Republic of the Philippines
Department of Environment and Natural Resources
Visayas Avenue, Diliman, Quezon City
Tel. Nos. (632) 929-66-26 to 29 • (632) 929-62-52
Website: http:/www.denr.gov.ph / E-mail: web@denrgov.ph

MEMORANDUM

FOR : The Assistant Secretary for Policy, Planning and Foreign- Assisted And Special Projects and Director, Forest Management Bureau In Concurrent Capacity

The OIC, Office of the Director and Assistant Director
Biodiversity Management Bureau

The Directors

Environmental Management Bureau
Land Management Bureau
Mines and Geosciences Bureau

FROM : The OIC Director, Policy and Planning Service

SUBJECT : **ADOPTION RE: MANUAL ON STORM SURGE AND COASTAL EROSION VULNERABILITY ASSESSMENT**

DATE : 04 MAR 2021

This is in connection with the Manual on Storm Surge and Coastal Erosion Vulnerability Assessment and the draft DENR Memorandum Circular adopting it which was submitted by the ERDB for review and consideration of the DENR Policy Technical Working Group (PTWG).

The Manual aims to serve as a national guide in the conduct of coastal vulnerability assessment within priority watersheds across the country towards the development of integrated vulnerability models. Through integrated vulnerability assessment, science-based reduction of disaster intensity is possible by providing local context in the development of site-specific adaptation strategies.

In this regard, may we request for your comments/inputs on the Manual and we will highly appreciate receiving your inputs/comments on or before 16 March 2021 before we schedule it for PTWG deliberation on its possible adoption.

For your preferential action, please.

MELINDA C. CAPISTRANO

MEMO NO. 2021 - 205

Republic of the Philippines
Department of Environment and Natural Resources
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Website: http:/www.denr.gov.ph / E-mail: web@denrgov.ph

DENR MEMORANDUM CIRCULAR
No. 2021-____________

SUBJECT : **ADOPTING THE MANUAL ON STORM SURGE AND COASTAL EROSION VULNERABILITY ASSESSMENT**

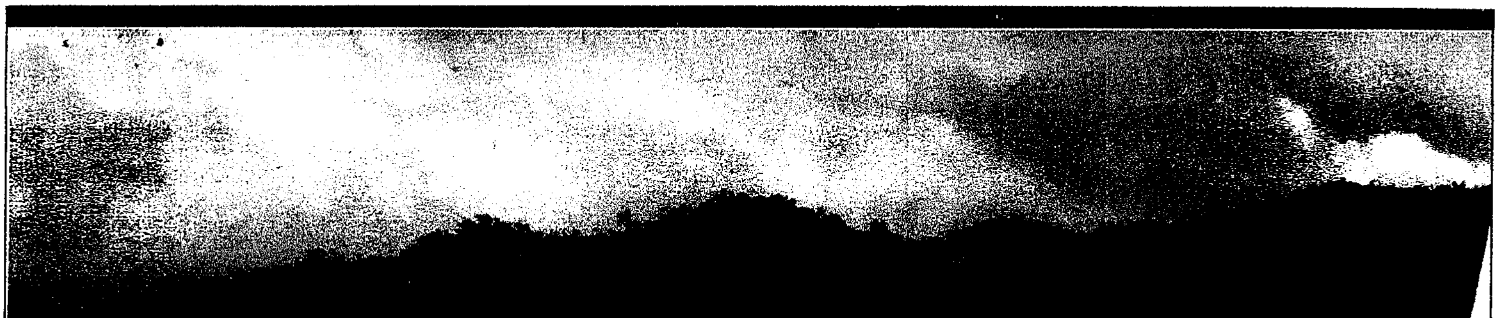
Pursuant to Executive Order No. 192, which mandates the Department of Environment and Natural Resources (DENR) as the primary government agency responsible for the sustainable development of the country's environment and natural resources, DENR Memorandum Circular No. 2008-05 entitled "Guidelines in the Preparation of Integrated Watershed Management Plan", and for the formulation of inputs to international and national frameworks and plans on climate change and disaster risk reduction through incorporation of criteria and approaches employed in existing vulnerability tools to arrive at a continuum (ridge to reef) vulnerability scenario, the hereto attached manual on "Storm Surge and Coastal Erosion Vulnerability Assessment" is hereby adopted for the guidance of all concerned.

The Manual shall serve as a national guide in the conduct of coastal vulnerability assessment within priority watersheds across the country towards the development of integrated vulnerability models.

The Ecosystems Research and Development Bureau (ERDB) shall conduct joint semi-annual monitoring and evaluation of integrated watershed management planning process of the watersheds to validate physical and financial accomplishments and to monitor compliance with the policies.

This Circular take effect immediately.

ROY A. CIMATU



Storm Surge and Coastal Erosion Vulnerability Assessment Manual

Please submit this accomplished form to:
Ecosystems Research and Development Bureau
Los Baños, Laguna

Climate change vulnerability assessment of coastal and marine areas

Recipient of Manual

Name: ____________
Office: ____________
Position: ____________
Contact number: ____________
Address: ____________

Please help us improve this manual:

	1 Very Unsatisfied	2 Unsatisfied	3 Neutral	4 Satisfied	5 Very Satisfied
Content	☐	☐	☐	☐	☐
Map presentation	☐	☐	☐	☐	☐
Usefulness (field application)	☐	☐	☐	☐	☐
Usefulness (map generation)	☐	☐	☐	☐	☐
OVERALL	☐	☐	☐	☐	☐

Other suggestions

____
____

Preface

The high exposure and sensitivity of our coastal areas to climate change impacts when coupled with low adaptive capacity translates into high level of vulnerability. To determine the vulnerability of coastal areas to climate change impacts, particularly to coastal erosion and storm surge, an integrative method covering the physical environment (exposure), present state of specific ecosystems (sensitivity), and ability to cope with climate change impacts (adaptive capacity) in coastal areas was developed and presented in this manual.

Exposure represents the physical aspect of vulnerability, particularly, those related to sea level rise exposure, wave exposure (tidal range and erosion and accretion). Sensitivity covers the characteristics of coastal areas relative to storm or typhoon frequency, proximity to river and other water bodies, vegetation cover, coastal landform or geomorphology, coastal slope, width of the reef flat and lateral extent of the reef relative to shoreline length. Adaptive capacity deals on the coastal community features that influence how the dwellers anticipate, responds, cope and recover from the climate change hazards. This vulnerability sub-factor focuses on the presence of man-made barriers, guideline on setback zones in CLUP, early warning system, evacuation system, beach or sand mining, coastal protection structures, land use pattern or coastal development, integrated and participatory coastal resources management program, environmental law enforcement, alternative or supplemental livelihood, information and education campaign, access to financial and technological resources, and resettlement sites.

A 5-point numerical scale was applied in the vulnerability matrix or rubric. Ascending values correspond to increasing contribution of indicators to the overall vulnerability. The average score was determined based on the number of indicators per sub-factor. The score for exposure, sensitivity, and adaptive capacity was factored in to compute for the overall vulnerability index. The index was computed using the equations of McLaughlin and Cooper (2010). The resulting coastal vulnerability sub-indices were tabulated scale to determine the degree of vulnerability (i.e. low to very high vulnerability) of the coastal area. The final vulnerability maps were generated through ArcGIS10.5.

Despite the data intensive process for GIS-based generation of vulnerability models, it is envisioned that more conservative models encompassing coastal areas will be generated with the guide of this manual. DENR hopes that generated vulnerability models will lead to less disaster in our coastal areas.

MAYUMI Q. NATIVIDAD
Assistant Director

Contents

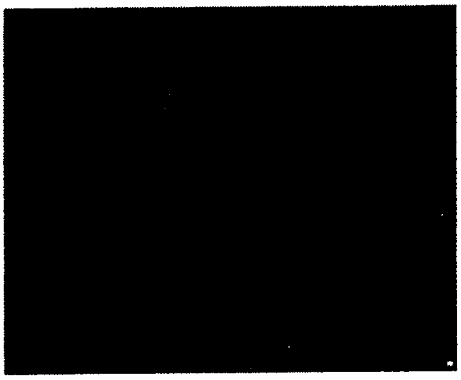
List of Tables

Acronyms

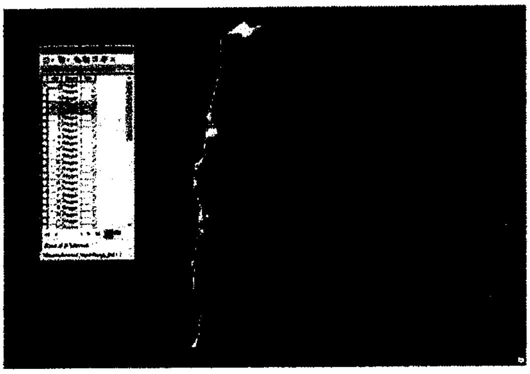
AC	Adaptive capacity
CAD	Computer Aided Design
CIV	Coastal Index of Vulnerability
CLUP	Comprehensive Land Use Plans
CRMP	Coastal Resources Management Program
DBH	Diameter at breast height
DENR	Department of Environment and Natural Resources
DOST	Department of Science and Technology
ERDB	Ecosystems Research and Development Bureau
GIS	Geographic Information Systems
GPS	Global Positioning System
IEC	Information, Education and Communication
IFSAR	Interferometric Synthetic Aperture Radar
IPCC	Intergovernmental Panel on Climate Change
IPCC-AR5	IPCC Fifth Assessment Report
LDRRMC	Local Disaster Risk Reduction and Management Council
LGU	Local Government Unit
LIT	Line-Intercept
MERF	Marine Environment Resources Foundation, Inc.
MGB	Mines and Geosciences Bureau
MPDO	Municipal Planning and Development Office
NAMRIA	National Mapping and Resource Information Authority
NOAA	National Oceanic Atmospheric Administration
NOAH	Nationwide Operational Assessment of Hazards
PA	Protected Area
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
SLR	Sea level rise
SPSS	Statistical Package for the Social Sciences
SSA	Storm Surge Advisory
TC	Tropical Cyclone
VA	Vulnerability Assessment

B. Datasets

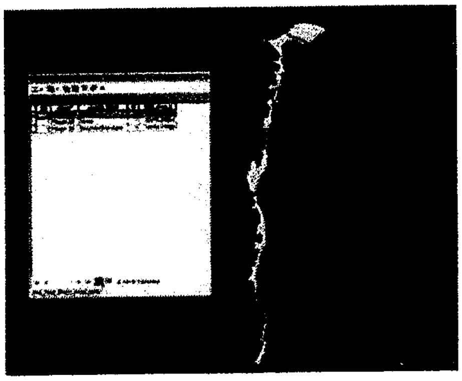
Slope



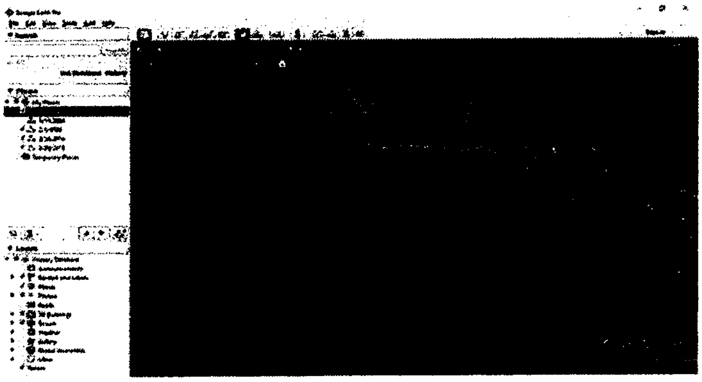
Rainfall



Storm surge exposure (SSA 1 by Project NOAH)



Mangrove cover (CRM, NAMRIA)



Shorline change

Geodata
Field data

- ✓ Beach width
- ✓ Habitat integrity (corals, seagrass and mangrove cover)
- ✓ Beach forest
- ✓ Coastal structures
- ✓ Adaptive capacity indicators
- ✓ Anecdotal accounts

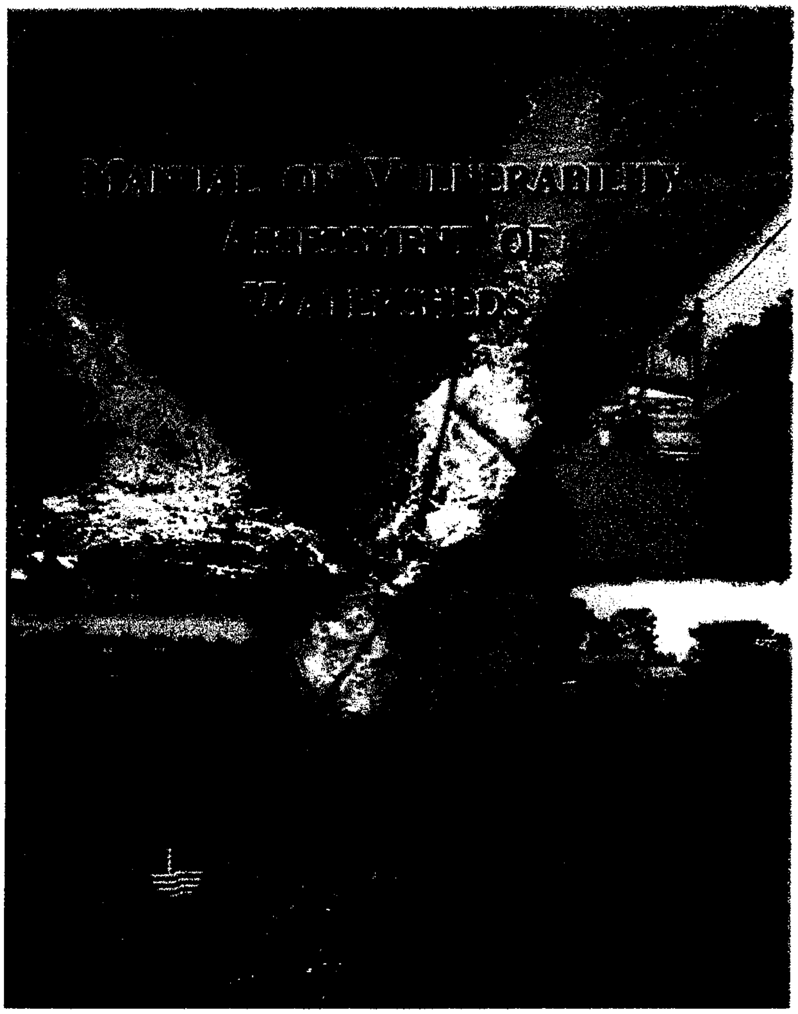


Fig.1 First manual on vulnerability assessment of watersheds (http://erdb.denr.gov.ph/wpcontent/uploads/2015/06/VA%20Manual.pdf).

