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Land Suitability Analysis of NPP's Potential Site in East Kalimantan Coastal Using GIS

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ABSTRACT

LAND SUITABILITY DETERMINATION OF NPP'S POTENTIAL SITE IN EAST KALIMANTAN COASTAL USING GIS. Nuclear Power Plant (NPP) site selection is the key phase of the nuclear power plant process and significantly influence the construction cost and safety. In order to prepare for nuclear power programs in East Kalimantan province, Geographical Information System (GIS) analysis along the coast of East Kalimantan province has been performed, which covered the Berau district, East Kutai, Kutai Kartanegara, and Samarinda. The research purpose is to find suitable site(s) along the coast of East Kalimantan province for nuclear power plants location using spatial analysis and modeling. The potential Nuclear Power Plant (NPP) site is based on several criteria, such as: geology, slope, soil type, land use, Human Induced Event (HIE), morfology, seismicity, and spatial planning. Based on the weighting and ranking results using GIS application: there are three locations serve as the potential NPP sites are obtained Kutai Kartanegara and Kutai Timur regency. Next, land suitability analysis is done by using GIS application which shows potential sites suitable general and specific criteria of the site evaluation process development.

ABSTRAK

PENENTUAN KESESUAIAN LAHAN UNTUK TAPAK POTENSIAL PLTN DI PESISIR KALIMANTAN TIMUR MENGGUNAKAN SIG. Seleksi tapak PLTN adalah fase kunci dari proses pemilihan tapak PLTN dan dapat berpengaruh signifikan terhadap biaya konstruksi dantingkat keselamatan. Untuk mempersiapkan program PLTN di provinsi Kalimantan Timur telah dilakukan analisis di wilayah sepanjang pesisir provinsi Kalimantan Timur, meliputi kabupaten Berau, Kutai Timur, Kutai Kartanegara, dan kota Samarinda. Tujuan penelitian adalah untuk mendapatkan lahan di sepanjang pesisir provinsin Kalimantan Timur yang sesuai untuk lokasi PLTN dengan menggunakan analisis spasial dan pemodelan SIG. Parameter yang digunakan dalam analisis ini yaitu struktur geologi, litologi, morfologi, kejadian akibat ulah manusia, tata guna lahan dan hidrologi. Berdasarkan hasil pembobotan dan pemeringkatan dengan menggunakan SIG (Sistem Informasi Geografi) diperoleh 3 lokasi yang sesuai untuk dijadikan sebagai tapak potensial PLTN, di antaranya 2 tapak terpilih berada di Kabupaten Kutai Kartanegara dan 1 tapak terpilih di Kabupaten Kutai Timur. Analisis kesesuaian lahan menunjukkan bahwa semua tapak potensial tersebut telah memenuhi kriteria umum dan teknis, antara lain karena bukan merupakan lahan bukan di area patahan, gambut, serta jauh dari pemukiman.
Kata kunci: kesesuaian lahan, tapak potensial, PLTN, SIG

1. INTRODUCTION

Nuclear Power Plant (NPP) construction plan in East Kalimantan Province could provide a significant addition to the entire electricity supply of Kalimantan. Currently, electricity demand and supply in East Kalimantan province is experiencing electrical supply shortage, with installed capacity 917,61 MW and demand projection until 2027 is 1,169 MW on stable economic growth condition[1]. The proposed electrical supply solution is by utilizing all energy sources both conventional and non-conventional new and renewable energy (NRE) including Nuclear Power Plant (NPP).

Indonesia's coal resources and production are mainly distributed over only four provinces, one of them is East Kalimantan Province[2]. Nevertheless, nuclear as a new kind energy soures can be utilized as an alternative energy resources for long-term energy planning[3], and

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calculated also on future electrical sources with 100 MW capacity[1].

