Jurnal Presipitasi
Media Komunikasi dan Pengembangan Teknik Lingkungan
e-ISSN: 2550-0023

Vol 22, No 3, 2025, 809-819
Article available at homepage presipitasi

Regional Case Study

Environmental Sensitivity Analysis of Oil Spills: A Case Study in Coastal Areas

Ichsan Prayoga Ardiansyah[1*], Liyantono[2,4], Hefni Effendi[3,4], Karaben Ikhtiyana Ikrari[5]

[1] Natural Resources and Environmental Management Study Program, Graduate School, IPB University, Bogor, Indonesia
[2] Department of Mechanical and Biosystem Engineering, IPB University, Bogor, Indonesia
[3] Department of Aquatic Resource Management, IPB University, Bogor, Indonesia
[4] Center for Environmental Research IPB University, Bogor, Indonesia
[5] Advanced Membrane Technology Research Centre (AMTEC), Faculty of Chemical and Energy Engineering, Universiti Teknologi Malaysia, Johor, Malaysia
* Corresponding Author, email: ichsanchem40@gmail.com

Abstract

The coastal areas of Karawang Regency are at risk of being affected by oil spills originating from oil pipelines leaking. The purpose of this research is to develop an environmental sensitivity index based on the assessment standards of the National Oceanic and Atmospheric Administration, with research locations in the Karawang Coast. The results showed that the resources in the Karawang coastal area that sensitive to oil spills are shoreline type of mangrove with a total length of 34.76 km of shoreline; consist of dense mangrove forest with an area of 173.14 ha; capture fisheries with 6,832 fishermen with a production of 9,319.38 tons/year; and aquaculture involving 5,643 fishing households with a production of 43,389.45 tons/year. The environmental sensitivity index value was concluded as very sensitive for mangrove beaches, mangrove forests in all locations and aquaculture in the Tirtajaya & Batujaya areas, while the capture fisheries and the capture aquaculture were concluded as sensitive. The environmental sensitivity index maps of the three themes indicated that the socio-economic component is the most sensitive component compared to other components. Specifically, the socio-economic components that were the most sensitive to the impact of oil contamination were aquaculture and capture fisheries areas.

Keywords: Coastal karawang; environmental sensitivity analysis; oil spill

1. Introduction

The oil and gas mining industry is one of the industries that provides considerable foreign exchange to the Indonesian economy from mining activities. Oil and gas exploitation activities have the potential for pollution and disruption to the environment from operational activities carried out both upstream and downstream (Sinapoy, 2019). Pollution events such as oil spills in the sea can result in damage to resources in coastal and marine areas that also interfere with human health through the food chain process of eaten biota containing accumulated hazardous materials (Plarenco, 2015).

Oil spills are a number of marine and coastal pollution events caused by tanker operations (ballast water), ship repair and maintenance, offshore loading and unloading terminals, and bilge water

(sewage, oil, grease, etc.), ship dismantling, oil pipeline leaks and tanker accidents often occur. The impacts of oil spills on organisms include lethal and sublethal to plankton and migratory fish. In addition, the consequences of oil spills in the sea will be very quickly felt by communities around the coast and very significantly damage the living environment around the coast (Putranto et al., 2017).

The impacts of oil spills and pollution are highly dependent on the types of ecosystems and economic activities affected, both in coastal areas and in the ocean. Different types of ecosystems and economic activities have different levels of importance. Therefore, it is necessary to map the degree of sensitivity of ecosystems and economic activities in coastal and marine areas that may be affected by disturbances due to oil and gas activities in the region (Purwanti et al., 2022).

The coast of Karawang Regency has the potential to be affected by oil spills originating from oil spills or leaks from ships passing through the coast of Karawang Regency. In addition, in the coastal area of Karawang Regency there are also oil and gas production wells that have the potential to cause oil pollution due to leakage of oil pipelines. The Environmental Sensitivity Index (ESI) and comprehensive environmental data are essential for the government to understand the condition of sensitive areas around oil and gas mining areas to mitigate environmental pollution resulting from oil spills and subsequently take prioritized actions to protect areas considered sensitive (Putra 2017).

The environmental sensitivity index requires studies to describe environmental characteristics (Rustandi et al. 2020). With such studies, identification and evaluation of sensitive areas around oil and gas concession areas can be carried out to be used as a direction in developing oil spill response strategies. ESI is needed in the research location considering that there is no ESI on the Karawang coast against oil spills where the ESI is carried out an assessment of environmental and socio-economic resources at risk of oil spills on the Karawang coast and provides a scientific basis for determining priority zones for oil spill mitigation, which has not been comprehensively studied in industrial coastal areas.

