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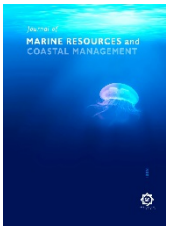

# Estimates of the economic damages of an oil spill on the coast of Muara Gembong, Bekasi Regency, West Java, Indonesia

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**ABSTRACT**

Coastal Muara Gembong is included in the Environmental Strategic Area, and the Natural Resources Strategic Area based on the Bekasi Regency Regional Spatial Plan 2011-2031. The Java Sea as the northern boundary of Bekasi Regency, one of the busy shipping routes originating from Tanjung Priok to Jayapura and Tanjung Priok to Surabaya, is the main source of oil spills that can occur around the coastal area of Muara Gembong. The coastal area of Muara Gembong has been affected by the Pertamina oil spill since July 21, 2019. The purpose of this study is to estimates the economic damages due to oil spills at Muara Gembong mangrove ecosystem. The economic damages are calculated by including two components, namely compensable value and recovery costs. Compensable value obtained by assessing natural resource damage, i.e. mangrove ecosystem, includes both the value of direct benefits and indirect benefits, which is IDR 497,519,413,897.09. The value of the recovery cost is IDR 40,611,959,689.98. So, the economic losses due to the oil spill on the Muara Gembong mangrove ecosystem is IDR 538,131,373,587.08. Along with these results, the government must also immediately be able to identify the impacts and calculate the value of losses or economic impacts to optimize the response to oil spill incidents.

**Keywords**: economic valuation, oil spill incident, compensable value, recovery cost

## INTRODUCTION

Oil pollution is one of the important problems in coastal and marine areas. Pollutants not only contaminate coastal zones and marine ecosystems but can also affect ecosystems in coastal and marine environment. Oil spills that occur in the marine environment will have an impact on marine organisms, such as benthos to invertebrates and marine mammals. Oil pollution will also have an impact on several types of birds. Water mixed with oil will also disrupt specific ecosystems in coastal and marine waters, such as coral reefs, seagrasses and mangroves.

Bekasi is one of coastal area which oil pollution often occurs. This pollution will have an impact on the destruction of marine biological resources in the area and will also have an impact on the economic life of the community which depends on the location of the waters around the oil spill. For this reason, an ecological and economic approach is needed in the decision-making process regarding oil spill mitigation [1].

Coastal Muara Gembong is included in the Environmental Strategic Area and the Natural Resources Strategic Area based on the Bekasi Regency Regional Spatial Plan 2011-2031. The Java Sea as the northern boundary of Bekasi Regency is one of the busy shipping routes originating from Tanjung Priok to Jayapura and Tanjung Priok to Surabaya is the main source of oil spills that can occur around the coastal area of Muara Gembong. Muara Gembong District has an area of 15.460 hectares consist of 6 villages, namely Pantai Mekar, Pantai Sederhana, Jayasakti, Pantai Harapan Jaya, Pantai Bakti, and Pantai Bahagia.

The coastal area of Muara Gembong has been affected by the Pertamina oil spill since July 21, 2019. The spill originated from a leak in the cape off the coast of YYA-1 of Pertamina Hulu Energi Offshore North West Java (PHE ONWJ) area of Karawang Regency waters [2]. The area of mangrove forests affected, which is 451 hectares of the total mangrove forest area before being affected by the oil spill, which is 3673 hectares [1].

Due to the vulnerability of the Muara Gembong coastal area and the danger of the perceived impact of an oil spill, it is necessary to take appropriate actions in tackling the impact of an oil spill, one of which is by estimating the losses due to pollution. To estimates the losses due to oil pollution, one of which is by calculating the value of ecosystem functions lost due to the impact of the oil spill [4].

The assessment of the economic impact of the oil spill can be carried out with an economic valuation approach using the concept of Total Economic Value (TEV). TEV basically includes an assessment of everything covered in environmental assets divided according to the value of benefits or not benefits (passive benefits). The calculation of the total value of losses due to oil spills includes three components: the compensable value, recovery or restoration costs and assessment costs [4]. According to [5] the cost of losses due to an oil spill can be estimated from three components, namely the cost

of environmental and socio-economic damage and the cost of cleaning up the oil spill.