Fig. 2 Climate change impacts on coastal areas within priority watershed: storm surge (left) and coastal erosion (right). (Photo source/credit: Philippine Central Info Negros and ACE CRC)

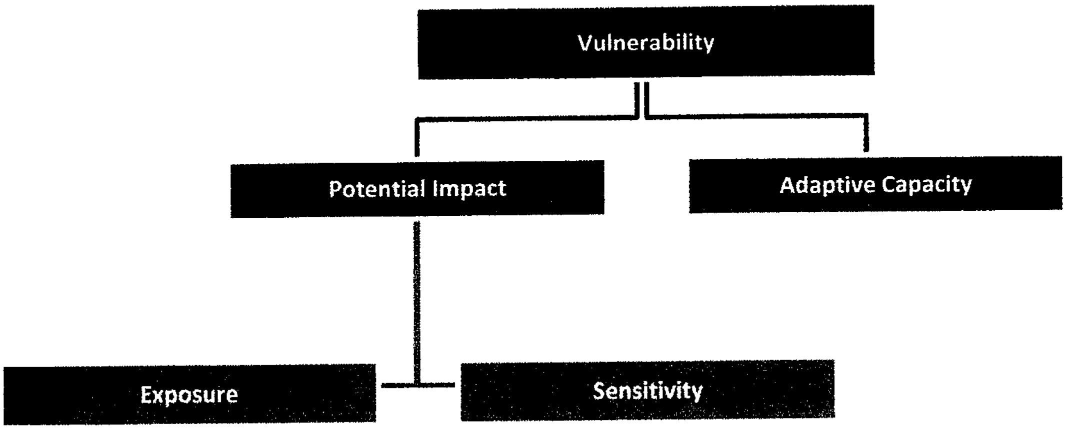


Fig. 3 The three main components of vulnerability: exposure, sensitivity and adaptive capacity (IPCC 2007). High exposure, high sensitivity and low adaptive capacity induce high vulnerability.

Increasing storm and typhoon intensity or frequency, changing precipitation patterns, increasing air and water temperature, ocean acidification, and sea-level rise are the effects of climate change observed not only in the coastal areas in the Philippines but across the world (NOAA 2010; MERF 2013). Sea-level rise due to thermal expansion and melting of land ice sheets and glaciers place coastal areas vulnerable to coastal erosion and storm surge (UNFCC 2007). Coastal erosion is the loss or displacement of land along the coastline due to the action of wind, waves, currents, tides, wind-driven water, runoff of surface water, storms and groundwater seepage (O'Neill 1985). The process provides terrestrial sediment to the coastal systems including beaches, dunes, reefs, mud flats, and marshes (European Commission 2004). On the other hand, storm surge is associated with water level oscillations, beyond the predicted astronomical tides, generated by wind forces of an atmospheric weather system such as tropical cyclones (Murty 1999; Lapidez et al. 2015). With the growing human interventions on the coastal zone, both natural processes can generate high economic, environmental, and social costs (European Commission 2004; UNFCC 2007).

The coastal areas of the Philippines are densely populated with more than 65 million of the population living within 822 coastal municipalities and cities (World Bank 2005). The Philippines is also one of ten countries most affected by extreme weather events (1993-2012) (Kreft and Eckstein 2013). Planning and implementing adaptation strategies in the coastal areas require understanding of the implications of climate of climate change, the specific assets that are most affected, and the associated impacts that cause the greatest damage. The basis for the adaptation strategy is a vulnerability assessment (NOAA 2010). Vulnerability assessment is a process for assessing, measuring, and/or characterizing the exposure, sensitivity, and adaptive capacity of a natural or human system to disturbance (Nelitz et al. 2013). The concept of vulnerability is defined differently in the various scientific areas and is closely related to other concepts, such as hazard, risk and resilience (Fig. 4); thus, coastal vulnerability assessment to climate change involves several concepts that must be clearly defined and to choose the scope and methods accordingly (Ramieri et al 2011).

Various methods or tools had been developed for vulnerability assessments. These are categorized into four categories, which include index-based methods, indicator-based approach, GIS-based decision support systems, and methods based on dynamic computer models (Ramieri et al. 2011). Each method has its own advantage and constraint depending on the scope, criteria, and issues to be evaluated. In the Philippines, vulnerability assessment tools for coastal ecosystems that consider the local context, availability of data, and participative approach are recently introduced (MERF 2013). These tools focus on the vulnerability of integrated ecosystem services, physical coast, and fisheries. The Ecosystems Research and Development Bureau have been implementing vulnerability assessment in Philippines watersheds with emphasis on flooding, landslide, and soil erosion (ERDB 2011). According to the International Federation of Red Cross and Red Crescent Societies (IFRC) that a disaster occurs when a hazard impacts on vulnerable people. As such, there is a need to develop an integrative method, or tool that centers on the population, properties, and infrastructure as exposed assets in the coastal area, while taking into account the vulnerability of the ecosystems to the identified climate change impacts, changes in adaptive capacity, and generation of vulnerability maps at local scale. It is also essential to incorporate criteria and approaches employed in the existing vulnerability assessment tools to arrive at a continuum (ridge to reef) vulnerability scenario.

Climate change vulnerability assessment of coastal and marine areas within priority watersheds	Storm surge and coastal erosion	Biophysical and coastal communities	Rubric scoring (1: Very low, 2: Low, 3: Moderate, 4: High and 5:Very High	Coastal index computation based on McLaughlin and Cooper (2010) and Ellison (2009)	Shoreline change (generated from ArcGIS) and storm surge inundation	Habitat conditions as indicators and inclusion of IFSAR data for slope generation	Community knowledge/participation on CRMP, environmental laws, communication technology, early warning system and alternative livelihood as indicators	Coastal vulnerability index (0-20: Very low; 20-40: Low; Moderate: 40-60; High:60-80; and Very High: 80-100)	VA map generated using ArcGIS; Recommended adaptation strategies

discussed in the succeeding part of this manual. The review of the rubric tool simply aims to familiarize the personnel on the ***factors categorized under the exposure, sensitivity and adaptive capacity*** for a particular hazard. Note that not all exposure or sensitivity factors for coastal erosion were used for storm surge assessment or vice versa. The factors are selected based on the published drivers and other factors influencing the susceptibility to coastal erosion and storm surge.

Exposure

This indicator is comprised of four sub-indicators. Scale the factors for rates of sea level rise, sea level rise exposure, tidal range and erosion/accretion rates. . These four indicators are also used for storm surge. Storm surge exposure at advisory 1 is added to determine the inundated area at 2m surge height.

Rates of sea level rise

Global sea level rise is affected by the thermal expansion of sea water and melting of land ice (Church et al. 2013 as reviewed by Kahana in 2016). Calculations from satellite observations revealed that global sea level rise rate is about 1.7mm/yr. A higher estimated value at 2.8 to 3.6 mm/yr was cited from the IPCC AR5 assessment with consideration of 90% probability of increase between 1993 and 2010. Average global sea level change is expected to rise 3.1 cm every ten years. A higher rising rate for water levels around the Philippines was reported with increase in values between 7.6 to 10.2 cm each decade (three times of the global average) (IDRC 2015). Local sea level is influenced by groundwater depletion (Konikow 2011), decreasing ocean salinity (Ishii et al. 2006; Antonov et al. 2002); subsidence of coastal areas (Anderson et al. 2010), strength of ocean currents (Ezer et al. 2013; Sallenger et al. 2012), among others.

Sea level rise exposure by 2050 [cm]

Based on the assumption of Clavano (2012), the rate of sea level around the Philippines is expected to rise by at least 20 cm in the next 40 years. This absolute rise is influenced by spatial variation, regional ocean-atmosphere dynamics, inland tides, climate patterns and weather effects.

Tidal range (m)

Tidal range is the vertical distance between consecutive high and low water level over a tidal cycle (Surge Watch 2014). This parameter determines energy distribution within the intertidal zone. Wave energy are more concentrated in the intertidal zone and more frequent at micro-tidal environments (<2 m) (Trenhaile 2016; Stormsurge Watch 2014). Tidal environment has shown to contribute a significant role in sediment transport (Allen et al. 1980). The developed rubric scoring for coastal erosion and storm surge used levels of tide within the micro-tidal (<2m), meso-tidal (2-4 m) and macro-tidal (>4m). Large tidal scale coinciding with the timing of surge relative to high water is critical in vulnerability assessment (Flather 2001).

Storm/typhoon frequency (no.)

Tropical cyclone (TC) frequency was based from the 1951-2013 record of TC in the Philippines. Tropical cyclone is a low-pressure system with strong winds in a counter-clockwise direction in the Northern Hemisphere. Tropical cyclones have a wind speed range of 40-300 kilometers per hour and a diameter from 300 to 100 km wide (Terry 2007; Cinco 2016). Tropical cyclone activity is deemed necessary for coastal erosion and storm surge assessment as local coastal communities are situated in typhoon-prone archipelago.

Rainfall amount (mm)

The vulnerability inputs for rainfall amount were based on the climate projections in 2020 and 2050 for the Philippines. The projected rainfall change was under the emission scenarios in the Fourth Assessment Report (A4) of the Intergovernmental Panel on Climate Change (IPCC). Seasonal rainfall change was computed with respect to the observed baseline rainfall data from (1971-2000).

Beach morphology (Beach width, coastal geomorphology and coastal slope)

Beach morphology determines how the coast responds to processes such as wave action and tidal currents, as well as to climate change hazards. Coastal slope also indicates the susceptibility of the coast to flooding and erosion. It is expected that low-lying coastal plains more likely to experience rapid erosion. Coastal slopes were derived from the IFSAR (Interferometric Synthetic Aperture Radar) data. The type of sediment was also noted during the survey. Finer sediments typically provide less inclination than larger grains (Asplund and Malmstrom 2018).

Proximity to river mouth (m)

Proximity to river mouth is part of sensitivity analysis for coastal erosion. River supplies the coastal area with sediment load which may consist of fine, cohesive or non-cohesive sediments (Mangor et al. 2017.)

Reef flat

Coral reefs reduce wave energy by an average of 97% (Ferrario et al. 2014). This wave attenuation benefits comes from the reef crest and reef flat of the coral reef environment. The reef crest extends from the seaward edge and the shallowest part of the reef while reef flat is the shallow part of the reef that reaches the shallowest part of the reef. The former dissipates 86% of wave energy while the latter attenuates approximately half of the remaining wave energy. The Coastal Resources Map of NAMRIA (2015) and primary data from underwater surveys are needed to generate the sensitivity sub-indices ratings.

Beach forest and vegetation

Beach forest and vegetation are important for improving slope stability, consolidating sediments and providing shoreline protection (Prasetya 2006).