2. Methods

The research approach in the activity includes data collection and analysis by considering two main systems, namely: (1) coastal resource system (ecological system), and (2) coastal community system (social system). In this study, ESI was developed using an equation that integrates the two systems. The development of the ESI refers to the approach adopted by National Oceanic and Atmospheric Administration (NOAA) (2019) and International Petroleum Industry Environmental Conservation Association (IPIECA) (2016).

According to NOAA, the development is carried out by considering three main components, namely.

1) Shoreline type and general environmental sensitivity to oil spills;
2) Sensitive key ecosystems and natural resources;
3) Sensitive socio-economic features.

The environmental sensitivity index describes the relative sensitivity of the environment as a result of the calculation of its determining components and is presented as a map image. The scope of the analysis in this research is limited to determining the value of environmental vulnerability to oil pollution. The analysis in this study is limited to determining the level of environmental vulnerability to oil pollution, with criteria guidelines developed by NOAA and IPIECA.

This research was conducted on the coast of Karawang Regency, West Java Province. Details of the research location can be seen in Table 1 and Figure 1.

Table 1. Research location

Map index	Map index name
A 01	Pakisjaya
A 02	Tirtajaya & Batujaya
A 03	Cibuaya

Map index	Map index name
B 01	Pedes
B 02	Cilebar
C 01	Tempuran & Cilamaya Kulon
C 02	Cilamaya Wetan

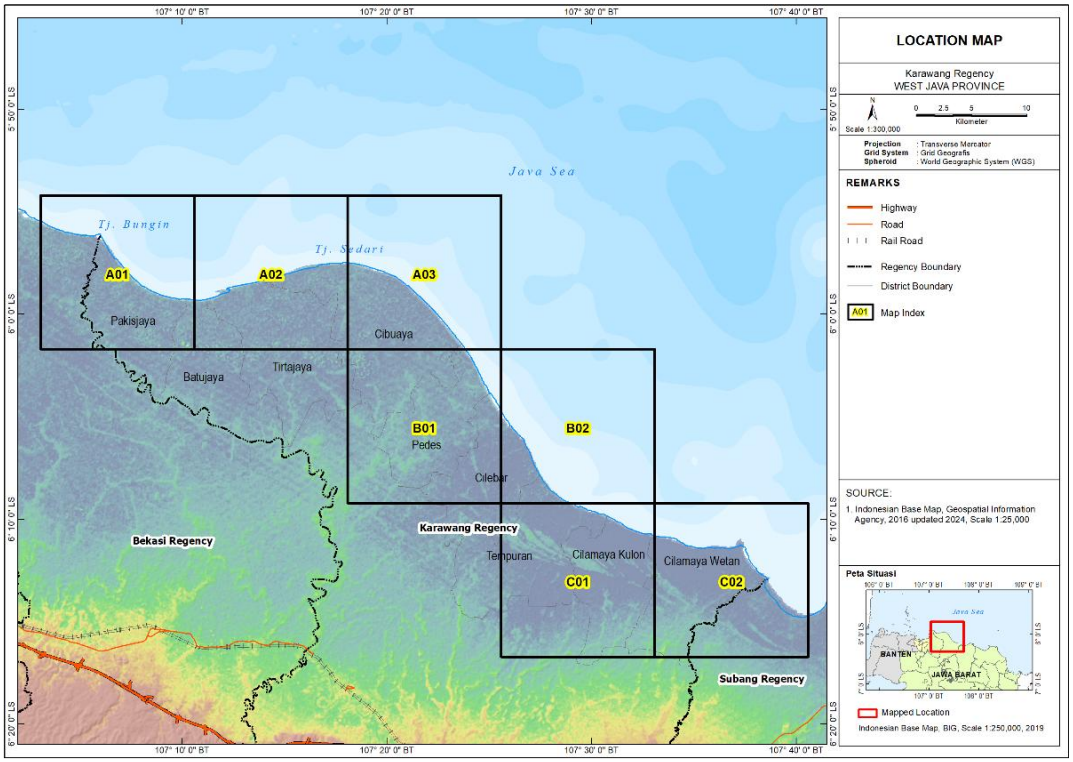

Figure 1. Research location

2.1. Shoreline type

The ESI rating for shoreline types is based on criteria developed by NOAA (2019) and adapted by IPIECA (2016), with a scale ranging from 1 (low sensitivity) to 10 (very high sensitivity), classified in Figure 2.