As a request from the local government of East Kalimantan toward the contruction plan of NPP in East Kalimantan province, site survey activities have been carried out, which covered potential site selection as the continuance of site pre-survey. In accordance with nuclear technology safety, site selection for NPP should comply with several safety requirements, namely: (a) external natural event, (b) external human-induced events, (c) radiological impacts on the public and on the environment, (d) emergency planning, and(e) onsiderations not directly related to nuclear safety[4]. There are several stages in the site screening process, namely (i) site pre-survey; (ii) site survey, (iii) site evaluation and (iv) pre-operational[5].

Previously, BATAN has performed site study in several área in Indonesia, i.e. in Muria (Jepara)[6], Kramatwatu (Banten)[7], West and South Bangka (Bangka Island)[8] and also Kalimantan. In 2014, NPP site selection using Geographical Information System (GIS) has been performed along the coastal area of West Kalimantan[9][10]. The analysis was performed based on weighting of criteria and spatial modeling utilizing GIS tools.

Spatial analysis on GIS-based process has been utilized for land suitability analysis in many sector. For instance, North Carolina Department of Environment and Natural Resources had a specific project on Land Suitability Analysis (LSA) in 2005 for establishing land use planning policies[11]. As quoted from Hopkins (1977) and Collins et al. (2001) in Malczewski (2004), "land-use suitability analysis aims at identifying the most appropriate spatial pattern for future land uses according to specify requirements, preferences, or predictors of some activity"[12].GIS systems provide a tool for handling decision analysis techniques such as multicriteria analysis by using Model Builder to define criteria[13]. In this regards, spatial analysis and model builder assumed to be a great combination of methods to be utilized on identifying suitable NPP site.

The objective of this paper is to find suitable site(s) along the coast of East Kalimantan province for nuclear power plants location using spatial analysis and modeling.

2. METHODS

Studied area covers the coastal line along East Kalimantan Province, administratively belonging to Kutai Paser, Penajam Paser Utara, Kartanegara, Kutai Timur and Berau regency, East Kalimantan Province. Figure 1 indicated the studied area of the focused area along the coastal line of the dedicated provinces.

Figure 1. Study area in East Kalimantan Province.

The first step of the study is preparing the proper maps (in terms of content and scale) to be analyzed in the next step. The required maps are listed below:

a) Map of East Kalimantan Province Administration
b) Map of East Kalimantan Province Geology
c) Map of Bontang City
d) Map of East Kalimantan Province Topography Contour
e) Map of East Kalimantan Province Soil Type
f) Map of East Kalimantan Province Land Use
g) Map of East Kalimantan Province River Watershed
h) Map of East Kalimantan Province Road Network

Several analysis tools are used to perform land suitability analysis. First, these mentioned analyses are conducted such as euclidean distance, buffer, and reclassify. Next, the overlay analysis is conducted as a spatial analysis technique to perform overlap toward a several maps[14].

The considered parameters of the NPP site selection data processing using overlay technique through intersect method. The intersect method has the smallest units and after that it merges with the scoring and the weighting factor. Afterward, the stage matching factor is performed using three parameters which are residential zonation, spatial pattern and peat land. Units with the highest score are defined as the NPP potential sites along the coast of East Kalimantan.

2.1. Data Processing Model Builder

The ARCGIS spatial analysis in the sequential stages involved map overlay development of the various criteria in the land suitability analysis. Model builder presents the analysis on a sequential form.

As quoted from Madurika et. al (2017), "Model Builder is a visual programming language for building geoprocessing workflows"[15]. By using model builder, a process is represented by flow chart (see Figure 2). Model builder consists of three components, namely: elements, connectors and text labels.

2.2. Scoring and Weighting

The NPP site suitability modeling by creating map stages of parameters indicated as follows: Geological Structure, Human Induced Event (HIE), Morphology, Lithology, Land Use, Hydrogeology, Residential Zonation, Peat Land, and East Kalimantan Spatial Pattern.

The parametric maps influence the NPP site which have their own hierarchy values. Each unit has different influence. The influence level is attached to a certain score. Each parameter has different weight. The value of the weight and influence is propotionate to each other. Scoring method is carried out by using the tiered weighted method. Table 1 shows the scoring and weighting factor for each parameter and criteria.