This study aims to calculate the total value of losses due to oil spills that occurred on the Muara Gembong coastal area. Previous studies have calculated the total value of the benefits of mangrove ecosystems in Mekar Village, Muara Gembong District [6]. However, in this study, the focus is on the value of losses, where not only the value of ecosystem benefits is taken into account. Besides that the scope area of this research is also wider, namely all villages covered by the coastal of Muara Gembong.

## METHODS

### Research Location

The location of the research taken was in Muara Gembong District, Bekasi Regency (Figure-1). The distribution of oil spills that occur along the coastal of Muara Gembong is shown in Figure-2. Muara Gembong Coast is located on the North Coast of Java where there are 33 types of mangroves found in the area [3].

### Data Collection

The data used is secondary data. Data obtained from previous research and news related to the topic under study. The data is in the form of the affected mangrove area, the volume of the oil spill, as well as the price and quantity of an item to calculate the value of productivity, replacement costs, rehabilitation costs, and cleaning costs of the affected area.

### Data Analysis

The assessment of the economic impact of the oil spill carried out with an economic valuation approach using the concept of TEV. TEV basically includes an assessment of everything covered in environmental assets divided according to the value of benefits or non-benefits [4,7-9]. In general, the approach used in this study is shown in Table-1.

Benefit transfer is the procedure for taking an estimate of the economic benefit collected from one site and applying it to another site [10]. The value obtained from other sites needs to be adjusted to the location of the study and by paying attention to the current currency value. Equation (1) used to calculate the present value.

$$PV = FV\frac{1}{(1+r)^n} \quad (1)$$

where $PV$ is present value, $FV$ is future value, $r$ is rate of return, and $n$ is number of periods.

The calculation of the total value of losses due to oil spills includes 3 components, namely the compensable value, recovery or restoration costs and assessment costs [4]. However, in this study, it only calculated the compensable value and restoration cost.

### *Compensable Value*

Compensable value is everything received, physical or non-physical, and must be calculated and given to a party or person who is generally an object affected by an oil spill. Compensable value consists of several values based on the type of utilization and utilization of marine natural resources in areas affected by oil spills. In the case of an oil spill on the Muara Gembong Coast, Bekasi Regency has an impact on mangrove ecosystems and fisheries sector. The economic lost from mangrove ecosystem and fisheries sector then calculated using the total economic value.

The productivity approach in economic assessment is used to provide natural resource prices (fisheries productivity) through an actual market price approach, especially for natural resources traded in the market [11]. Calculation of the fisheries productivity approach using the Equation (2).

$$\text{Total value of fisheries productivity} = (Q_1 \times P_1) + (Q_2 \times P_2) \quad (2)$$

where $Q$ is quantity of fisheries product and $P$ is price of fisheries product.

The estimated value of indirect benefits calculated using the replacement cost and benefit transfer approach. This approach is applied to the function of mangrove ecosystems as wave-retainers or breakwater, biodiversity and carbon sinks. Then, TEV is the sum of the value of direct benefits (fisheries productivity) and the value of indirect benefits that have been identified and quantified.

### *Recovery Cost*

Recovery costs are costs incurred in recovery efforts to make the environment function again as it was. The cost of restoring the environment affected by the oil spill is divided into two, namely the cost of cleaning up oil spills in coastal and marine areas and the cost of rehabilitating the ecosystem environment. Each recovery cost is calculated using a direct cost analysis approach [4]. In this study, the cost of cleaning up oil spills is obtained by the benefit transfer approach.