- 1A Exposed rocky shore
- 1B Exposed, solid man-made structures
- 1C Exposed rocky cliffs with boulder talus base
- 2A Exposed wave-cut platforms in bedrock, mud, or clay
- 2B Exposed scarps and steep slopes in clay
- 3A Fine- to medium-grained sand beaches
- 3B Scarps and steep slopes in sand
- 4 Coarse-grained sand beaches
- 5 Mixed sand and gravel beaches
- 6A Gravel beaches (granules and pebbles)
- 6B Riprap structures and gravel beaches (cobbles and boulders)
- 7 Exposed tidal flats
- 8A Sheltered scarps in bedrock, mud or clay and sheltered rocky shore
- 8B Sheltered, solid man-made structures
- 8C Sheltered riprap
- 8D Sheltered rocky rubble shores
- 8E Peat shorelines
- 9A Sheltered tidal flats
- 9B Vegetated low banks
- 9C Hypersaline tidal flats
- 10A Salt and brackish water marshes
- 10B Freshwater marshes
- 10C Swamps
- 10F Mangroves

Figure 2. Shoreline Type

The ESI already ranks the environmental sensitivity of the shoreline into 10 levels. These can be simplified into 3 to 5 classes, keeping only the most sensitive types of e for the strategic map. An example is shown in Table 2.

Table 2. Simplification of ESI sensitivity rankings

ESI	Simplified ESI
Index 1 and 2	1 (very low)
Index 3,4,5 and 6	2 (low)
Index 7	3 (medium)
Index 8	4 (high)
Index 9 and 10	5 (very high)

2.2. Ranking the sensitive ecosystems and natural resources

The criteria ESI for ecosystems and living natural resources in this study adopted the criteria developed by IPIECA (2016) as presented in Figure 3.

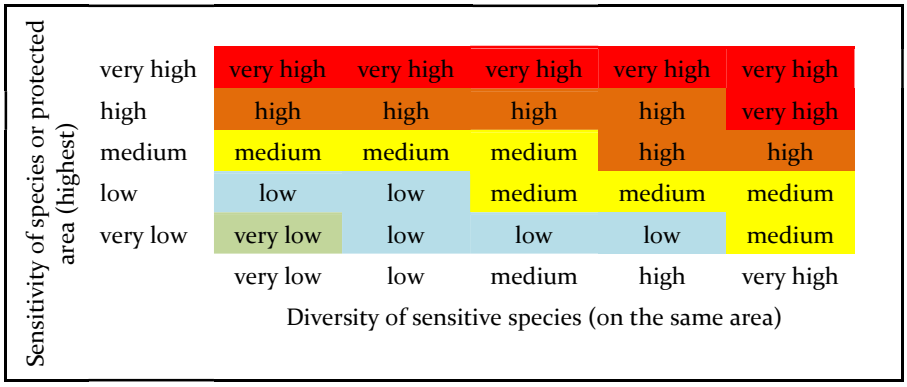

Figure 3. Diversity of sensitive species

Vulnerable natural resources can be assessed based on the duration of recovery after an oil spill incident. In addition, various existing lists or classifications can be utilized to rank them, such as the IUCN red list (which includes conservation status and distribution information on endangered species), and lists of rare or threatened species and habitats. Estimates of potential impacts should also be taken into consideration. Sensitivity ratings may also include managed areas, e.g. low to medium sensitivity for regional protection status, medium for national protection status, and high for international protection status. If multiple sensitive species occur in the same area, the highest sensitivity is retained.

2.3. Ranking the socio-economic features

Determination of the sensitivity of sensitive areas due to land use and human activities that are affected, either directly or indirectly by the oil spill, is done with a similar approach to ecologically sensitive areas. Some parameters that can be used to classify land use from a socio-economic aspect include: 1) Level of importance of an activity; 2) Number of individuals or workers involved; 3) Level of income generated; 4) Duration of disturbance caused by different levels of pollution (Plarenco, 2015).

The ranking of socio-economic features is based on the pattern of socio-economic activities found in the study location. In this study, four main activities that may be affected if there is an oil spill will be ranked, namely: activities of capture fishermen, aquaculture fishermen, settlements, and tourism (Khabibi, 2021).

3. Result and Discussion

3.1. Environmental Sensitivity Index

3.1.1. Shoreline type

Coastal types in Karawang coastal areas show sensitivity for the mangrove category has a very high sensitivity with a total length of 34.76 km of coastline, or equivalent to 44.74% of the entire study site. Mangrove-vegetated coastal types are classified as highly sensitive because mangroves are the habitat of various types of fish and invetebrates that are very distinctive. In addition, mangroves have breathable roots which have pores to capture nutrients and oxygen. If these pores are covered with oil contamination, it can cause mangrove death. In addition, oil spills cause direct and severe damage to mangrove ecosystems, including defoliation, animal mortality, and the loss of mangrove seedlings and saplings themselves and over time, mature trees can also die as a result of oil spills (Lassalle et al., 2021). While the longest beach type is a coarse-grained sandy beach that has less sensitivity with a coastline length of 40.28 km or equivalent to 51.85% of the entire study site.