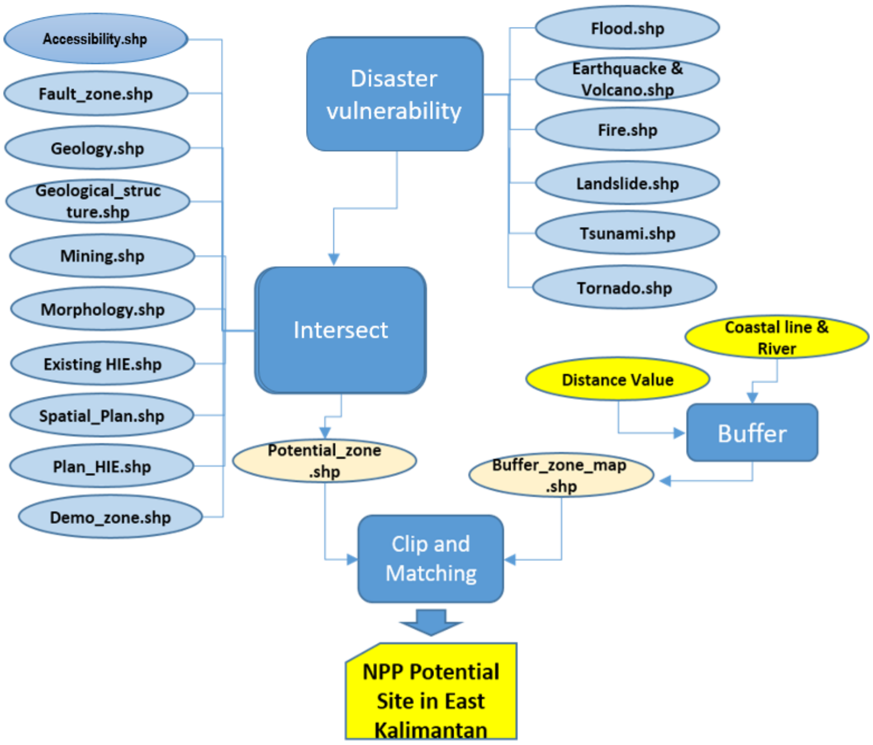

Figure 2 Model Builder of Site Selection in East Kalimantan.

Table 1. Scoring and Weighting[2]

Parameter	Weighting factor	Criteria	Score
Geological Structure	11	Unfractured	4
		Low Fractured	3
		Medium Fractured	2
		High Fractured	1
External Human Induced Event (Distance from the facility center)	9	> 75 Km	4
		50 - 75 Km	3
		25 - 50 Km	2
		< 25 Km	1
Morphology	8	Flat	4
		Undulated	3
		Hilly	2
		Mountainous	1
Lithology	8	Igneous rock	4
		Metamorphic rock	3
		Sediment rock	2
		Alluvium	1
Land Use	6	Empty land	4
		Shrubs	3
		Plantation	2
		Constructed land	1
Hidrology	4	< 5m from the surface	4
		5 - 10 m from the surface	3
		10 - 15 m from the surface	2
		> 15 m or no ground water	1

2.3. Matching Stage

This is an elimination stage where the potential areas were matched with other factor such as peat land, residential zonation, and East Kalimantan coastal area[2]. Table 2 shows the matching factors for each parameter and criteria.

Table 2 Matching Factors

No	Parameter	Criteria	Result
1	Peat land	Peat	No
		Non-peat	Yes
2	Residences Zone	Residential Zonation	No
		Non-residential zonation	Yes
3	Spatial Pattern / Land Status	Protected Forest	No No No
		Local Protected Areaas	
		Wildlife reserve	
		Natural preservation	
		National Park	
		Other usage area	Yes

Areas which possess potency but located at peat land, near the residential zonation and the spatial planning has been appointed as an area that could not be change its designation, then this area will be eliminated as non-potential area.

3. RESULT AND DISCUSSION

Preliminary step was carried out by collecting and analysis data to define the NPP site parameters. The East Kalimantan site parameters are determined by using HIE, lithology, morphology, disaster prone region, spatial planning, geological structure and fault. Those parameters obtained through spatial and differentiation data as the satellite image and the Digital Elevation Model (DEM).