Adaptive capacity

A semi-structured questionnaire is used on the adaptive capacity assessment of coastal communities situated within the outlet of priority watersheds. Nineteen parameters to be ranked from 1 to 5 corresponding to very low to very high AC levels were used to determine the ability of the communities to deal with coastal hazards. These parameters are the number of ordinances relative to beach/sand mining law, proximity of settlement to coastline, coastal protection structure, land use pattern/ coastal development, integration and implementation of coastal zoning plan in the CLUP, awareness of community on the guidelines of setback zone, presence of coastal resources management program (CRMP), community participation to CRMP, presence of environmental laws, knowledge of the community on the presence of environmental laws, enforcement of environmental laws, dissemination of information and education campaign materials, early warning device PA system, communication technology, evacuation center, resettlement areas, LGU knowledge and application of geo-hazard map, community knowledge on geo-hazard map and alternative or supplemental livelihood.

Households within the target coastal barangays are interviewed (minimum of 30 respondents). Results are encoded in the SPSS software for descriptive analysis and computation of AC values needed for the model generation. The detailed adaptive capacity assessment is presented on the Field assessment part of this manual.

Step 3. Desk study

Review the data needs and availability prior to the conduct of the field assessment. The geodata such as **administrative, historical, slope, coastal resources or storm surge map** are among the commonly acquired information prior to actual field assessment.

Coastal polygon

The coastal polygon represents the target area for the assessment. This unit of interest is demarcated from Google Earth. The demarcation covers the exposed area of the coastline and must be within the recognized 3km coastal area boundary. This allows data assembly on common scales across the target coastal strip.

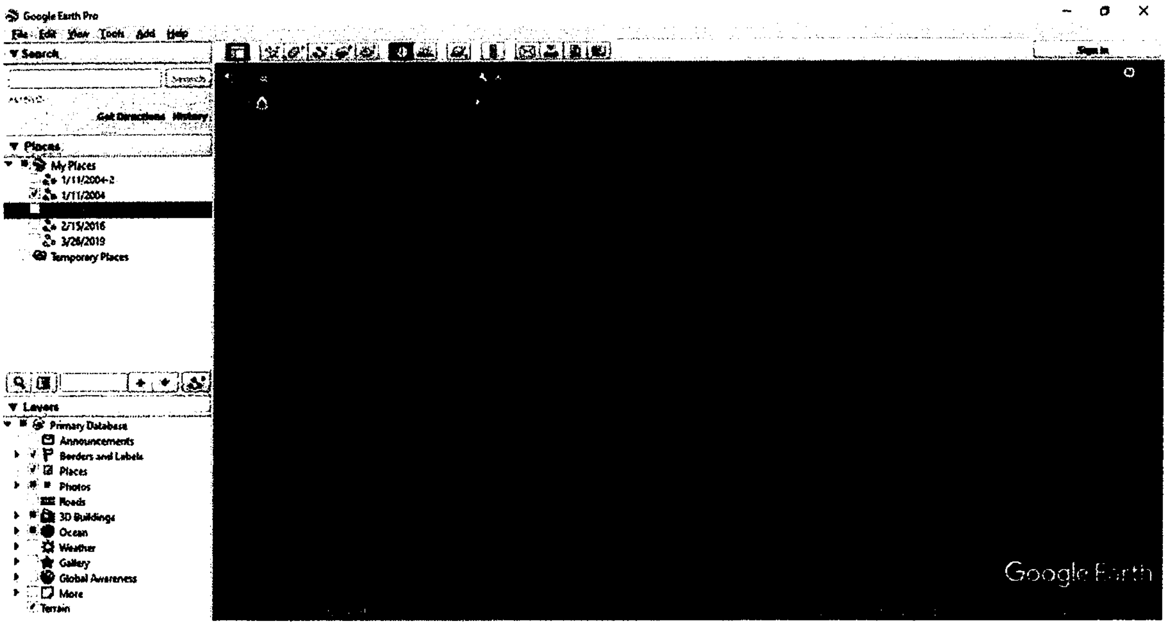


Fig. 8 Digitized shoreline polyline in the 2004 imagery of Baluarte, Tagaloan, Misamis Oriental.

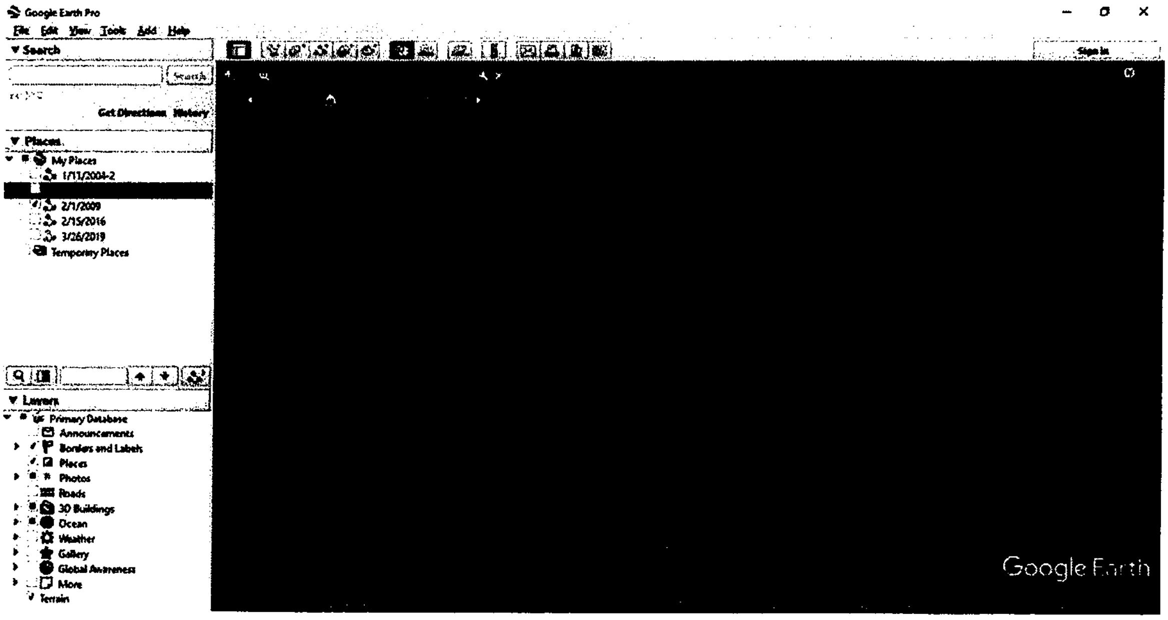


Fig. 9 Digitized shoreline polyline in the 2009 imagery of Baluarte, Tagaloan, Misamis Oriental.

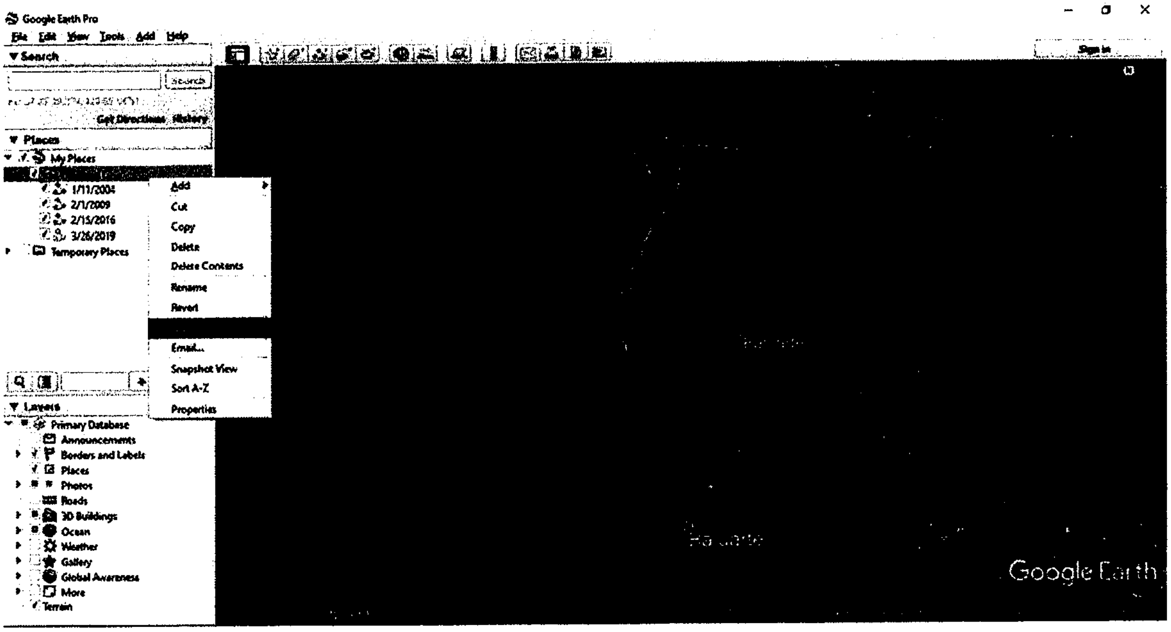


Fig. 12 Consolidated demarcated shorelines of Baluarte, Tagaloan, Misamis Oriental.

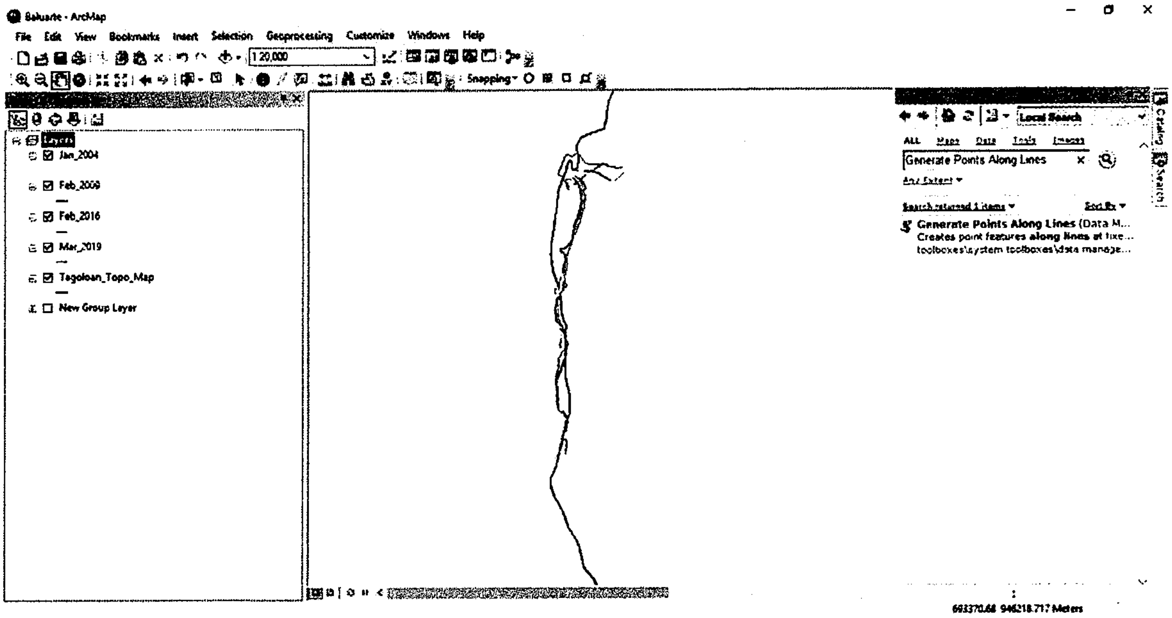
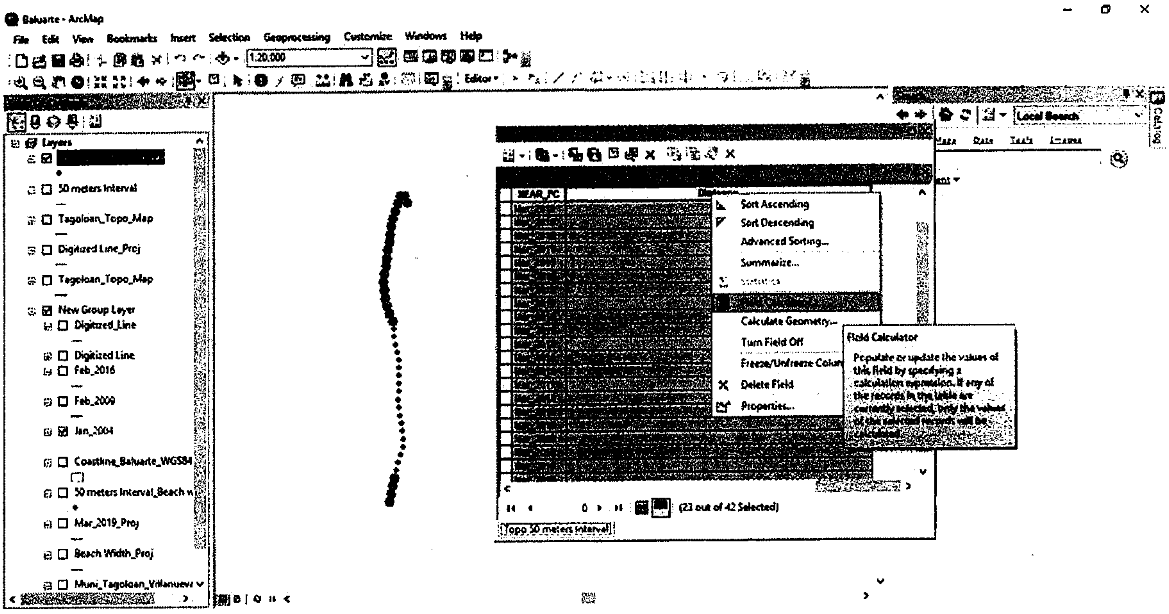


Fig. 13 Start of shoreline change analysis using ArcGIS.



