion intensity [19]. The large slope upstream causes easy erosion, which will carry sediments up and down. And the slope of the downstream slopes which are small and tend to be sloping makes the sediment settle downstream. This is one of the factors causing sedimentation in the Ayung River Estuary.

F. Hydro Oceanographic State

In general, based on the results of wind data from the Ngurah Rai Meteorological and Climatology Agency station for twenty years from 1994 to 2013 the dominant wave direction originates from the southeast, east and south as shown in Fig. 5.

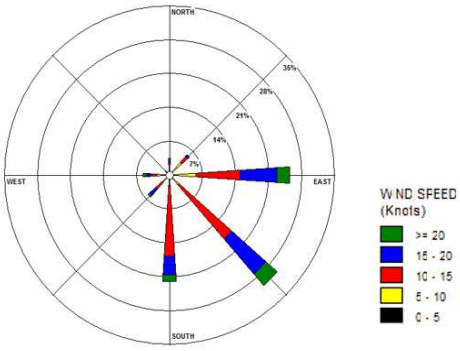

Fig. 5 Wind Rose of Padanggalak Beach

Wind regime and sediment supply are known to control the formation of bare-sand dunes [20] largely. Changing coastlines around river mouths is a complex process. One of the causes of changes in coastline around the estuary is the influence of sediment supply from the estuary to the coastal area around the estuary [21].

Water flowing on the ground or river surface carrying fine rock floating, floating, or shifted at the bottom of the river to a lower place. Gusts of wind can also lift dust, sand, and even larger materials. The stronger the gust, the greater the carrying capacity. In the desert, for example, large piles of sand can be blown by the wind and moved elsewhere. While glaciers, although slow in motion, have a large carrying capacity [22].

Fig. 6 Dominant Wave Direction of Padanggalak Beach

The direction of wind coming from the south and east will cause carryover of sediment from the Padanggalak beach into the mouth of the river it is also a factor in the transport of sediment to settle at the river estuary.

G. Sedimentation Conditions in the Ayung River Estuary

To see the pattern of sedimentation that occurs at the Ayung river estuary can be seen from Google Earth photos every three years, and visible differences in the location of sedimentation and the amount of sedimentation that occurs.

Fig. 7 Sedimentation Condition in Ayung River Estuary Condition in 2003

Fig. 8 Sedimentation Condition in Ayung River Estuary Condition in 2009

Fig. 9 Sedimentation Condition in Ayung River Estuary Condition in 2012

Fig. 10 Sedimentation Condition in Ayung River Estuary Condition in 2015

Fig. 11 Sedimentation Condition in Ayung River Estuary Condition in 2018

In early 2003 it was seen that more sedimentation occurred near the Padanggalak beach, and there were no temple buildings on the Padanggalak beach. In contrast, for the following years, it occurred near the Tangtu beach after the construction of temples on the Padanggalak beach. This could indicate that the land-use change, such as the construction of temples on the Padanggalak beach, changed the pattern of sedimentation that occurred in the Ayung River.

H. Ayung River Estuary Sedimentation Management Strategy

System managers must address the possibility of irreversible consequences of sediment management strategies. There are potential ways to minimize negative impacts and benefit from the effects of dredged disposals [23]. Management of these systems requires knowledge of sediment dynamics to inform decisions on issues related to sediment disposal and its environmental impacts [24].

The study developed management objectives and considered all feasible management options that address the identified issues of concern that are affecting the estuary [25]. The strategy to manage the river estuary sedimentation is determined based on several considerations. The consideration can be the characteristics of the estuary, causes of sedimentation, sediment characteristics, and so on. River management can be done with several alternatives, including the following:

1) Land Use Arrangement: The extent and type of human activities in the catchment (i.e., land use) can influence the magnitude of sediments, nutrients, and salts sources. First, the presence of vegetation, which affects nutrient levels in catchments, can be greatly influenced by the land use, with less dense vegetation in urban and agricultural regions [26]. Land use management in watersheds is intended to regulate land use, following existing spatial planning patterns so that land erosion can be reduced.