The potential site map is established using binary scoring method. Each parameter has two possibilities value, either the parameter is supported or not. This method is quite different due to weighting scoring method for each parameter.

3.1. Human Induced Event (HIE)

HIE Map is established by extracting the HIE location in East Kalimantan in the form of gas/oil, mineral mines, airport, industry, non-metal, and gas pipe line. The locations are then buffered on a radius 15 km for airport and 10 km for others (see Tabel 3). Radius of HIE map as Figure 3. The SDV is selected by considering the site conditions and by preserving the conservative judgements to guarantee the site safety.

Table 3. HIE Classification and Scoring

HIE	SDV	Score
Airport (International) Airport (Small)	16 Km 10 Km	0 0
Oil and Gas Industry	10 Km	0
Metal and Non-metal Industry	10 Km	0
Mineral and Coal mine	10 Km	0
Gas pipe line	10 Km	0
Non HIE	-	1

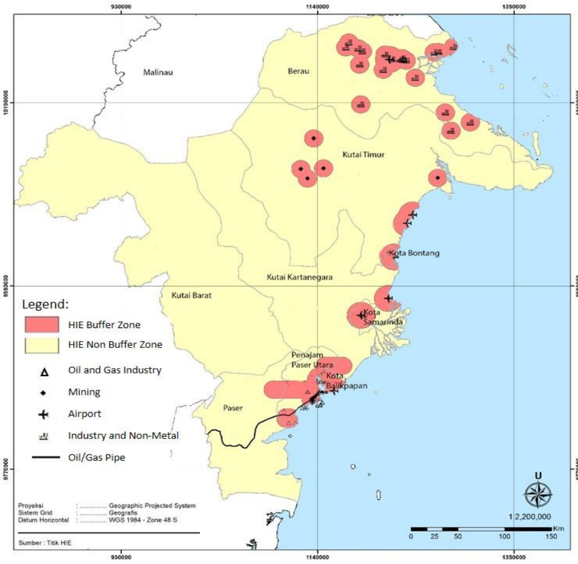

Figure 3 HIE Zonation Map.

3.2. Morphology

Morphology map is established by extracting data from DEM-SRTM of East Kalimantan. Morphology classification is based on the slope classification (see Table 4 and Figure 4).

Table 4 Morphology Classification

Morphology	Slope	Scoring
Flat/Almost Flat	0 – 2 %	1
Smoth Undulating	3 – 7 %	0
Undulating	8 – 13 %	0
Hill	14 – 20 %	0
Low relief mountain – Middle relief mountain	21 – 55 %	0
Middle relief mountain – High relief mountain	56 – 140 %	0
Highest relief mountain	>140 %	0

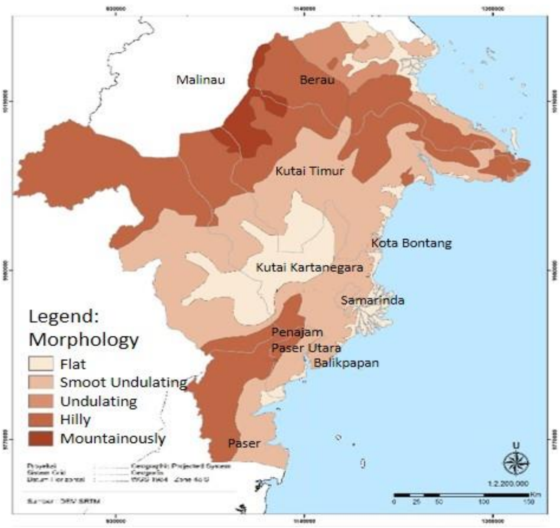

Figure 4 Morphological Map.

3.3. Disaster Prone

Disaster prone map is established by analyzing buffer regions of the potential disaster. East Kalimantan region has some disaster vulnerability in term of earthquake, volcano eruption, landslide, and forest fires. These regions are then buffered to a radius of 60 km for earthquake and volcano eruption and 30 km for forest fires and landslides (as in Table5 and Figure 5).