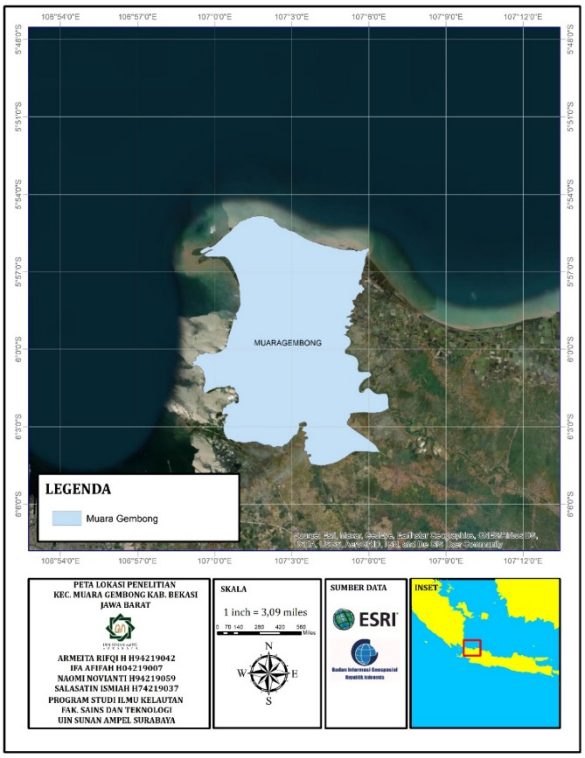


**Figure-1.** Location of Muara Gembong Coast, Muara Gembong District, Bekasi Regency

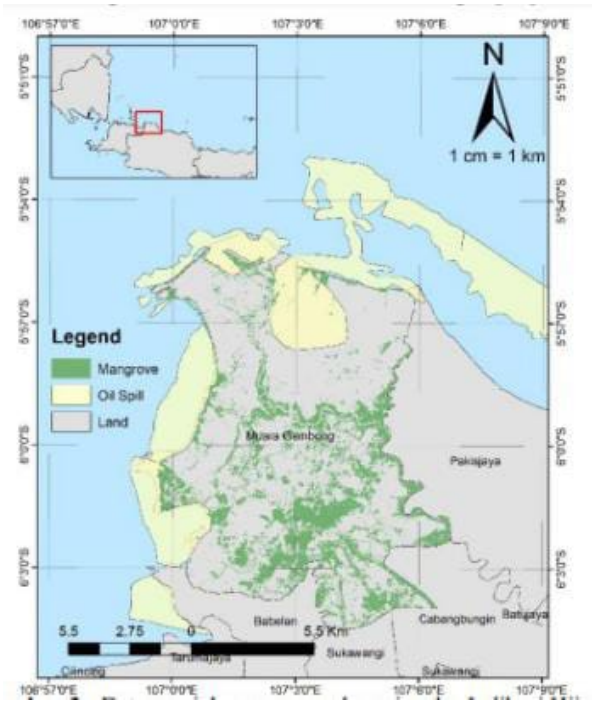


**Figure-2**. Map of the distribution of oil spills on the coast of Muara Gembong on 2019 [3]

## RESULTS AND DISCUSSION

### Compensable Value: Direct Value

The value of the direct benefits of the mangrove ecosystem at the research site, which was identified as the benefits lost due to the oil spill, was in the form of activities to the use of mangrove ecosystems to the fisheries productivity. The benefits and their economic value can be seen in Table-2. This value approached the results of a study from [6] which calculated the total economic value of mangrove ecosystems in the Mekar Beach area, Muara Gembong District. Mekar Beach is one of the beaches located in the Muara Gembong District. The value of the direct benefits in the study was adjusted to the area of the affected mangrove area and converted to the current value.

**Table-1.** Valuation approach and methods used to estimates the economic value of mangrove ecosystem due to oil spill on Muara Gembong Coast

| | | |
|---|---|---|
| **Compensable Value: Direct Value** | | |
| 1 | Shrimp farm | Benefits transfer |
| 2 | Milkfish pond | |
| 3 | Seaweed ponds | |
| 4 | Crab catching | |
| 5 | Mangrove seedlings | |
| 6 | Firewood | |
| 7 | Fishing | |
| **Compensable Value: Indirect Value** | | |
| 8 | Breakwater/shoreline stabilization | Replacement cost |
| 9 | Biodiversity | Benefits transfer |
| 10 | Carbon sinks | Benefits transfer |
| **Recovery Costs** | | |
| 11 | High seas clean-up cost | Benefits transfer |
| 12 | Coastline clean-up cost | Cost analysis |
| 13 | Rehabilitation costs | Cost Analysis |

**Table-2**. Direct value Muara Gembong mangrove ecosystem

| Types of Benefits | Value (IDR/year) |
|---|---|
| Shrimp farm | 121,038,788,161.74 |
| Milkfish pond | 124,322,786,289.98 |
| Seaweed ponds | 112,594,221,546.09 |
| Crab catching | 1,151,165,752.08 |
| Mangrove seedlings | 9,059,960,134.49 |
| Firewood | 241,598,936.92 |
| Fishing | 321,417,654.44 |
| Total | 368,729,938,475.74 |

The value of lost due to the oil spill on the Muara Gembong Coast in the use of mangrove ecosystems is IDR 368,729,938,475.74 per year (Table-2) or IDR 817,583,012.14 per ha per year, as mangrove area Muara Gembong Coast of 451 ha. The value is obtained based on the results of identifying the use of mangrove ecosystem resources by the surrounding community in Muara Gembong District, Bekasi. Fisheries productivity resulting from the ponds of milkfish, shrimp, and seaweed as well as crab catches is a form of utilization of the mangrove ecosystem that produces the greatest value, especially the results of milkfish ponds (34%) (Figure-3).