2) River Basin Management: Watershed management is closely related to regulations, planning, implementation, and training. Land management activities are intended to conserve and save water and soil conservation. Watershed management includes the following activities:

- Maintenance of vegetation in the upper reaches of the watershed.
- Planting vegetation to control the speed of water flow and soil erosion.
- Maintenance of natural vegetation or proper planting of waterproof vegetation along drainage embankments, canals, and other areas to control excessive flow or soil erosion.
- Construction of unique structures for sediment control such as jetty and others.

3) Normalization of River Flow: In river basins that have a small slope, sedimentation tends to occur. As a result of this sediment, the river channel will become narrow and shallow so that it disrupts the flow of water, and there will be an increase in floodwater levels. Therefore, dredging and channel widening are needed—dredging and widening the channel system aimed at increasing the capacity of the river and smoothing the flow. For the dredging and widening design is required, the hydrological, hydraulics, and sedimentation analysis. The possible changes to sediment management are intended to create a more efficient system of dredging and licensing that works with the environment, reduce disruption to businesses, and reduces costs for stakeholders. The next steps in work will be to identify practical options for improved methods and then to invite dredging stakeholders to a series of workshops to encourage discussion and collaboration [27].

Based on some alternatives that can be done to manage sedimentation that occurs at the river estuary, the best comprehensive strategy that can be done for the Ayung river estuary is a jetty construction method. Before doing the jetty construction, it will better begin with the normalization of downstream rivers and continue by maintenance dredging annually, which is carried out through cooperation between the government and the community. Besides being used as sediment control, the jetty that was built can be developed as a tourist location around the estuary area.

IV. CONCLUSION

Based on the explanation above, it can be concluded as follows; sedimentation that occurred in the Ayung river estuary is due to soil type, topography and hydro oceanographic condition of the area and the pattern of sedimentation that occurred changed after changes in land use on the Padanggalak coast, such as the construction of the Campuhan Windhu Segara Temple. Sedimentation management strategies that can be carried out for the Ayung River estuary are the first is with the jetty construction method, which begins with the normalization of the downstream river, and the second is maintenance dredging, which is carried out through cooperation between the government and the community. Besides being used as sediment control, the jetty that was built can be developed as a tourist location around the estuary area.

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REFERENCES

[1] Asdak C. 2007. Hydrology and Control of Watersheds. Yogyakarta: Gadjah Mada University Press. Yogyakarta.

[2] City of Launceston on behalf of the Launceston Flood Authority (LFA). 2019. Kanamaluka/Tamar River Estuary Sediment Raking Program Review.

[3] Joseph S. Guevara, Rodolfo Silva, and Debora Lithgow. 2019. Assessment of Sedimentation in a Coastal Lagoon: Chantuto-Panzacola, Mexico, Journal of Coastal Research 92 (sp1), 145-156.

[4] Kordesch, W.K., M. Delaney, S. Hutto, M. Rome, and S. Tezak. 2019. Coastal Resilience Sediment Plan. Report of Greater Farallones National Marine Sanctuary. NOAA. San Francisco, CA. 104 pp.

[5] Bo Huang et al. 2019. IOP Conf. Ser.: Earth Environ. Sci. 227 052021.

[6] Aprizon Putra, Ulung Jantama Wisha, and Gunardi Kusumah. 2017. Spatial Analysis of the River Line and Land Cover Changes in the Kampar River Estuary: The Influence of the Bono Tidal Bore Phenomenon. Forum Geografi, 31(2).; DOI: 10.23917/forgeo.v31i2.5290.

[7] Mamadou Alpha Sow, Virginie Payre, Frederic Julien, M. Camara, David Baque, et al. 2018Geochemical composition of fluvial sediments in the Milo River basin (Guinea): is there any impact of artisanal mining and a big African city, Kankan. Journal of African Earth Sciences, 145, pp.102-114.

[8] Eryani, I Gusti Agung Putu. 2015. Water Potential of the Petanu and Saba River Estuaries as Water Resources Management Models in Bali Province. Dissertation. Udayana University. Denpasar.

[9] Tendean, M. 2012. Hydrophyte Based Sediment Transport Spatial Model along the Ranoyapo Amurang River Estuary. Doctoral Program. Brawijaya University. Malang.