Table 5. Disaster Prone Classification and Scoring

Disaster Type	Buffer	Score
Earthquake	60 km	0
Eruption	30 km	0
Landslide	30 km	0
Forest Hotspot	30 km	0
Non Disaster Prone	–	1

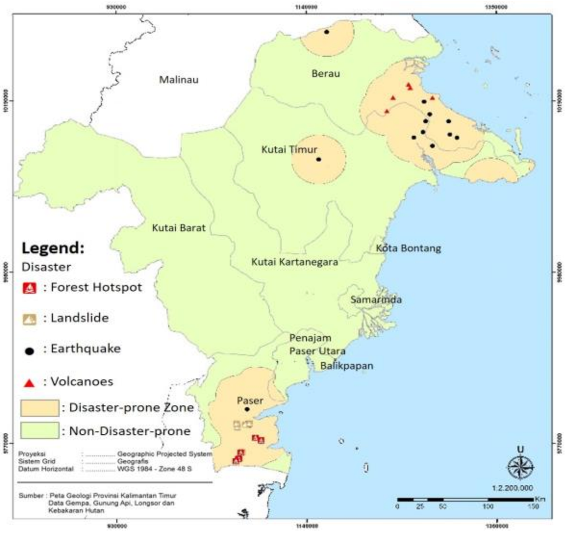

Figure 5. Hazards Risk Map.

3.4. Spatial Planning

The existing spatial planning map is processed by binary scoring. The spatial planning classification in East Kalimantan are the usage area, protected forest, production forest, and nature preserve/wildlife reserve. Scoring of spatial planning as listed in Table 6 and Figure 6.

Table 6. Spatial Planning Classification and Scoring

Spatial planning type	Score
Other usage area	1
Protected forest	0
Production forest	0
Wild life reserve	0
Natural preserve	0

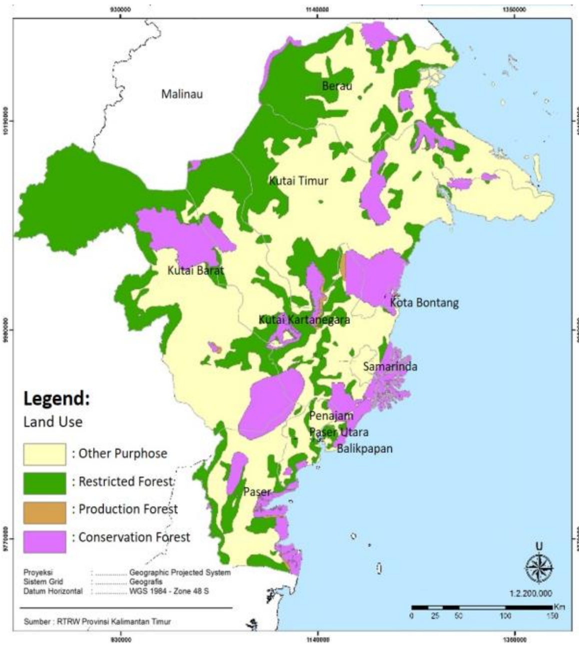

Figure 6. Landuse Patern.

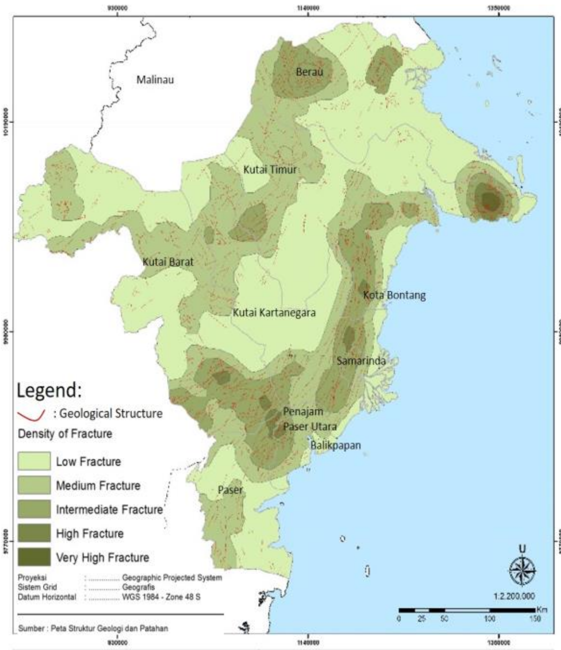

Figure 7. Structure Density Map.