For utilization as mangrove seedlings, one hectare of mangrove forest can produce 16,000 seedlings. For utilization as firewood, some residents collected dried trees from mangrove forests and then took the wood for sale. In one hectare of mangrove forest can be collected five bunches of firewood. As for the benefits of fishing, fishing is located on the Blacan River, precisely the river that is the barrier between Pantai Mekar Village and Pantai Harapan Jaya Village (a village included in the Muara Gembong District). The average visitors per week are 200 people.

The direct value of the Muara Gembong mangrove ecosystem is much greater than the direct value of the mangrove ecosystem in Pasar Ngalam Village, Seluma Regency, where the direct value is only IDR. 42,140,000.00/ha/year [12]. However, it is much smaller than the direct value of the mangrove ecosystem in Karangsong Village, Indramayu with IDR 3,486,594,145.00/ha/year [13]. This shows that the direct value of mangrove ecosystems in each region has different results. This difference can be caused by the economic value of productivity (such as the number of catches, market prices, etc.) per year and the condition of the mangrove ecosystem in each area.

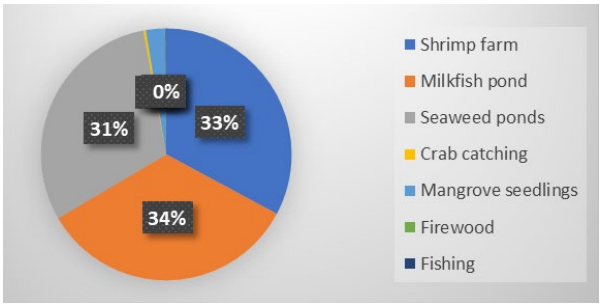


**Figure-3.** Percentage of direct benefit or utilization of Muara Gembong mangrove ecosystem

**Compensable Value: Indirect Value**

Indirect value are benefits derived indirectly from mangrove ecosystems such as physical benefits and biological benefits, which are identified as the value of the benefits lost due to oil spills. The types of direct benefits and their value of Muara Gembong mangrove ecosystem can be seen in Table-3.

**Table-3.** Indirect value Muara Gembong mangrove ecosystem

| Types of Benefits | Value (IDR/year) |
|---|---|
| Breakwater | 127,835,187,541.20 |
| Biodiversity | 101,519,987.25 |
| Carbon sink | 852,767,892.90 |
| Total | 128,789,475,421.35 |

One of the benefits of the mangrove ecosystem is the function of mangroves as a buffer for coastal abrasion. The value for this benefit is obtained through a replacement cost approach, by estimating the cost of making coastal concrete for breakwaters [11]. The estimated cost of making a breakwater building with a size of 150 m × 20 m × 5 m is depicted in the [14], which is IDR 2,921,147,000 or around IDR 19,474,313 per meter. The estimate is based on prices or costs in 2012. To get an estimate of the current value, the value is converted to the average inflation value that occurred in 2022. To make a 4510-meter-long breakwater building (as long as coastal line with mangrove), IDR 127,835,187,541.20 is required.

This value is much greater than the results of the research in Pabean Udik Village, Indramayu with an estimated value of the construction of a breakwater of IDR 20,200,000.00 [15]. This very large difference in value is due to the calculation of the estimated construction of the breakwater using conventional tools and materials, namely tires, paranet, bamboo, and rope. So it does not refer to the estimated cost of making a breakwater based on [14] in which the tools and materials used are much more modern and more expensive, i.e. concrete material. The economic value of the function of mangroves as a buffer for coastal abrasion (breakwater) also has the highest percentage (99%) compared to other types of indirect benefit (Figure-4).