Sandy beaches have low sensitivity to oil spills due to several factors including: 1) high porosity and permeability i.e. sandy beaches have high porosity and permeability allowing oil to more easily penetrate and disperse into the sediments, thereby reducing surface impacts (Hasibuan 2015); 2) natural filtration i.e. sandy textures act as natural filters, trapping oil particles and preventing them from spreading widely (Dewi et al. 2015) wave occurrence and tidal influence i.e. the gentle slope and wave action aids in the natural cleaning process by washing away oil residues and encouraging biodegradation (Dewi et al., 2015); 2) low organic content i.e. sandy beaches typically have lower organic content compared to other coastal environments, meaning there is less material for oil to stick to and persist (Hasibuan, 2015). Meanwhile, mangrove vegetation is very difficult to clean once oil contamination has occurred (Odisu et al., 2021). The artificial solid structure/concrete beach type has the lowest length of 0.16 km with a sensitivity class of insensitive. The calculation of environmental sensitivity index values for complete shoreline types can be seen in Table 3.

Table 3. Shoreline sensitivity

Shoreline type	Type	Length (km)	Percentage (%)	ESI value	ESI rating
1B	exposed, solid man-made structure	0.16	0.21	1	very low
4	coarse-grained sand beaches	40.28	51.85	2	low
8B	sheltered, solid man-made structure	2.49	3.21	4	high
10F	mangroves	34.76	44.74	5	very high

Table 4. Shoreline sensitivity per location

Location	Shoreline type	Lenght (km)	Esi Value	ESI rating
A01	4	7.26	2	low
	8B	2.49	4	high
	10F	0.95	5	very high
A02	4	6.86	2	low
	10F	7.54	5	very high
A03	4	13.9	2	low
B01	4	6.54	2	low
	10F	0.30	5	very high
B02	10F	10.94	5	very high
C01	4	5.72	2	low
	10F	2.76	5	very high

Location	Shoreline type	Lenght (km)	Esi Value	ESI rating
C02	1B	0.16	1	very low
	10F	12.27	5	very high

Table 4 shows that sandy beaches with coarse grains (type 4) have a less sensitive vulnerability (IKL value 2) scattered in several locations namely A01, A02, A03, B01 and C01. Mangrove beaches (type 10F) which have a very sensitive vulnerability, have a significant length in several locations such as A02, B02, and C02. Beaches with solid artificial/concrete structures (type 1B) only exist at location C02 with a very small length (0.16 km), and have an insensitive ESI class. The sensitivity of the beach types at the study sites were all classified with reference to NOAA (2019) and IPIECA (2016).

3.1.2. Ranking the Sensitive Ecosystems and Natural Resources

1) Mangroves

Mangroves have a very important role in coastal resource management in most parts of Indonesia, although not in all areas. The main function of mangroves in coastal areas is as a link between land and sea. Through mangroves, plants, animals, and other elements and plant nutrients can be transferred both to the land and to the sea. Mangroves also serve as filters to reduce the negative impacts of major environmental changes, as well as a source of food for marine and terrestrial biota. Without mangroves, marine and coastal production would decline significantly.

Mangrove ecosystems cannot survive in oil-polluted environments. Oil spills can clog the breathable roots of mangroves, inhibiting the gas exchange process. In addition, damage to mangroves can also be caused by toxic compounds contained in the oil. Mangroves grow in areas with low settling rates which also tend to be places where oil accumulates from spills (Odisu et al. 2021).

The sensitivity of mangrove ecosystems is measured based on the diversity of species present, the level of sensitivity of these species, and the protection status of the mangrove ecosystem itself. The results of the environmental sensitivity index analysis for mangrove ecosystems in coastal Karawang show that all locations have a very sensitive ESI class. This is because mangroves have a protected status (protected area), so they fall into the category of very sensitive vulnerability. In addition, like the shoreline type, mangroves are a type of beach with very sensitive sensitivity according to NOAA (2019). Details of the environmental sensitivity class of mangrove ecosystems in coastal Karawang are presented in Table 5.