[10] Dibyosaputro, S. 1979. River Water Yield Sediment Study in the Upper Lukulo River Drainage Area above the Karangsambung Kebumen AWLR. Degree program. Gadjah Mada University. Yogyakarta.

[11] Ouillon, Sylvain. 2018. Why and How Do We Study Sediment Transport Focus on Coastal Zones and Ongoing Methods. Water, 10 (390): 1-34.

[12] Foster, G. R., and Meyer, L.D. 1977. Soil erosion and sedimentation by water-overview. Michigan: Am. Soc. Of Agric. Eng., St. Joseph.

[13] P. L. M. de Vet, B. C. van Prooijen, I. Colosimo, T. Ysebaert, P. M. J. Herman, and Z. B. Wang. 2020. Sediment disposals in estuarine channels alter the ecomorphology of intertidal flats. Journal of Geophysical Research: Earth Surface, 125, https://doi.org/10. 1029/2019JF005432.

[14] National Estuary Program (NEP). 2016. Basic Information about Estuaries. United States Environmental Protection Agency. United States

[15] Bali-Penida River Basin. 2012. Preparation of a Water Resources Management Plan for the Bali-Penida River Region (Phase I). Bali-Penida River Basin. Denpasar.

[16] Waikato Regional Council. 2008. Sedimentation in Estuaries. Newzealand Government.

[17] Saptiningsih, Endang, and Sri Haryanti. 2015. Cellulose And Lignin Content Various Source Of Organic Materials After Decomposition In Latosol Soil. Bulletin of Anatomy and Physiology Volume XXIII, Number 2.

[18] Muslimawati, N.M., and Prima Widayani. 2016. Spatial Analysis of Soil worm disease Transmitted Helminth with Soil Characteristics Through Geomorphological Approach in Bantul Regency. Jurnal Bumi Indonesia. Vol 5 No. 1.

[19] Zhanyu Zhang, Liting Sheng, Jie Yang, Xiao-An Chen, Lili Kong, and Bakhtawar Wagan. 2015. Effects of Land Use and Slope Gradient on Soil Erosion in a Red Soil Hilly Watershed of Southern China. Sustainability 2015, 7, 14309-14325.

[20] Jerome R. Mayaud and Nicholas P. Webb. 2017. Vegetation in Drylands: Effects on Wind Flow and Aeolian Sediment Transport. Land, 6 (64): 1-24.

[21] Kasury, Ahmad Reza. 2016. Simulation of Coastal Change towards the Labuhan Hajj Jetty Plan. Journal of Civil Engineering. Syiah Kuala University

[22] Anwas, O.M. 1994. The shape of the face of the earth. Yogyakarta Muhammadiyah University.

[23] Emma L. Jackson, Nathan B. English, Andrew D. Irving , Andrew M. Symonds, Gordon Dwane, Owen T. Nevin, and Damien T. Maher. 2019. A Multifaceted Approach for Determining Sediment Provenance to Coastal Shipping Channels. J. Mar. Sci. Eng. 2019, 7(12), 434; https://doi.org/10.3390/jmse7120434.

[24] Baptist, M. J., Gerkema, T., van Prooijen, B., van Maren, D., van Regteren, M., Schulz, K., et al. 2019. Beneficial use of dredged sediment to enhance salt marsh development by applying a 'Mud Motor'. Ecological Engineering, 127, 312–323. https://doi.org/10.1016/J.ECOLENG. 2018.11.019.

[25] Newcastle City Council, Port Stephens Council, Maitland City Council, NSW Office of Environment and Heritage, and Local Land Services. 2017. Hunter Estuary Coastal Zone Management Plan. BMT WBM. Australia.

[26] A. Lintern, J.A. Webb, D. Ryu, S. Liu, U. Bende-Michl, D. Waters, P. Leahy, P. Wilson, and A. W. Western. 2018. Key Factors Influencing Differences In Stream Water Quality Across Space. WIREs Water. doi: 10.1002/wat2.1260.

[27] Cowes Harbour Commission. 2018. Studies on Estuary Sedimentation Management. https://www.cowesharbour commission.co.uk/studies_on_estuary_sedimentation_management.