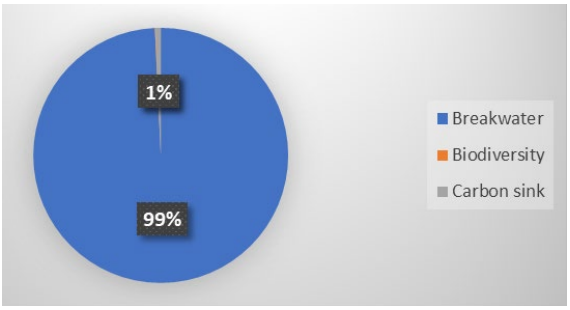


**Figure-4.** Percentage of indirect benefit or utilization of Muara Gembong mangrove ecosystem

Furthermore, the value of biodiversity is obtained by the benefit transfer approach, by multiplying the value of the benefit US$ 15/ha/year [16]. With the IDR exchange rate to the US dollar, which is IDR 15,007 (in July 2022), so that a value of IDR 225,099.75/ha/year is obtained. This result is multiplied by the total area of the mangrove forest ecosystem affected by the oil spill in Muara Gembong, which is an area of 451 ha [3]. Thus, the value of biodiversity, as the value of the benefits of resources lost in the ecosystem affected by the oil spill, on the Muara Gembong Coast is IDR 101,519,987.25/year.

Mangroves ecosystem also has function or playing their role as carbon sinks. This is due to the presence of biomass, density, and high productivity [6]. The value of this benefit calculating used a benefit transfer approach, by consuming a carbon sequestration value of US$ 126/ha/yr [17]. So that the value of the benefits of the lost resources in the form of carbon sequestration for mangrove forests affected by the oil spill covering an area of 451 ha on the Muara Gembong Coast is IDR 852,767,892.90. From all the descriptions above, the total of indirect values from the coastal mangrove ecosystem of Muara Gembong is IDR 128,789,475,421.35 (Table-3), with the type of benefit that provides the most value is the value of mangrove ecosystem as the breakwater (Figure-4).

The economic value of lost resources is obtained by summing the economic value of direct benefits and indirect benefits per year. So that the total economic value of the lost resources was obtained by IDR 497,519,413,897.09 (Table-4). The direct benefits of the Muara Gembong mangrove ecosystem provides greater value than its indirect benefits, with a percentage of 74% (Figure-5). This shows that the Muara Gembong mangrove ecosystem is still actively used by the surrounding community and is a source of livelihood.

**Table-4.** Total economic value of Muara Gembong mangrove ecosystem

| Types of Benefits | Value (IDR/year) |
|---|---|
| Direct Value | 368,729,938,475.74 |
| Indirect Value | 128,789,475,421.35 |
| Total | 497,519,413,897.09 |

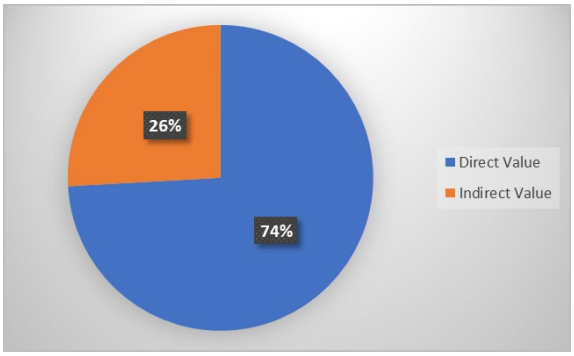


**Figure-5.** Percentage of direct and indirect value of Muara Gembong mangrove ecosystem

**Recovery Costs**

According to [4], recovery is part of the control of pollution and/or environmental damage carried out in the context of environmental conservation. Recovery costs are costs that must be incurred in order to recover efforts to make the environment or its parts function again as before. In this case, the cost of restoring mangrove ecosystems due to oil spills on the Muara Gembong Coast includes the cost of cleaning up oil spills on the high seas and coastal areas, and the cost of rehabilitating mangrove ecosystems (Table-5).

**Table-5.** Mangrove ecosystem recovery costs

| Types of Costs | Value (IDR) |
|---|---|
| High seas clean-up | 37,149,351,309.98 |
| Coastline clean-up | 1,980,000,000.00 |
| Mangrove rehabilitation | 1,482,608,380.00 |
| Total | 40,611,959,689.98 |

The cost of cleaning up oil spills on the high seas is obtained by the benefit transfer approach. By using the assumption of estimated average clean-up costs in the Australian region, because it is located quite close to Indonesia geographically, of US$ 6,900/ton [18-19]. The volume of oil spills recovered from the sea is 6390 bbl [20] or equivalent to 358.77 tons. So that the cost of cleaning up the oil spill on the sea off the coast of Muara Gembong is IDR 37,149,351,309.98