Field Calculator

Populate or update the values of this field by specifying a calculation expression. If any of the records in the table are currently selected, only the values of the selected records will be calculated.

Fig. 16 Computations of shoreline change. Repeat the procedure for other reference shorelines.

$$Shoreline\ change = \frac{Difference\ of\ shoreline}{Year\ difference}$$

In this case, the computed shoreline change rate was -0.40 m/yr. Note this value as input in the critical factor analysis. During the field assessment, shoreline change may be validated through **anecdotal accounts** and **evidences of field erosion**. Examples are given in the field assessment part of this manual.

Slope

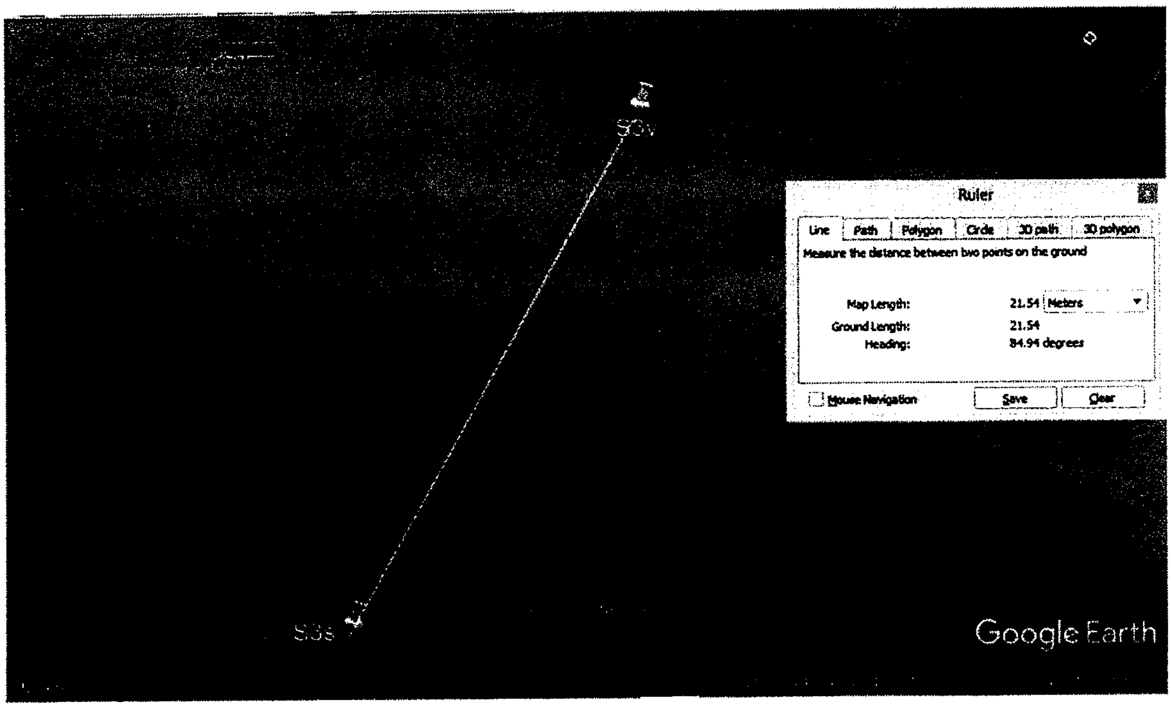
Slope map is generated using the Interferometric Synthetic Aperture Radar (IFSAR) data. The result will be verified in the field as part of coastal geomorphology analysis using the Emery method (1961). The generated slope maps along the shoreline of Barangay Baluarte, Tagaloan, Misamis, Oriental and Baragay Ondoy in Ibajay, Aklan are presented as examples. Based on this set of geodata, the slope of Baluarte ranged from 0.0051 to 8.6042. Ondoy on the other hand displayed slope values from 0-3.55. These slope values are among the sensitivity inputs for coastal erosion and storm surge.

Using the ruler tool, measure the distance form the first to the last point, the obtained values corresponds to beach width. Record the values using meters (m) as the unit of measure.

Table 4. Pre-determined stations and measurements for beach width assessment.

Station	Easting		Northing		Beach width (m)
	deg	min	deg	min	
S1-S	120	16.052	14	50.294	24.55
S1-E	120	16.062	14	50.303	
S2-S	120	16.021	14	50.341	18.16
S2-E	120	16.029	14	50.347	
S3-S	120	16.000	14	50.416	21.54
S3-E	120	16.012	14	50.417	

Fig. 19 Generation of pre-determined transect using Google Earth.



Measure the distance between two points on the ground

Map Length: 21.54 Meters
Ground Length: 21.54
Heading: 84.94 degrees

Fig. 22 Beach width measurement using the ruler tool in Google Earth (Station 3).

Coastal resources

The presence and extent of cover of coral reef, seagrass and mangrove areas also important sensitivity parameters as these natural habitats protect protection from natural hazards. These coastal features can generally attenuate the surge impacts from the coasts to inland communities (Wamsley et al. 2010). Ferrario (2014) revealed that the entire reef can reduce wave energy and height. The reef flats alone were able to dissipate the remaining wave energy (65%) and wave height (43%) from the reef crest. As for mangrove, the reported reduction surge rate through this ecosystem was between 5-15 cm/km, even up to 50 cm/km (McIvor et al. 2012; Krauss et al. 2009; Zhang et al. 2012). These natural habitats can dissipate the wave energy via breaking and frictional dissipation (Lowe et al. 2009; Guannel 2016).

Numerical simulations have also shown that coastal wetlands have the potential to attenuate storm surges and waves depending on the coastal landscape and the strength and duration of the storm (Wamsley et al. 2010). A wide vegetation belt (300 m) on a mild slope (1:500) was proven to increase the reduction of water depth and velocity. The reported maximum decrease in surge and velocity was 1.37 m and 1.07 m/s, respectively, compared to the values on landward areas without vegetation (Das et al. 2011). Sparse vegetation offers limited protection to the community once surges propagate into inland areas.

As shown in the next two figures, the geodata on coastal resources from NAMRIA indicated the presence of mangrove in Baluarte, Tagaloan, Misamis Oriental while all three important coastal habitats were recorded in San Diego, Lian, Batangas. Such data will be validated in the field through underwater surveys. The validated onsite status and health of these ecosystems translates into the quality of the protection services rendered into the

Storm surge

Project NOAH storm surge advisory is intended to give forecast with 24-hour lead time before the passage of a tropical cyclone in the country. Each forecast is based on Storm Surge Advisory (SSA) which was based on the combination of storm surges and maximum tide levels: SSA 1 (0.01m to 2m); SSA 2 (2.01 to 3m), SSA3 (3.01m to 4m) and SSA (4m and above). These advisories provide the extent, depth and hazard level of storm.

For this vulnerability assessment, the percentage of affected area in the demarcated polygon is determined through the **overlay analysis of SSA 1 shapefiles in ArcGIS**. If about 80% of the polygon is inundated at the lowest level of advisory, the area is considered to be very sensitive to storm surge. Overlay of SSA 1 in Baluarte, Tagaloan, Misamis Oriental is shown in the image. The result showed that 75% of the area is inundated at lowest level of advisory. Result of such overlay analysis can be a **guide question** in determining the present site condition in terms of its existing adaptation strategies to storm surge and provide pointers on possible interventions in case higher SSA will be applicable in their area.

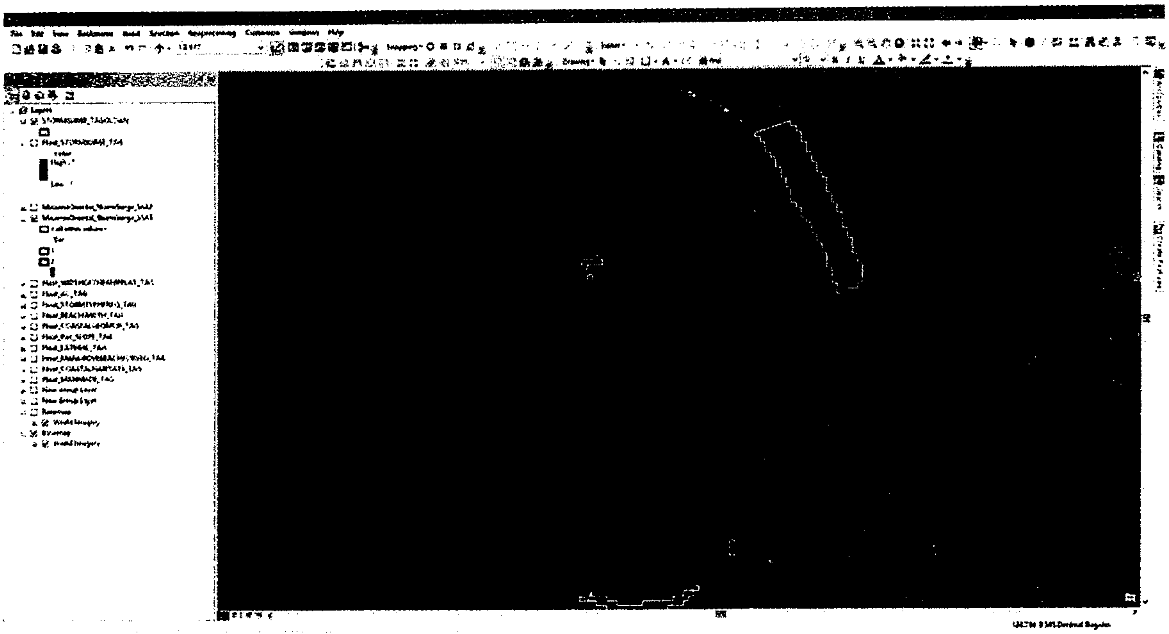


Fig. 25 Example of using geodata on storm surge advisory in Tagaloan, Baluarte, Misamis Oriental.

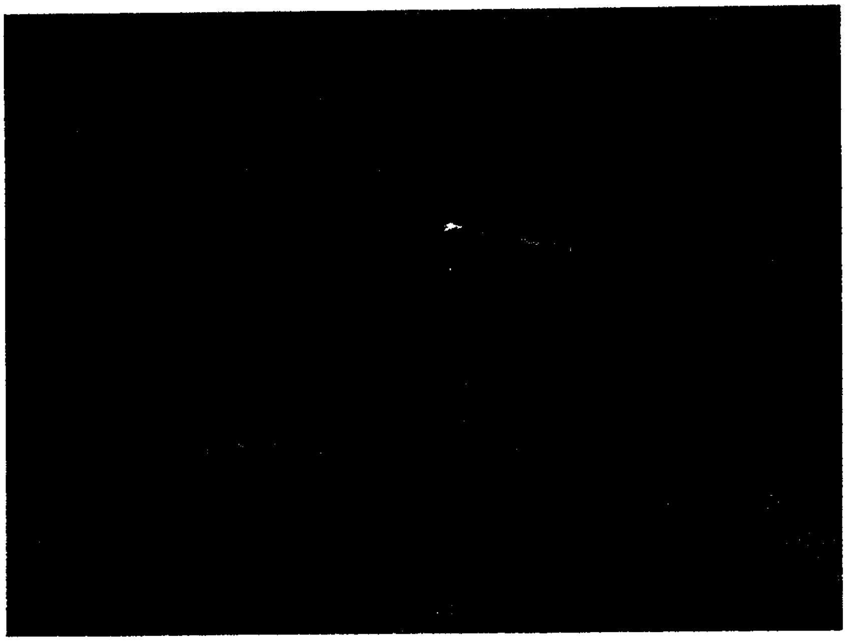


Fig. 27 Underwater survey in Ibajay, Aklan.