Table 5. Mangroves sensitivity

Location	Area (ha)	Density class	Protection class	ESI rating
A01	2.37	2	5	very high
	14.74	4	5	very high
A02	25.12	2	5	very high
	45.76	3	5	very high
	173.14	4	5	very high
A03	10.84	3	5	very high
	38.87	4	5	very high
B01	2.62	2	5	very high
	0.62	4	5	very high
B02	45.58	4	5	very high
C01	2.49	2	5	very high
	1.57	3	5	very high
	17.98	4	5	very high
C02	1.42	3	5	very high
	31.57	4	5	very high

Mangrove ecosystems are critical in maintaining ecological balance and protecting the coast from erosion. Therefore, although some mangrove sites have a lower density, their protection status elevates their sensitivity value. Overall, the mangrove ecosystem falls within the protected area and therefore has a high ESI value and is highly vulnerable to oil spills that can cause long-term ecological damage because oil components such as polycyclic aromatic hydrocarbons (PAHs) are toxic and persistent. They can remain in soil and sediment for years, inhibiting the natural regeneration of mangroves and causing a decline in coastal land fertility (Kingston, 2002). The highly sensitized mangrove ESI class also corresponds to the shoreline type ESI for mangroves which is highly sensitized (NOAA, 2019).

2) Coral reefs

Sensitivity analysis of coral reef ecosystems was conducted by considering ecosystem sensitivity parameters (percentage coral cover) and area protection status. These parameters were then calculated using the ecosystem and resource sensitivity classification matrix. The results of the analysis show that the environmental sensitivity index values of urn corals and sedulang corals are less sensitive and moderate. Less high sensitivity is due to the condition of the cover and protection status is quite low. Coral reef cover along the north coast of West Java, is in varying conditions with examples for Biawak Island, the overall average condition is categorized as moderate (34.69% live coral cover) (Rizal et al. 2020). As for protection status, protected coral reefs according to the Marine Protected Atlas (2024) for the coastal areas of western Java are protected areas around Ujung Kulon, Thousand Islands and around Biawak Island. The coral cover and protection status resulted in the sensitivity index results for coral reefs on the Karawang coast are less sensitive and moderate. The complete results of the calculation of the sensitivity analysis of coral reef ecosystems are presented in Table 6.

Table 6. Coral reefs sensitivity

Location	Condition	Coverage class	Protection status	Protection class	ESI rating
Karang Guci	poor	low	not protected	low	low
Karang Sedulang	good	high	not protected	low	medium

3.1.3. Ranking the Socio-Economic Features

1) Capture fisheries

Capture fisheries in coastal Karawang is one of the important sectors in the local economy, supported by the rich marine resources in the north coast of Java Island supported by the rich marine resources in the north coastal region of Java Island. The oil spill significantly reduced fisheries products leading to a substantial decrease in fishermen's income. For example, fisher losses after an oil spill can reach up to 76%, equivalent to IDR 177,875 per trip due to reduced fish catch (Alvernia et al. 2021). The sensitivity results of capture fisheries incorporate several components, namely activity importance, number of fishers, amount of income and duration of pollution disturbance. The results of the sensitivity analysis show that several areas (B01, B02, C01, C02) have a sensitive sensitivity index value, which means that the environment is very vulnerable to disturbances and requires more attention so that disturbances do not occur. The sensitive index is because in these areas capture fisheries are the main occupation and have a high enough economic impact on the income of the community so that the sensitivity index is sensitive. As for location A02, the sensitivity index is not sensitive, indicating that the residents in that location do not make capture fisheries their main occupation. The environmental sensitivity value of capture fisheries in coastal areas is presented in Table 7.

Table 7. Capture fisheries sensitivity

Location	Number of fishermen	Production (ton)	SIoA	SNoE	SRIP	SDoIDP	ESI value	ESI rating
A 01	428	292.50	4	1	2	3	2.5	medium
A 02	492	19.68	3	1	1	3	2.2	low
A 03	488	176,22	4	1	2	3	2.5	medium
B 01	680	1,383.98	5	1	4	3	3.2	medium
B 02	648	1,660.36	5	1	5	3	3.5	high
C 01	2044	4,372.74	5	5	4	3	4.2	high
C 02	2052	1,413.90	5	5	2	3	3.8	high

Description:
SIoA : score importance of the activity
SNoE : score number of employed
SRIP : score revenue income percapita
SDoIDP: score duration of interruption degrees of pollution

2) Aquaculture fisheries

Aquaculture activities are closely related to the source of income, especially for fishermen. The sensitivity analysis of aquaculture was conducted based on the type of aquaculture (traditional, semi-intensive and intensive), the number of aquaculture fishers, the amount of income and the level of disturbance duration. In the coastal area of Karawang, brackish aquaculture is commonly practiced in traditionally managed ponds, with milkfish and shrimp as the main commodities. The water source used for traditional ponds usually comes from the river estuary. Oil entering the pond's waterway system can cause water quality degradation, biota mortality, and crop failure, which in turn has a direct impact on the economic and social resilience of coastal communities (Alvernia et al., 2021).