The cleanup of the oil spill on the coastline of Muara Gembong involves the surrounding community. According to the results of a survey conducted by [1], the people of Muara Gembong have a good knowledge of the negative impacts caused by oil spills on mangrove ecosystems on the coast of their area so that their handling in cleaning up oil spills exposed in coastal areas where there are mangrove forests is quite responsive. A cost analysis approach is used to quantifying the cost of cleaning up oil spills in coastal areas, by calculating direct costs related to recovery efforts carried out [4]. There are 2,200 local communities from fisher and farmers whose jobs have been recorded as affected by this oil spill incident [2]. In exchange, Pertamina provides wages of IDR 150,000.00/day for affected fisher who participate in collecting waste oil spills for four days [21]. So that the nominal costs incurred in efforts to clean up the oil spill in the coastal area of Muara Gembong were IDR. 1,980,000,000.00.

The next recovery cost is the cost of rehabilitation. To calculate these costs, a cost analysis approach is used. The cost of mangrove rehabilitation here includes the cost of replanting mangrove seedlings in the area affected by the oil spill, which is 451 ha with a standard planting distance of 2.5 m × 2.5 m [11]. The price of mangrove seeds per stem is IDR 1,500 [6] and planting wages follow the wages of farm workers/fisher in Bekasi, which is IDR 30,449/day/person [22]. Assuming planting is carried out by 20 people/ha [11] that in planting mangroves covering an area of 1 ha with a planting distance of 2.5 m × 2.5 m can be done by 20 people. Then, by converting it into the current value, the rehabilitation costs incurred for the Muara Gembong mangrove ecosystem are IDR 1,482,608,380.00.

By summing the value of the cost of cleaning up oil spills in coastal and marine areas as well as the cost of rehabilitating mangrove ecosystems in Muara Gembong, so that the total value of recovery costs due to oil spills in the Muara Gembong mangrove ecosystem is IDR 40,611,959,689.98 (Table-5).

**Total Economic Damages**

In this study, the value of damages or losses due to oil spills was quantified based on the economic value of lost resources (compensable value) and recovery costs. The economic value of the lost resources has been obtained of IDR 497,519,413,897.09 (Table-4) and recovery costs of IDR 40,611,959,689.98 (Table-5). Thus, the value of losses due to oil spills in the Muara Gembong mangrove ecosystem is obtained, amounting to IDR 538,131,373,587.08 (Table-6).

Table-6. Total economic damages

| Types of Fees | Value (IDR/year) |
|---|---|
| Compensable value | 497,519,413,897.09 |
| Recovery costs | 40,611,959,689.98 |
| Total | 538,131,373,587.08 |

Oil spill incidents have occurred several times and are known to use an economic valuation approach in calculating the value of the loss. However, the obstacle faced by the government in using economic valuation instruments in the availability of basic data which is often not available. This makes it difficult to calculate changes in the benefits of goods and services produced by ecosystems.

The economic impact arising from an oil spill should not be a burden on the state. Polluters must be held responsible either for accidental events, negligence or accidents. The polluter pays principle is also in accordance with applicable laws and regulations both internationally and nationally

## CONCLUSION

Oil spill incidents can occur at any time and anywhere, especially those that are close to shipping lanes and oil drilling activities. This requires the government's vigilance as well as the ability to deal with incidents that occur quickly. Along with that, the government must also immediately be able to identify the impacts that have arisen, calculate the value of losses or economic impacts and sources of pollution.

Calculation of the economic impact of an oil spill can be done using an economic valuation approach. This technique can be used as a standard for the government because the assessment with this technique provides the advantage of calculating all the benefits of lost goods and services, both direct economic, ecological and socio-cultural in nature. In total, the economic impact value in this study is calculated by including two components, namely the cost of compensated economic losses and rehabilitation costs.

The amount of economic value of the lost resources, i.e. mangrove ecosystem, includes both the value of direct benefits and indirect benefits, which is IDR 497,519,413,897.09. The amount of recovery costs includes high seas clean up, high seas clean up and rehabilitation, which is IDR 40,611,959,689.98. Total value of losses due to oil spills in the Muara Gembong mangrove ecosystem was obtained from the accumulated economic value of lost resources and recovery costs of IDR 538,131,373,587.08.

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