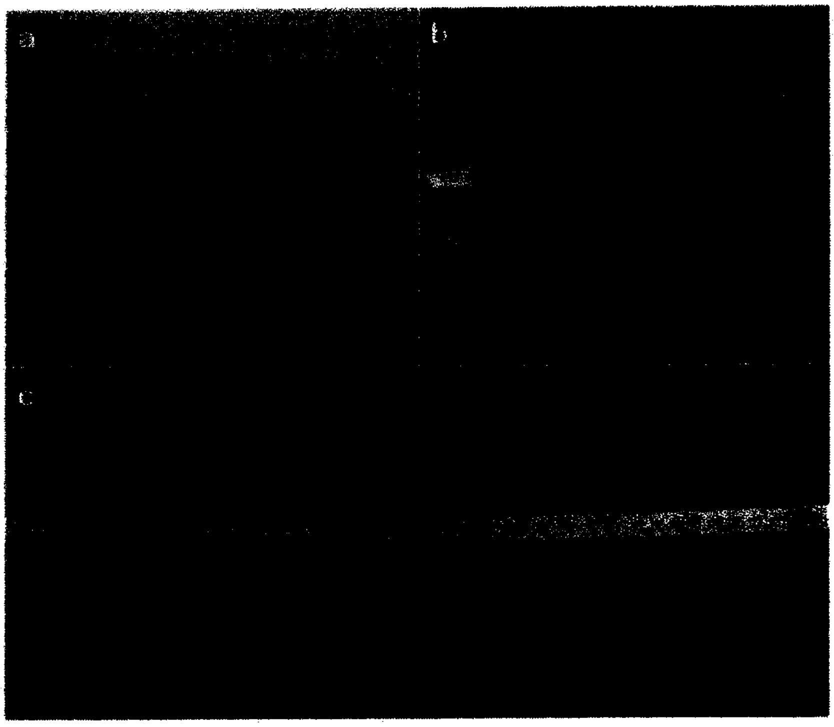


Fig. 28 Example of benthic lifeforms observed at the sampling stations: a. colonies of branching *Porites* on the reef near the pier structures, b. submassive colonies of *Porites* at the marine sanctuary, c. benthic attributes intercepted by the transect at the sampling site.

Quantitative survey of seagrasses is undertaken using the methods in English et al. (1997). A transect is laid perpendicular to the shoreline heading seaward until seagrasses are no longer found. A 0.5 x 0.5 m quadrat will be pressed along the transect at every 5-m interval. Seagrass within the quadrat is identified to species level and counted. Substrate

Beach morphology

In field shoreline morphology assessment, beach width measurements are taken along the coastline. Obtained values from the actual assessment will be compared with the measurements taken using the recent satellite imagery of the coastline. Deviations between results are determined and factors resulting to such are identified through available information, documentation of coastal erosion evidences in the area or anecdotal accounts. The conduct of shoreline morphology assessment was based on Emery method (1961). The tool used is two graduated poles separated by a definite distance (in this case 2m). The alignment and reading of the intersection between the two poles determines the change in elevation and beach width along the profile. The reading will start from the mark of the lowest shoreline until the exposed portion of beach or coastline. Remember to follow a straight path from the starting point of measurement until the last point. A transect may also be laid to serve as guide by the observers. Two individuals hold the poles, maintains its level and before reading the elevation change in the observation points. A third person is assigned to record the measurements and document the data gathering.

Obtained measurements are used to generate shoreline models using MS Excel and AutoCAD. This serve as additional visual reference in determining vulnerability levels along the coastal strip. Moreover, this could also serve as identification of priority areas in coastal erosion management as this supplies the information on which areas of the coast have diminishing beach area.

Fig. 30 Beach morphology assessment.

Fig. 33 Macro-documentation of sediment in the site.

Table 5. Grain-size anlaysis in San Diego, Lian, Batangas.

Station	**Sieve number**	**Opening (mm)**	**Mass of soil retrieved (g)**	**Percent retained**	**Percent passing**
1	35	0.5	22.8	22.8 %	77.20 %
	40	0.42	6.9	6.9 %	93.10 %
	60	0.25	50.8	50.8 %	49.20 %
	100	0.149	15.2	15.2 %	84.80 %
	140	0.105	1.00	1.00 %	99.00 %
	>140		3.30	3.30 %	96.7%
			100.00		
2	35	0.5	14.00	14.00 %	86.00 %
	40	0.42	5.40	5. 40 %	94.60 %
	60	0.25	62.60	62.60 %	37.40 %
	100	0.149	13.60	13.60 %	86.40 %
	140	0.105	1.40	1.40 %	98.60 %
	>140		3.00	3.00 %	97.00 %
			100.00		
3	35	0.5	14.80	14.80 %	85.20 %
	40	0.42	5.90	5.90 %	94.10 %
	60	0.25	56.70	56.70 %	43.30 %
	100	0.149	15.20	15.20 %	84.80 %
	140	0.105	3.80	3.80 %	96.20 %
	>140		3.60	3.60 %	96.40 %
			100.00		

Fig. 35 Abandoned stilt house in Misamis Oriental. Elevated houses offer protection from inundation in the area.

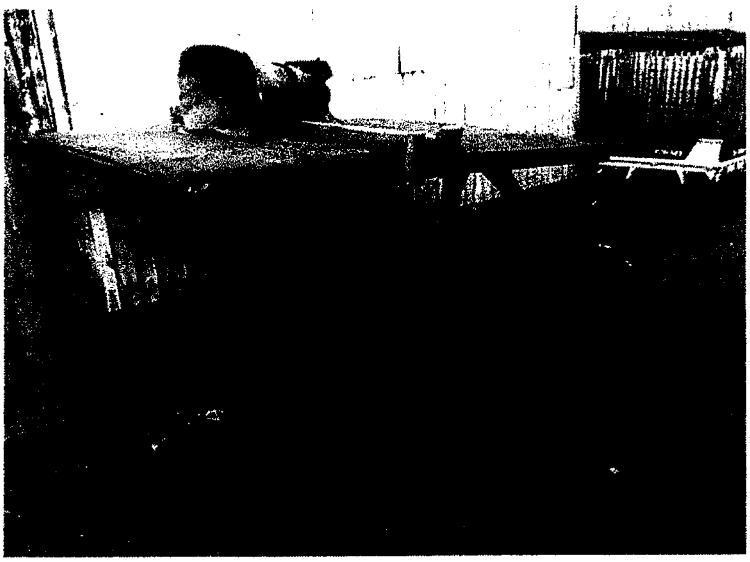


Fig. 36 A common early warning communication device in coastal barangay is megaphone. Designated *purok* leaders give updates or instructions to their constituents regarding water level rising and mode of evacuation during the passage of typhoon.

Table 7 Guide in scaling of exposure and sensitivity factors affecting the vulnerability of coastal areas to coastal erosion and storm surge (adapted from Gornitz 1990 as reviewed by McLaughlin and Copper 2010; ERDB 2017).

Scale	Description
1	Factor contributes to **very low** exposure/sensitivity/adaptive capacity
2	Factor contributes to **low** exposure/sensitivity/adaptive capacity
3	Factor contributes to **moderate** exposure/sensitivity/adaptive capacity
4	Factor contributes to **high** exposure/sensitivity/adaptive capacity
5	Factor contributes to **very high** exposure/sensitivity/adaptive capacity

Table 8. Scale of factors for coastal vulnerability assessment.

Vulnerability sub-indicators	CE	SS	Description	Scale	Rate
Exposure factors					
Relative sea level rise (mm/yr)	✓	✓			
(Ozyurt 2007 and Ramieri et al. 2011)			<1	1	Very low
			1-2	2	Low
			3-5	3	Moderate
			6-7	4	High
			>7	5	Very high
Sea level rise exposure by 2050 (cm)	✓	✓			
(Clavano 2012)			0	1	Very low
			10-20	2	Low
			21-30	3	Moderate
			31-40	4	High
			>40	5	Very high
Tidal range (m)	✓				
			<1	1	Very low
			1-1.4	2	Low
			1.5-1.8	3	Moderate
			1.9-2	4	High
			>2	5	Very high
Tidal range (m)		✓			
			>2	1	Very low
			1.9-2	2	Low
			1.5-1.8	3	Moderate
			1-1.4	4	High
			<1	5	Very high
Erosion/Accretion rates (m yr $^{-1}$)	✓	✓			
			2.1	1	Very low
			1.1-2.0	2	Low

Vulnerability sub-indicators	CE	SS	Description	Scale	Rate
Width of the reef flat (m)	✓	✓	>90	1	Very low
			81 - 90	2	Low
			71 - 80	3	Moderate
			61 - 70	4	High
			<60	5	Very high
Lateral extent reef flat (% length of the shoreline)	✓	✓	>90	1	Very low
			71- 90	2	Low
			51-70	3	Moderate
			31-50	4	High
			<30	5	Very high
Beach forest and vegetation	✓	✓	>50% forest or canopy cover	1	Very low
			<50% forest or canopy cover	2	Low
			Brushland	3	Moderate
			Grassland	4	High
			Sparsely vegetated	5	Very high
Coastal habitat	✓	✓	>50% coral, seagrass, and mangrove cover	1	Very low
			<50 % coral, seagrass, and mangrove cover	2	Low
			>50% coral-seagrass or seagrass-mangrove cover	3	Moderate
			<50% coral-seagrass or seagrass-mangrove cover	4	High
			<50% coral or seagrass or mangrove cover	5	Very high
Structures on the foreshore	✓		<2 short groins (5 m long) and/or few properties on the easement with no shoreline modification	1	Very low
			-		
			Short groins & solid-based pier (5 to 10 m long), seawalls and structures with aggregate length of <10 % of the shoreline length	3	Moderate
			-		

Vulnerability sub-indicators	CE	SS	Description	Scale	Rate
			Concrete breakwater	3	Moderate
			Concrete armors and boulders	4	High
			Seawall	5	Very high
Land use pattern/ coastal development	✓	✓			
			Commercial/ industrial	1	Very low
			Unclaimed	2	Low
			Agricultural/open space	3	Moderate
			Settlement/residential	4	High
			Protected	5	Very high
Integration and implementation of Coastal Zoning Plan in the CLUP	✓	✓			
			Not integrated and implemented (presence of settlements in seawater)	1	Very low
			Integrated but not implemented (presence of settlements within 3m zone)	2	Low
			Limited implementation (presence of settlements within 20m zone)	3	Moderate
			Partially implemented (presence of settlements within 40 m zone)	4	High
			Fully implemented (no presence of settlements within the setback zone)	5	Very high
Awareness of community on the guidelines in setback zone	✓	✓			
			Not aware	1	Very low
			Low level of awareness	2	Low
			Average level of awareness	3	Moderate
			High level of awareness	4	High
			Very high level of awareness	5	Very high
Presence of CRMP	✓	✓			
			None	1	Very low
			1	2	Low
			2	3	Moderate

Vulnerability sub-indicators	CE	SS	Description	Scale	Rate
			no reported apprehension/ violation	5	Very high
Information and education campaign materials	✓	✓			
			No IEC materials seen nor read	1	Very low
			Dissemination of IEC materials only after the occurrence of storm surge and coastal erosion	2	Low
			Dissemination of IEC materials before and after the occurrence of storm surge and coastal erosion	3	Moderate
			Occasional dissemination of IEC materials	4	High
			Regular dissemination of IEC materials	5	Very high
Number of early warning device PA system (batingaw, bandillo, staff gauge, rain gauge)	✓	✓			
			No available	1	Very low
			1	2	Low
			2	3	Moderate
			3	4	High
			>4	5	Very high
Number of communication Technology (mobile, 2-way radio, TV, radio)	✓	✓			
			No available	1	Very low
			1	2	Low
			2	3	Moderate
			3	4	High
			>4	5	Very high
Evacuation centers	✓	✓			
			No evacuation centers	1	Very low
			<=30% of potential affected households could be accommodated	2	Low
			31%-65% of potential affected household could be accommodated	3	Moderate
			66%-99% of coastal households could be	4	High

Vulnerability sub-indicators	CE	SS	Description	Scale	Rate
			26%-50% of the total respondents have knowledge of geohazard maps	3	Moderate
			51%-75% of the total respondents have knowledge of geohazard maps	4	High
			No knowledge on the presence of geo-hazard maps	5	Very high
Alternative or supplemental livelihood	✓	✓			
			not available all throughout the year	1	Very low
			available only for 1 to 3 months	2	Low
			available for 4-6 months	3	Moderate
			available for 7 to 11 months	4	High
			available all throughout the year	5	Very high

Chapter 3
Application

Conversion of vector file (polygon) to raster file

Prepare the polygon of the parameter to process and open its attribute table.