The results of the sensitivity analysis for aquaculture in coastal Karawang provide a clear picture of locations at high risk of oil spills. Therefore, a more comprehensive protection strategy is needed, such as the development of early warning systems, regular water quality monitoring, and integration of mitigation in coastal spatial plans (NOAA, 2019; IPIECA, 2016). All locations in coastal Karawang are very vulnerable to oil spills, so more effective mitigation is needed so that the risk can be minimized considering the impact on the economy of all Karawang coastal communities. The complete sensitivity of aquaculture in coastal Karawang is presented in Table 8.

Table 8 Aquaculture fisheries sensitivity

Location	Aquaculture households	Production (ton)	SIoA	SNoE	SRIP	SDoIDP	ESI value	ESI rating
A 01	396	6,701.65	4	5	5	3	4.2	high
A 02	1,155	14,542.02	5	5	5	3	4.5	very high
A 03	1,291	7,521.95	4	5	4	3	4.0	high
B 01	310	2,614.09	5	4	5	3	4.2	high
B 02	442	2,776.95	5	5	4	3	4.2	high
C 01	1,399	5,355.39	5	5	3	3	4.0	high
C 02	650	3,877.40	5	5	4	3	4.2	high

3) Tourism

Pollution caused by oil spills has a major influence on the lives of residents around the spill site, including the tourism sector (Meinarni 2016). Tourism activities in the research location are in the form of nature tourism such as beaches and mangroves. Oil spills can cause a decrease in the aesthetic quality of the environment, air pollution due to pungent odors, and contamination of tourist areas that cause a decrease in tourist interest and disruption to the economic activities of communities that depend on this sector (ITOPF, 2020). The sensitivity of tourist areas is calculated based on the importance of the activity, the number of employees, income and the duration of the pollution disturbance. Location A03 shows

sensitive criteria with a very dominant type of tourism, namely mangrove tourism which is professionally managed and the number of visitors is quite large. To maintain the sustainability of the coastal tourism environment, efforts need to be made such as increasing community-based emergency response capacity and education and involving tourism managers in early warning systems and environmental SOPs (IPIECA, 2016; UNEP, 2014). The sensitivity class of tourism areas in coastal Karawang is presented in Table 9.

Table 9. Tourism sensitivity

Location	Type of tourism	SIoA	SNoE	SRIP	SDoIDP	ESI value	ESI rating
A 03	beach, mangrove	4	5	5	3	4.0	high
B 01	beach	3	3	4	3	3.3	medium
B 02	beach, mangrove	3	3	2	3	2.0	low
C 01	beach	3	4	1	3	2.8	medium

4) Residential

The sensitivity of residential areas in coastal Karawang was assessed by population, income, house type and duration of pollution disturbance. Coastal settlements are highly vulnerable to oil spills due to their proximity to pollutant sources and lack of environmental mitigation infrastructure. In addition to polluting water and air sources, oil spills can also disrupt people's daily activities, threaten health, and reduce property values in the area (Kingston, 2002). The ESI results show that the sensitivity of the majority of settlements has a sensitive criterion because they are inhabited by a large population with income dependent on the fishing and aquaculture sectors which are very sensitive to pollution except for location A03 which has a small population with a medium sensitivity criterion.. In full, the sensitivity of residential areas in coastal Karawang is presented in Table 10.

Table 10. Residential sensitivity

Location	SIoA	SNoE	SRIP	SDoIDP	ESI value	ESI rating
A01	4	4	3	3	3.5	high
A02	4	5	3	3	3.8	high
A03	4	3	3	3	3.2	medium
B01	4	4	3	3	3.8	high
B02	4	3	3	3	3.5	high
C01	4	5	3	3	3.8	high
C02	4	4	3	3	3.8	high

3.2. Environmental Sensitivity Index Map

The environmental sensitivity of the three components namely coastal type, ecosystem and biodiversity, and socio-economic shows that the socio-economic component is the most sensitive component compared to other components. The socio-economic component that is most sensitive to the impact of oil contamination is the area of aquaculture and capture fisheries. Where these two things are the premier income of the Karawang coastal community (Alvernia et al., 2021; Rustandi et al., 2020). Apart from the socio-economic component, another component that is also very sensitive to oil contamination is the mangrove area. Mangroves play an important role in sequestering carbon, stabilizing the coastline, and providing habitat for marine life, so damage from oil spills in this ecosystem can have long-term ecological impacts (Kingston, 2002).