3.5. Geological Structure

Geological structure map are based on the density. The geological structure acquired from existing geological map is processed to establish density map which classified into several classes as shown in Figure 7. Density calculation is performed using lineament data (geological structure) counted by ArcGIS with Line Density tools (Spatial Analyst)[13].

Table 7. Structure Classification and Scoring

Line Type	Skor
Low Fracture	1
Medium Fracture	0
Intermediate Fracture	0
High Fracture	0
Very High Fracture	0

3.5.1. Fault Zonation

Fault zonation is mapped through buffering all existing fault in the East Kalimantan region. Fault line is extracted from East Kalimantan geological map. Buffering is done within 25 km radius. The map classification involved the zonation and non-zonation buffer fault maps (Figure 8 and Table 8).

Table 8 Fault Classification and Scoring

Fault zonation	Buffer	Score
Fault buffer zonation	25 km	0
Non fault buffer	-	1

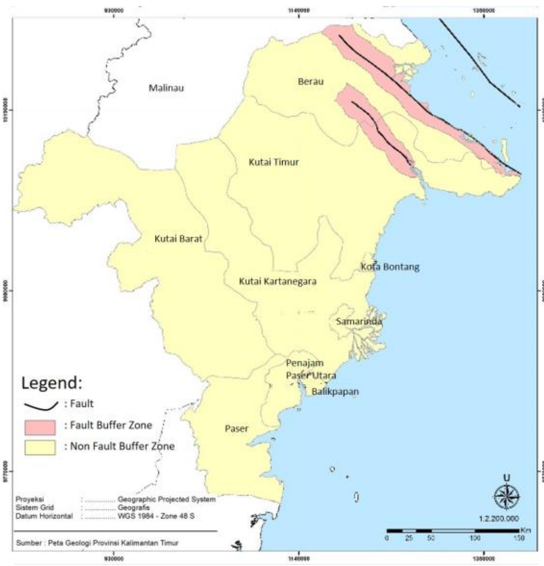

Figure 8. Fault Buffer Map.

3.5.2 Lithology Map

Lithology data is used through digitization process of East Kalimantan geological map as shown in Figure 9. East Kalimantan is dominated by igneous rock and sediment. Igneous rock is set to have bigger score than sediment rock. Alluvium is also set to have a better score value rather than limestone and mudstone due to their characteristic of less massive (Figure 9).

Table 9. Clasification and Score of Surface Geology

Rock Type	Constituent Material	Score
Igneous	Intrusive Granite	1
	Intrusive Intermediate	1
	Ekstrusive, Pyroclastic	1
	Ekstrusive Intermediate	1
Sediment	Alluvium	1
	Limestone	0
	Mudstone	0
Metamoprh	Meta-sediment	0