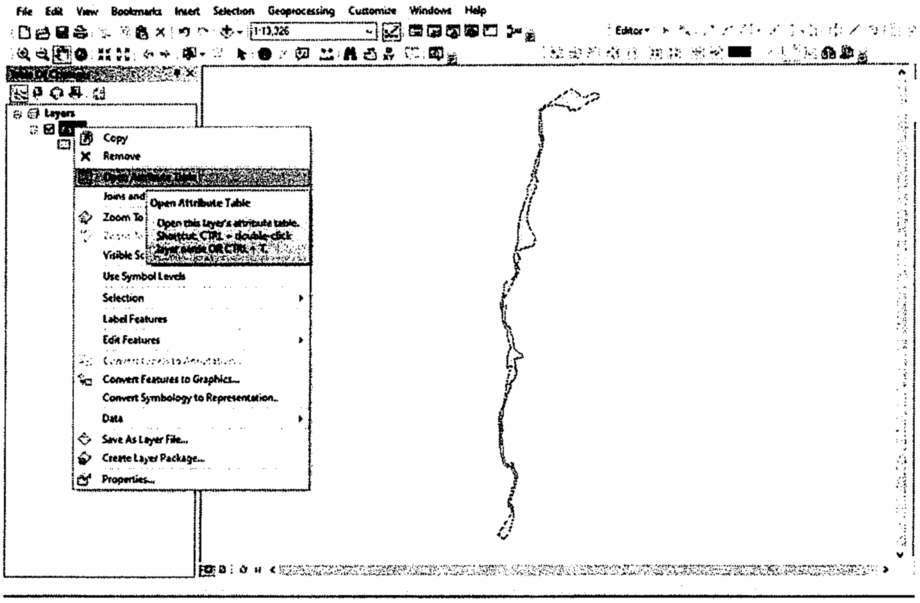


Fig. 39 Conversion of vector to raster file.

In the **Table options**, click the drop-down button and select **Add field**.

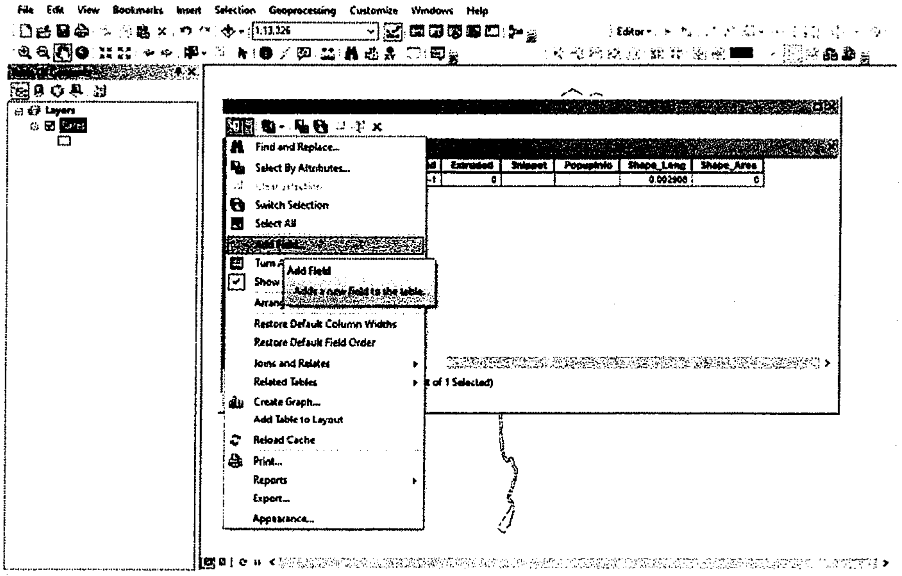
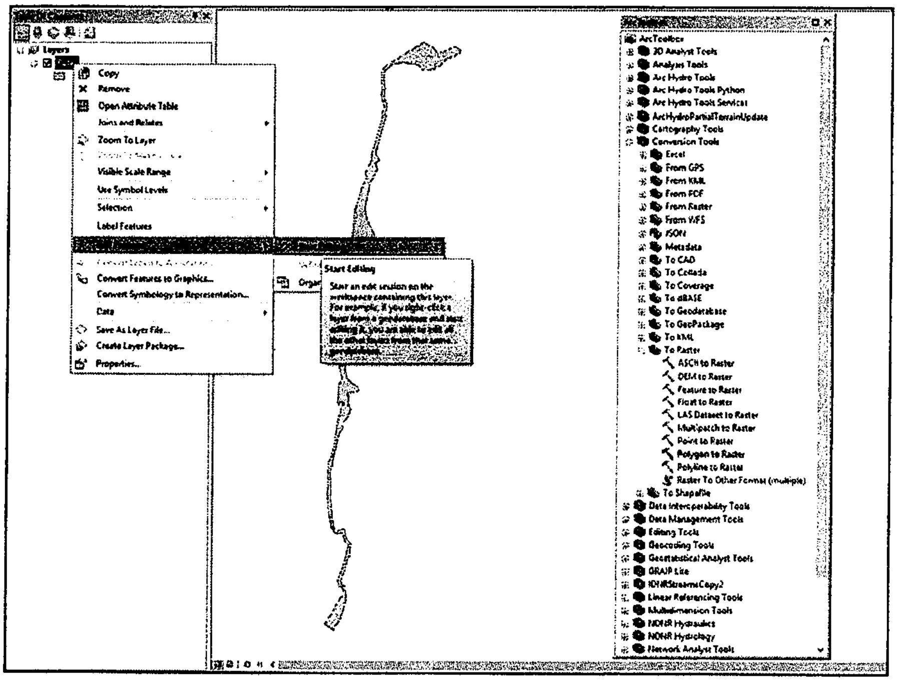


Fig. 40 Creation of additional attribute input.

Add '**Rating**' field and choose '**Double**' as its type. Then click OK.

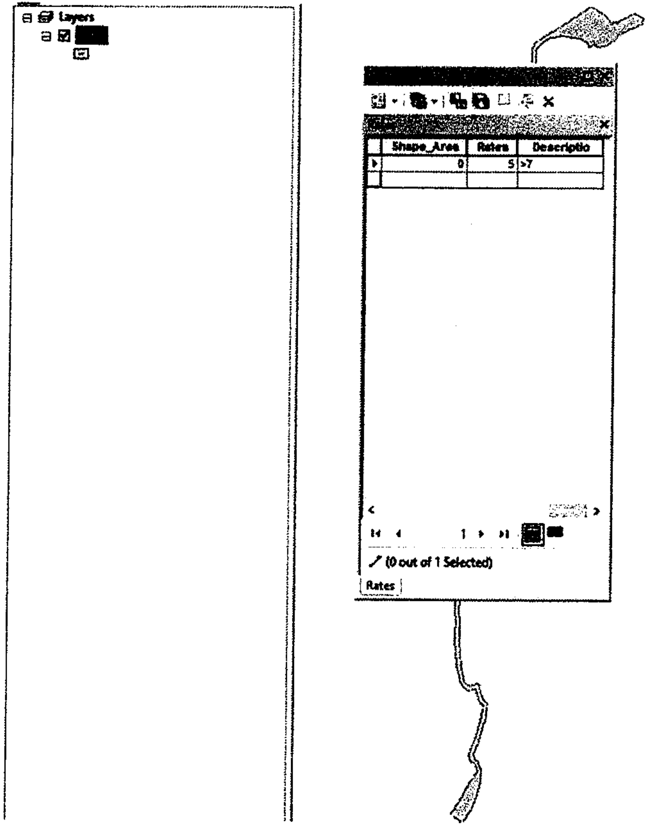


Start Editing

Start an edit session on the workspace containing this layer.

Fig. 43 Start of editing for rating and description values.

Edit the values for Ratings and Description (based on critical factor result).

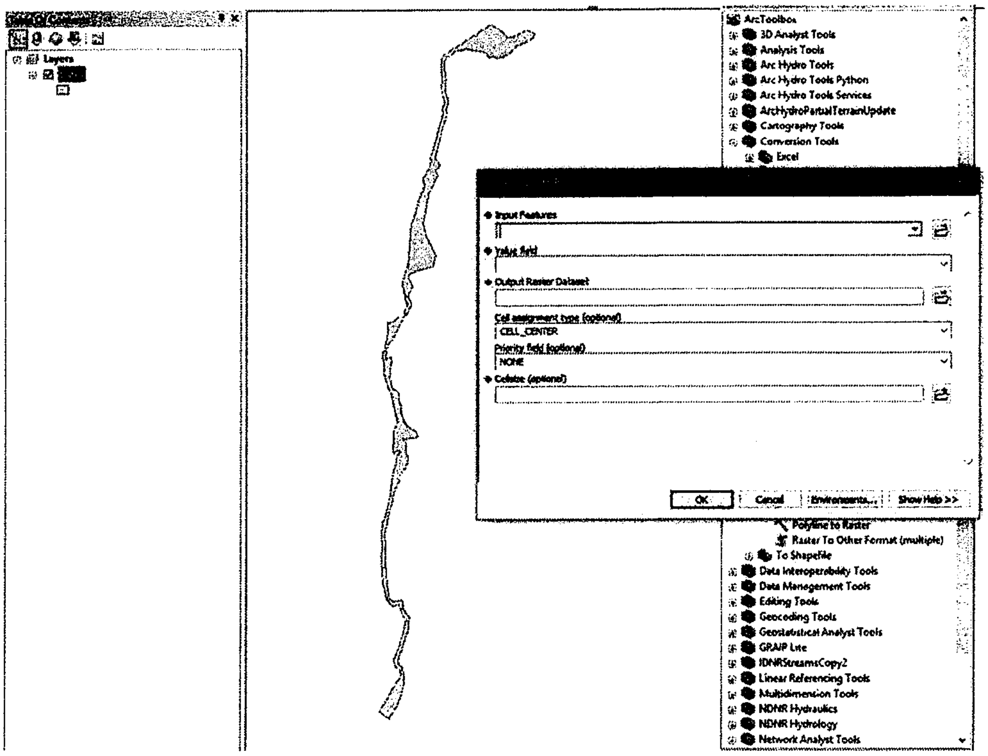


Shape_Area	Rates	Descriptio
0	5	>7

(0 out of 1 Selected)

Fig. 44 Use of critical factor analysis results in ArcGIS.

After editing, navigate to Editor Toolbar then select Stop Editing and save edits.



Input Features

Value field

Output Raster Dataset

Cell assignment type (optional): CELL_CENTER

Priority field (optional): NONE

Cellsize (optional)

Fig. 47 Details of file conversion.

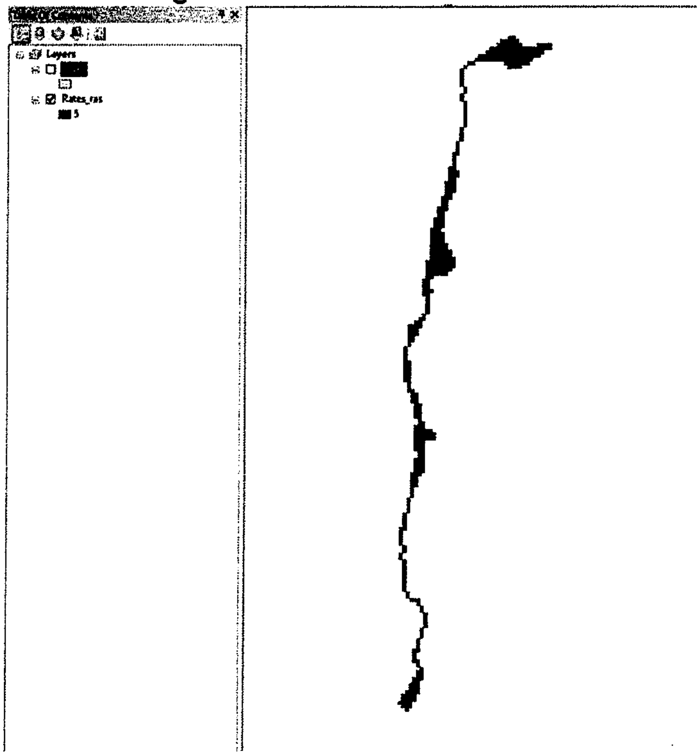
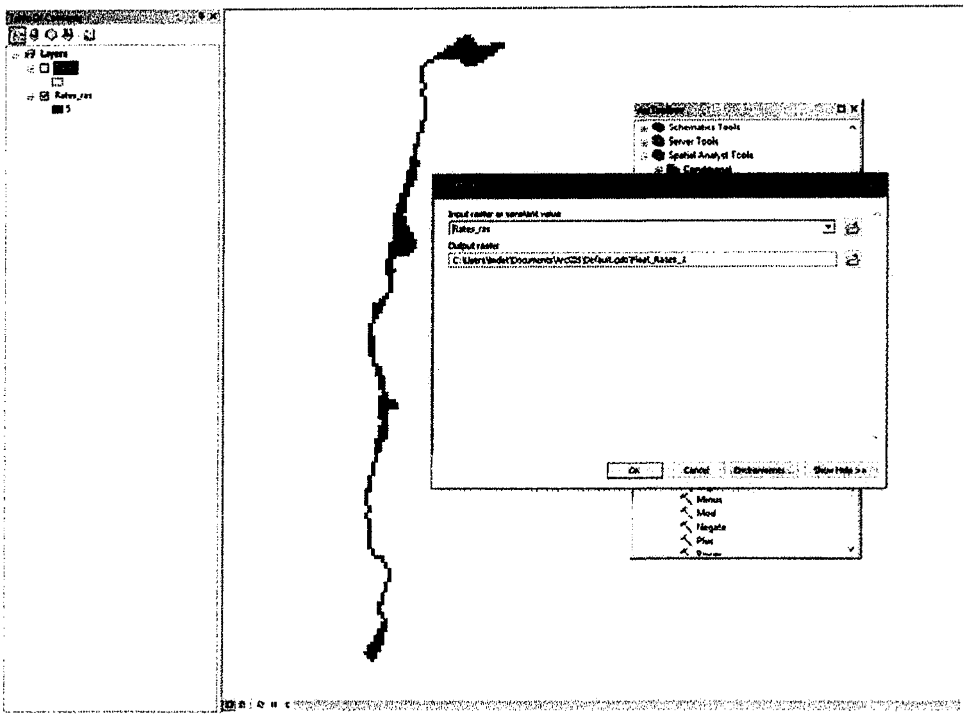


Fig. 48 Result of Polygon to Raster conversion of Rates parameter.