Spatial information in the ESI map is very important to support environmental risk mitigation planning, especially against oil spills and as a basis for formulating more adaptive and risk-based coastal area management strategies (NOAA, 2019; IPIECA, 2016). The existence of good cooperation between stakeholders in tackling oil spills both from the government as a regulator and the private sector as an industrial actor in the area adjacent to the Karawang coast is good to do in preventive efforts. The environmental sensitivity index map of the three themes can be seen in Figure 4.

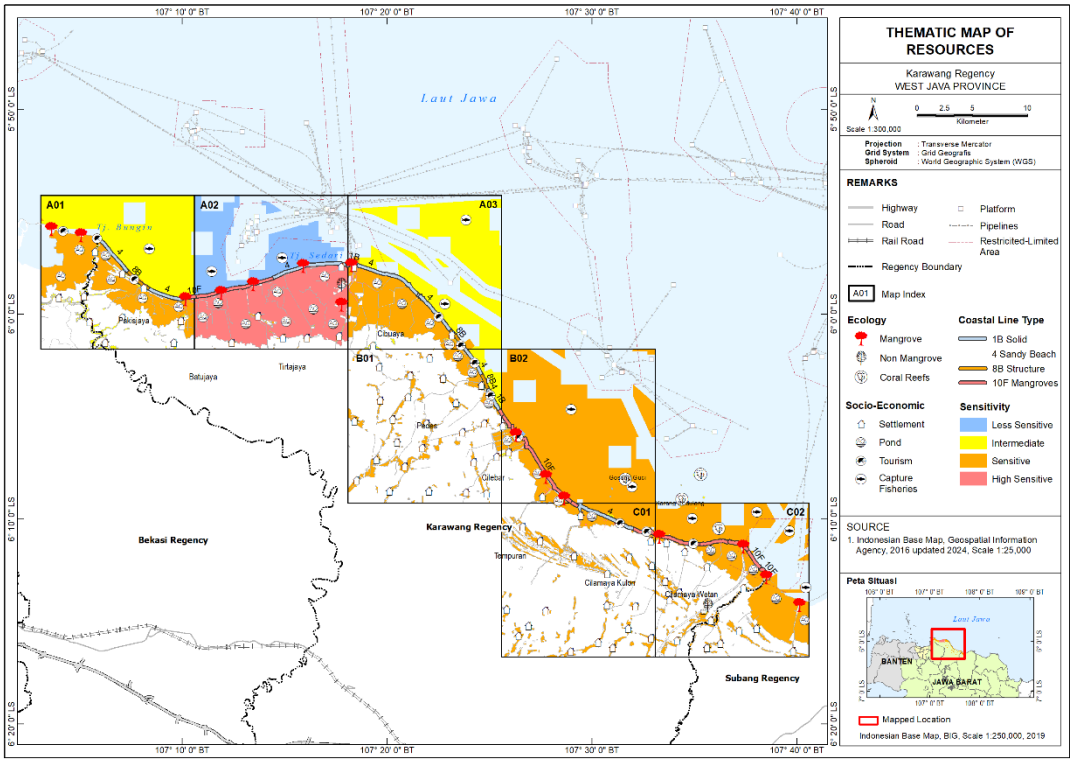

Figure 4. Karawang coastal environmental sensitivity index map

4. Conclusions

Resources in the Karawang coastal area that are sensitive to oil spills include beach type with a total length of 34.76 km of mangrove beach (44.74%); dense mangrove forest with an area of 173.14 ha; capture fisheries with 6,832 fishermen and production of 9,319.38 tons/year; and aquaculture with 5,643 fishing households and production of 43,389.45 tons/year. The environmental sensitivity index value for mangrove beaches, mangrove forests in all locations and aquaculture in the Tirtajaya & Batujaya areas has a very sensitive ESI class. While capture fisheries and capture aquaculture have a sensitive ESI class. The IKL maps of the three themes show that the socioeconomic component is the most sensitive component compared to other components. The socio-economic components that are most sensitive to the impact of oil contamination are aquaculture and capture fisheries areas.

The results show how important it is to designate areas with highly sensitive ESI values as priority zones for protection and mitigation in spatial planning documents and environmental contingency plans. Local governments and industry players in the Karawang coastal area need to develop strategic measures such as providing early warning systems, SOPs for emergency handling of oil spills, and long-term ecological rehabilitation efforts based on spatial data. Therefore, the IKL map not only serves as a means of risk identification, but also serves as a scientific basis for adaptation, participatory and sustainable.