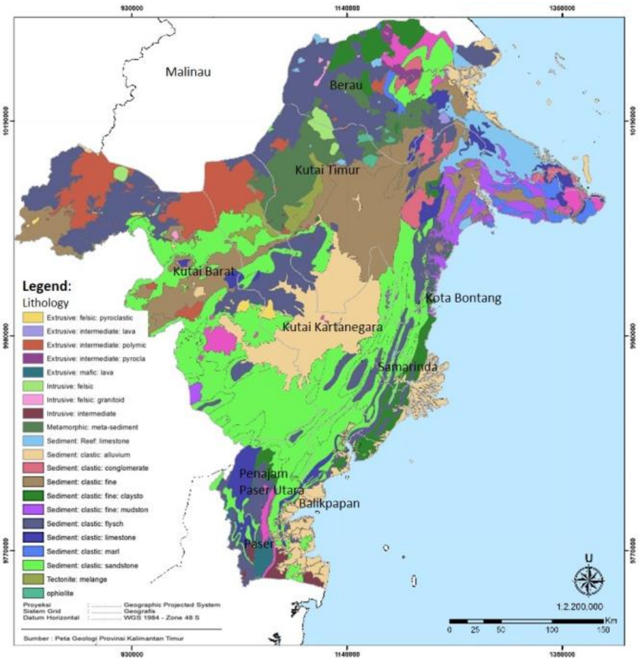

Figure 9. Geological Map of East Kalimantan.

Region suitability is resulted from the research actual suitability. The suitability level based on data availability and did not consider assumption or improvement of the management level as to overcome physical obstacles or existing hurdles.

The weighting and rating results produced, three suitable locations as the NPP potential sites (Figure 10). The detailed inquiries are as follow:

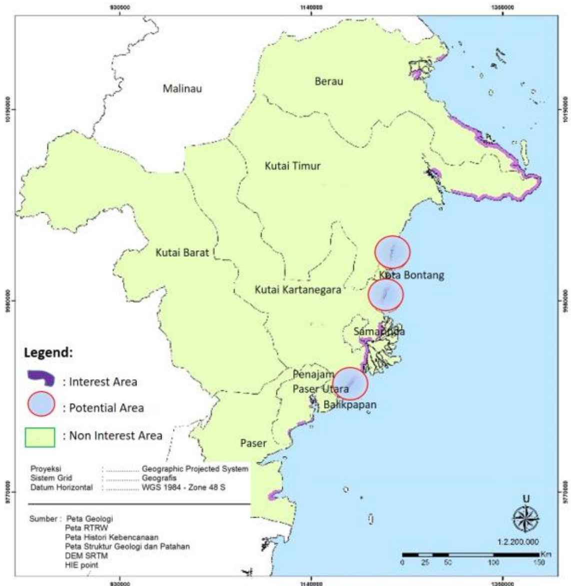

Figure 10. Potential Area in East Kalimantan Province.

3.6 Weighting Evaluation on Site Selection

NPP interest site selection as stipulated in BAPETEN Chairman regulation is based on general criteria for pre-survey site which covers coolant water supply, population density, the distance to hazardous strategic industry, the distance to oil and gas piping network, the availability of ground water, the type of land cover shouldn't include of natural swamp or water inundation, the distance to airport and seaport, protected area (natural reserve, wildlife reserve, and cultural heritage), and also the distance to the nearest military facility.

IAEA, USNRC and DOE recommended that land use planning is amongst the logic method to determine NPP site, and also to minimize negative environmental effect to support suistanable development. In addition, most countries in the world is aiming to assure the NPP safety toward earthquake, flood and land erosion, to provide optimum electricity capacity while protecting biophysical environment and social economic. Hence, construction of NPP should comply with all the regulation both from BAPETEN and also recommendation from IAEA.

Table 10. Potential Site in East Kalimantan With Land Cover

No	Regency	Potential Area
1	Muara Badak, Kutai Kartanegara Coordinate: 1219677 9983378 Area:4.800.148 m^2	
2	Bontang Timur, Kutai Timur Coordinate: 1227682 10028666 Area:1.421.097 m^2	
3.a	Samboja, Kutai Kertanegara Coordinate: 1195850 9898878 Area: 1.895.248 m^2	
3.b	Samboja, Kutai Kertanegara Coordinate: 1179353 9882050 Area: 5.218.549 m^2	

The NPP technical and non-technical aspects should coincide with the land use plan in order to assure that site selection comply with environmental regulation. Table 10 indicated the map of land suitability analysis for NPP in East Kalimantan. LANDSAT satellite image overlaid above the potential site (Table 10). The overlaid map shows that potential site one and four located at an open land. Meanwhile, two potential site located at forest and paddy rice field. The third potential site is mixed up land and open land. Fourth potential site is located at open land which contains quartz. Therefore, based on data interpretation of remote sensing and weighting, all selected potential sites is located as the recommended NPP site. Nevertheless, further and deeper study is necessary in order to acquire NPP selected site.