Input raster or constant value
Rates_ras
Output raster
C:\Users\[illegible]\Documents\ArcGIS\Default.gdb\Float_Rates_1

Fig. 50 Creation of geodatabase for float layer.

The generated float layers will be used in the generation of thematic maps for each parameter in the critical factor analysis under the hazard of interest.

Table 9. Color scheme for critical factor analysis.

Degree	Score
■	5
High susceptibility	4
■	3
■	2
■	1

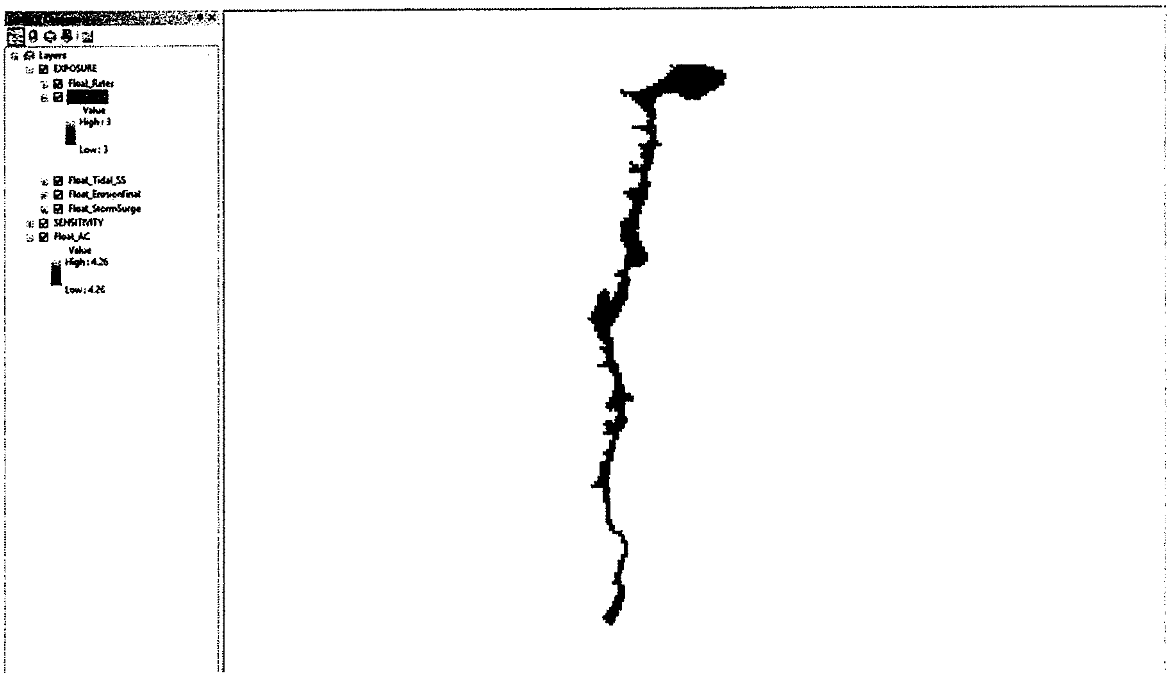


Fig. 53 Preparation of thematic map based on SLR exposure.

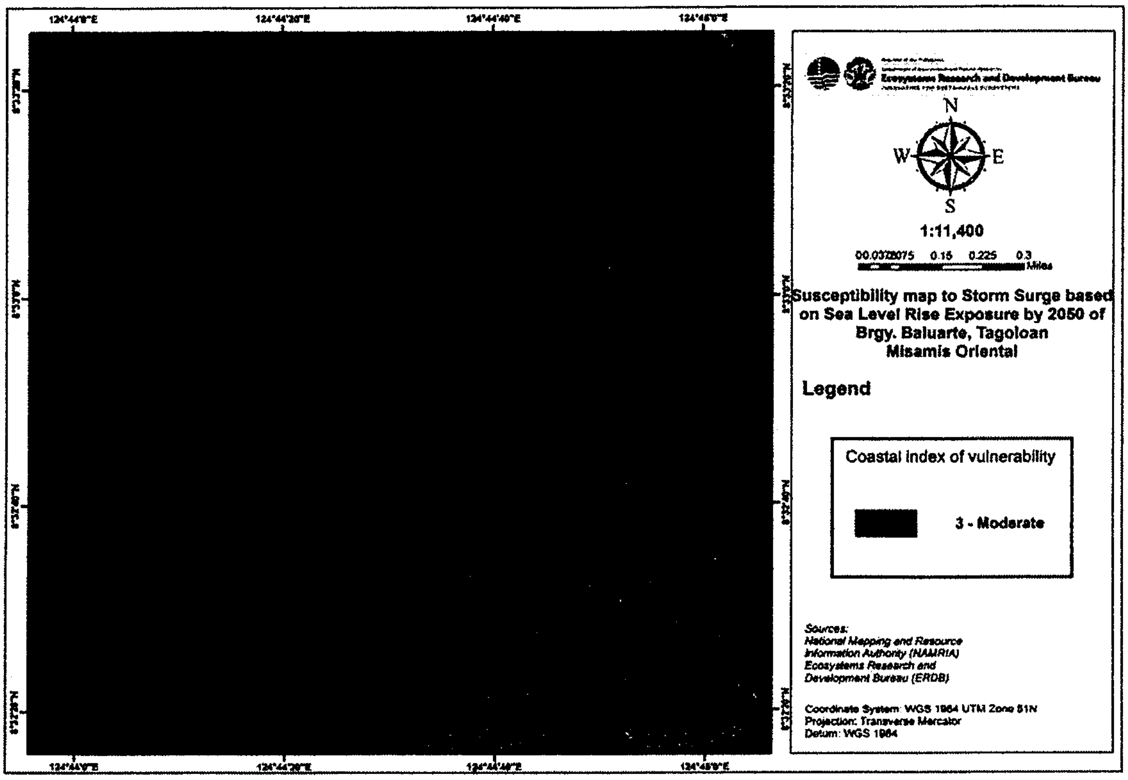


Fig. 54 Susceptibility map to storm surge based on sea level rise exposure (2050).

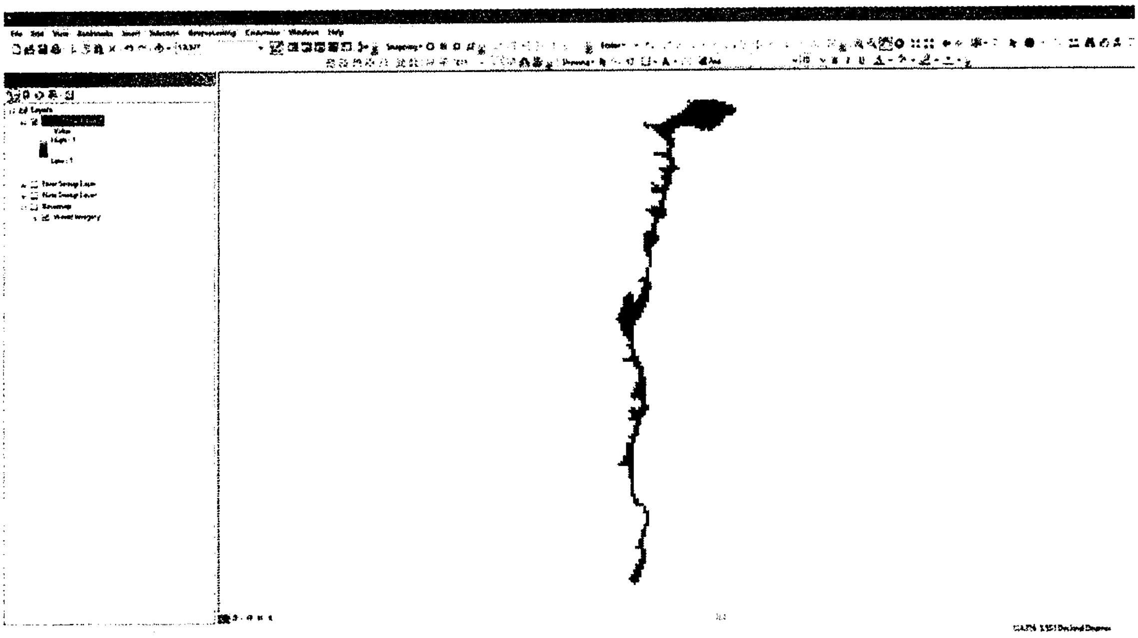


Fig. 57 Preparation of thematic map based on tidal range.

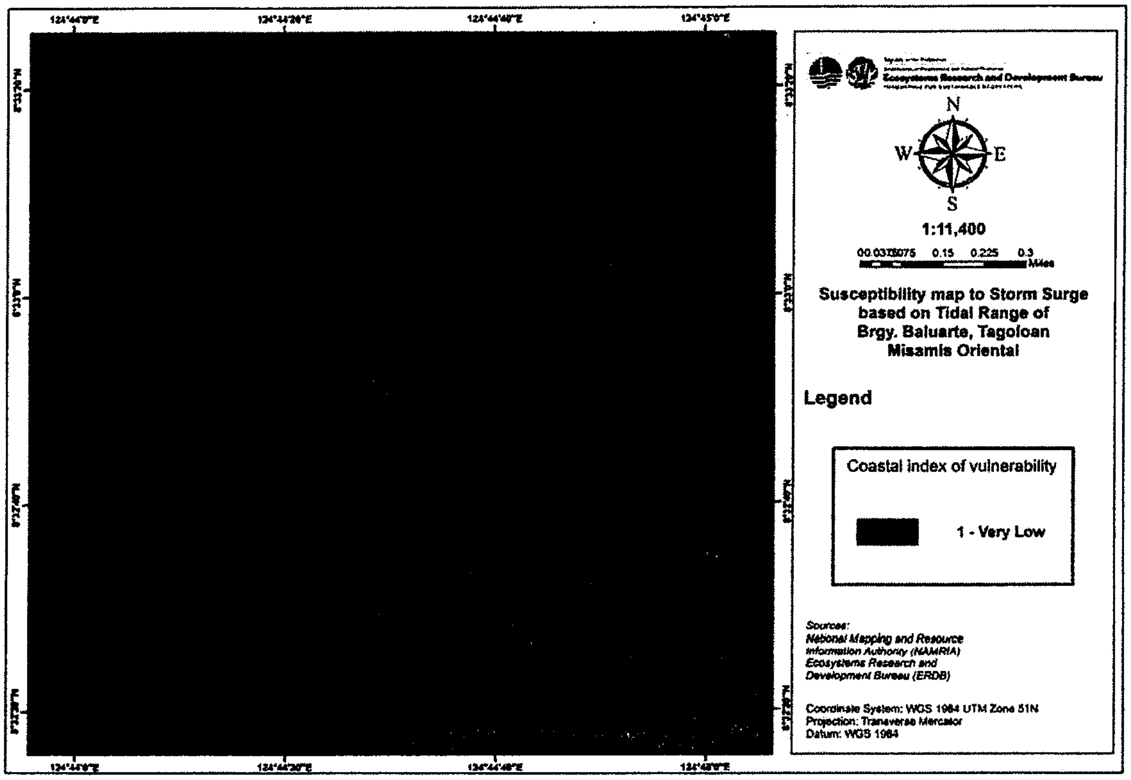


Fig. 58 Susceptibility map to storm surge based on tidal range.