Acknowledgement

Acknowledgments are especially addressed to BMT, PHE ONWJ, PPLH and PSL IPB University.

References

Alvernia, P, Utomo, S, Soesilo, T, E, B, and Herdiansyah, H. 2021. Studies of fishermen's economic loss due to oil spills. IOP Conference Series: Earth and Environmental Science 802(1).

Dewi, I, S, Budiarsa, A, A, and Ritonga, I, R. 2015. Distribution of microplastic at sediment in the Muara Badak Subdistrict, Kutai Kartanegara Regency (in Bahasa). Depik 4(3), pp.121–131.

Hasibuan, A, S, Z. 2015. Pemanfaatan bahan organik dalam perbaikan beberapa sifat tanah pasir pantai selatan Kulon Progo. Planta Tropika: Jurnal Agro Sains 3(1), pp.31–40.

IPIECA. 2016. Sensitivity mapping in visual analysis. 2012(1), pp.95–102. Available at: https://doi.org/10.7901/2169-3358-2003-1-95 [Accessed 15 May 2025].

ITOPF (International Tanker Owners Pollution Federation). 2020. Effects of oil pollution on social and economic activities.

Khabibi, R. 2021. Analisis spasial kepekaan lingkungan untuk mitigasi bencana tumpahan minyak di Taman Nasional Kepulauan Seribu. [Unpublished thesis].

Kingston, P, F. 2002. Long-term environmental impact of oil spills. Spill Science & Technology Bulletin 7(1–2), pp.53–61.

Lassalle, G, and Dubucq, D. 2021. Preliminary assessment of probable impacts caused by the largest oil spill in Brazil history on selected mangrove stands using satellite imaging. IEEE International Geoscience and Remote Sensing Symposium, pp.681–684.

Meinarni, S. 2016. Dampak pencemaran lingkungan laut terhadap Indonesia akibat tumpahan minyak Montara di Laut Timor. Jurnal Komunikasi Hukum 2(2), pp.228–235.

National Oceanic and Atmospheric Administration (NOAA). 2019. Environmental sensitivity index guidelines, Version 4.0. April.

Odisu, T, Okieimen, C, O, and Ogbeide, S, E. 2021. Post oil spill petroleum hydrocarbon components transport and evaluation in parts of the Niger Delta mangrove swamp of Nigeria: A case of hydrocarbon component transport through non-turbulent water. European Journal of Sustainable Development Research 5(1), em0152.

Plarenco. 2015. Penyusunan peta kepekaan lingkungan wilayah pesisir dan laut Teluk Jakarta. Volume ke-7.

Purwanti, M, and Lestari, Y, D. 2022. Praktik pengungkapan sustainability report dan environmental incidents: Studi pada sustainability report perusahaan BUMN PT. Pertamina (Persero) tahun 2017–2018. Portofolio: Jurnal Ekonomi, Bisnis, Manajemen, dan Akuntansi 18(1), pp.84–100.

Putra, I, E. 2017. Analisis indeks kepekaan lingkungan (IKL) pesisir pantai timur Kabupaten Tanjung Jabung Timur terhadap potensi tumpahan minyak. Universitas Jambi, pp.1–15.

Putranto, S, Zamani, N, P, Sanusi, H, S, Riani, E, and Fahrudin, A. 2014. Analisis dan pemetaan indeks kepekaan lingkungan (IKL) di Kabupaten Banggai dan Banggai Kepulauan, Sulawesi Tengah. Jurnal Ilmu dan Teknologi Kelautan Tropis 9(1), pp.357–374.

Rizal, A, Apriliani, I, M, Herawati, H, and Paradhita, L. 2020. Distribution and condition of coral reefs in the waters of Biawak Island, Indramayu Regency, West Java, Indonesia. World Scientific News 144(March), pp.141–157.

Rustandi, Y, Damar, A, Fahrudin, A, Rakasiwi, G, Affandy, A, Hamdani, A, Mulyana, D, and Kamsari. 2020. An approach to environmental sensitivity index study at coastal area toward oil spill accident: A case study on the northern and southern coast of Madura Island. IOP Conference Series: Earth and Environmental Science 420(1).

Sinapoy, M, S. 2019. Analisis fiqh lingkungan terkait penyalahgunaan pengelolaan pertambangan terhadap kerusakan lingkungan hidup. Halu Oleo Law Review 3(1), p.85.

UNEP. 2014. Environmental management of oil spills in coastal ecosystems. United Nations Environment Programme