4. CONCLUSION

Based on the result of spatial analysis of land suitability using GIS application in East Kalimantan province, the potential area for NPP has been decided. Potential site selection along the East Kalimantan coastal area has been performed using general and specific criteria. Land suitability for potential site acquired two sites in Kutai Kartanegara and East Kutai district. The study based on the result of weighting and matching from several data categorized as the NPP site feasibility such as geology, slope, soil type, human induced event, lithology, seismicity, land use, spatial planning, and residencies. Application of GIS is helpful in term of data processing for site and spatial analysis used to determine NPP potential site.

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REFERENCES

[1] PLN, “Rencana Usaha Penyediaan Tenaga Listrik 2018-2027,” Jakarta, 2018.
[2] D. Arinaldo and J. C. Adiatma, “Indonesia ’ s Coal Dynamics :,” Jakarta, 2019.
[3] IAEA, *Nuclear power for a clean-energy future*, no. December. Vienna: IAEA, 2017.
[4] IAEA, *IAEA Safety Standard Series No. SSG-35: Site Survey and Site Selection for Nuclear*

Installations. Vienna: IAEA, 2015.

[5] R. Ioan, "NPP SITING," in *Joint ICTP-IAEA School of Nuclear Energy Management*, 2012, no. November.

[6] Suntoko H "Pemilihan Tapak PLTN di Semenanjung Muria" *Jurnal Pengembangan Energi Nuklir.*, vol. 1, no. 4, pp. 173–185, 1999.

[7] Suntoko H "Inventarisasi Tapak Potensial PLTN di Wilayah Provinsi Banten," *Jurnal Pengembangan Energi Nuklir.*, vol. 9, no. 2, pp. 11–20, 2007.

[8] Y. Yuliastuti, H. Susiati, and Y. S. Budi Susilo, "Kondisi Geomorfologi Dan Karakteristik Sedimen Dasar Laut Di Wilayah Perairan Sebagin Untuk Evaluasi Tapak Pltn Di Bangka Selatan," *J. Pengemb. Energi Nukl.*, vol. 17, no. 2, p. 97, 2015.

[9] H. Susiati, "Penentuan tapak potensial pltn dengan metode sig di wilayah pesisir propinsi kalimantan barat," *J. Pengemb. Energi Nukl.*, vol. 16, no. 2, pp. 131–142, 2014.

[10] H. Susiati, Y. S.B.S., K. Anzhar, B. Kironi, and J. Mellawati, "Aplikasi Data Penginderaan Jauh Dan Sig Dalam Pemilihan Tapak Potensial Pltn Kalimantan Barat," *J. Pengemb. Energi Nukl.*, vol. 17, no. 2, p. 121, 2015.

[11] "Land Suitability Analysis – User Guide 1 Nc Division Of Coastal Management Nc Center For Geographic Information And Analysis Land Suitability Analysis User Guide Land Suitability Analysis – User Guide," North Carolina, 2005.

[12] J. Malczewski, "GIS-based land-use suitability analysis: A critical overview," *Prog. Plann.*, vol. 62, no. 1, pp. 3–65, 2004.

[13] K. M. Johnston, "Spatial Analyst – Finding the Best Locations Using Suitability Modeling," in *Esri User Conference*, 2017.

[14] S. Pourebrahim, M. Hadipour, and M. Bin Mokhtar, "Integration of spatial suitability analysis for land use planning in coastal areas; case of Kuala Langat District, Selangor, Malaysia," *Landsc. Urban Plan.*, vol. 101, no. 1, pp. 84–97, 2011.

[15] H. Madurika and G. Hemakumara, "GIS based analysis for suitability location finding in the residential development areas of greater Matara region," *Int. J. Sci. Technol. Res*, vol. 6, no. 02, pp. 96–105, 2017.