Sensitivity

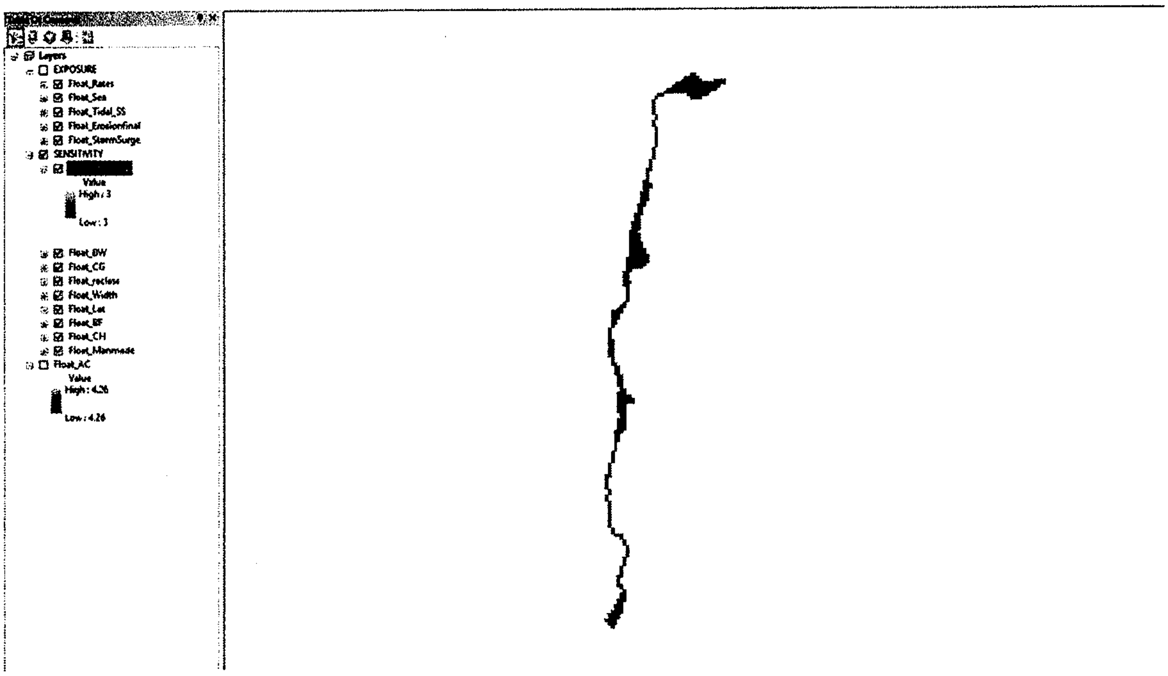


Fig. 61 Preparation of thematic map based on storm frequency.

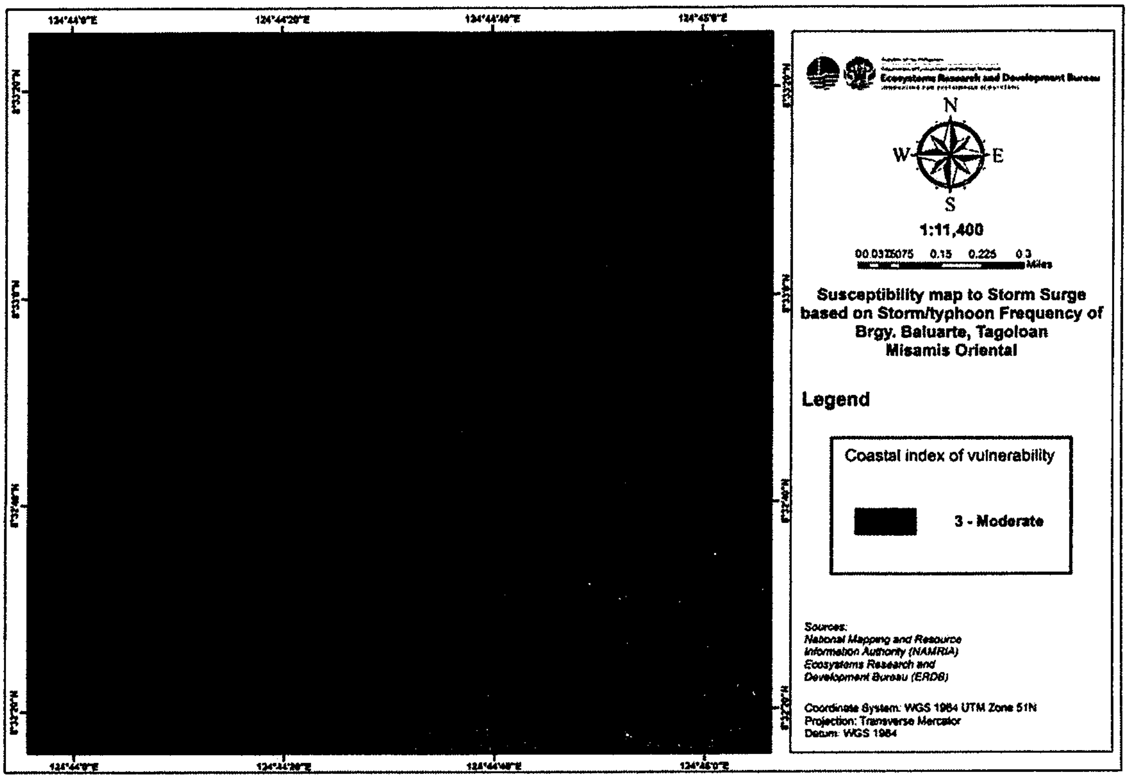


Fig. 62 Susceptibility map to storm surge based on typhoon frequency.

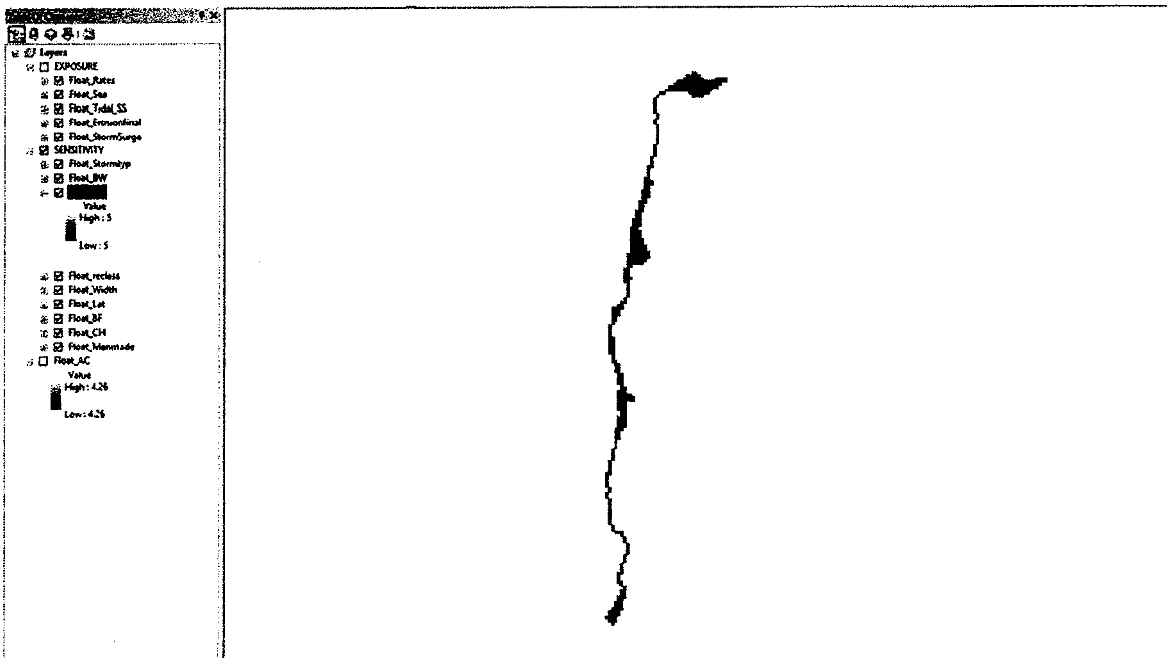


Fig. 65 Preparation of thematic map based on geomorphology.

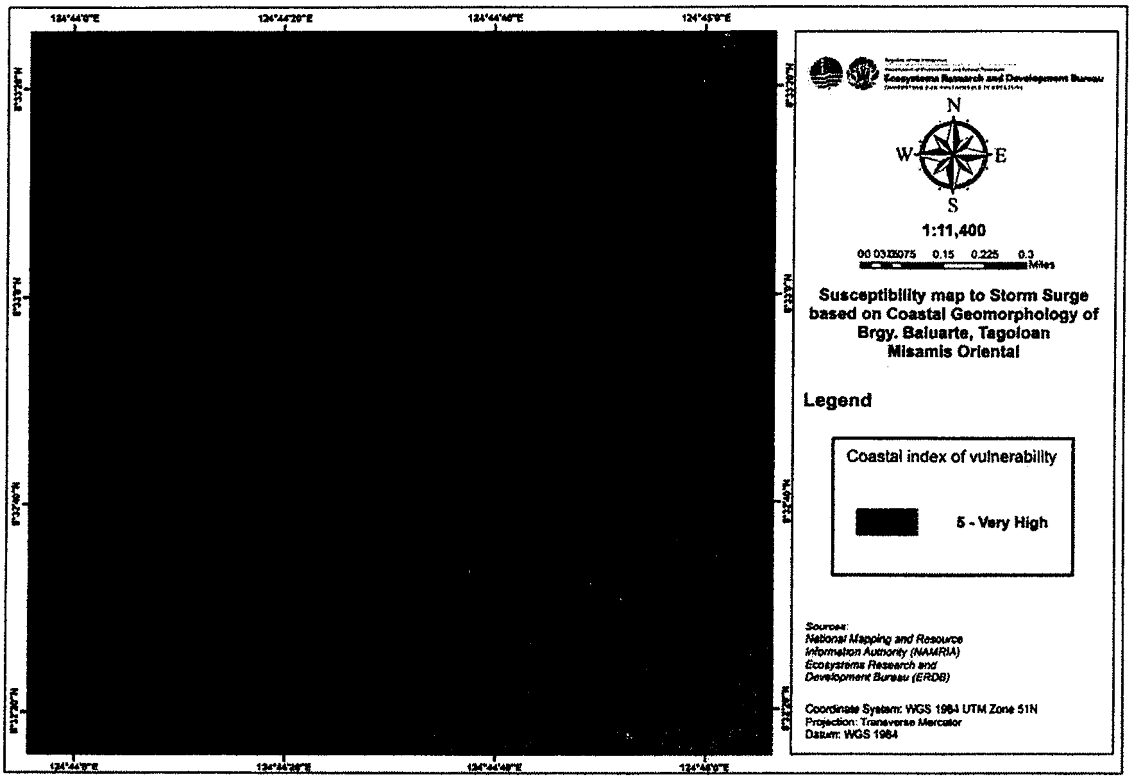


Fig. 66 Susceptibility map to storm surge based on coastal geomorphology feature.

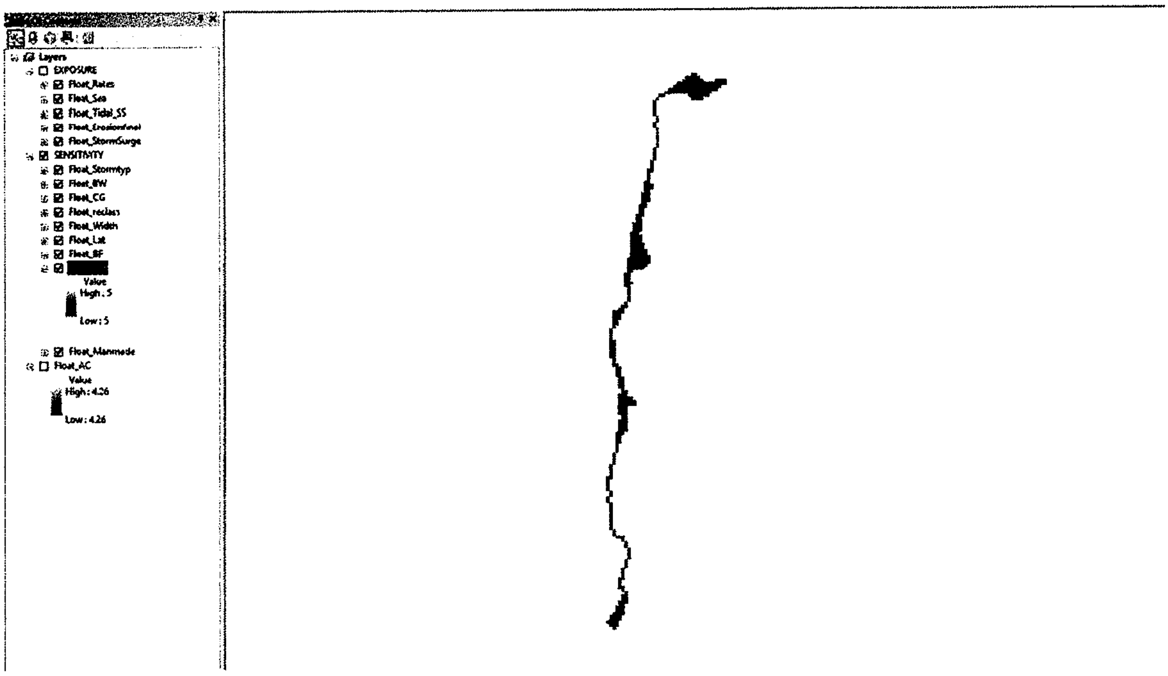
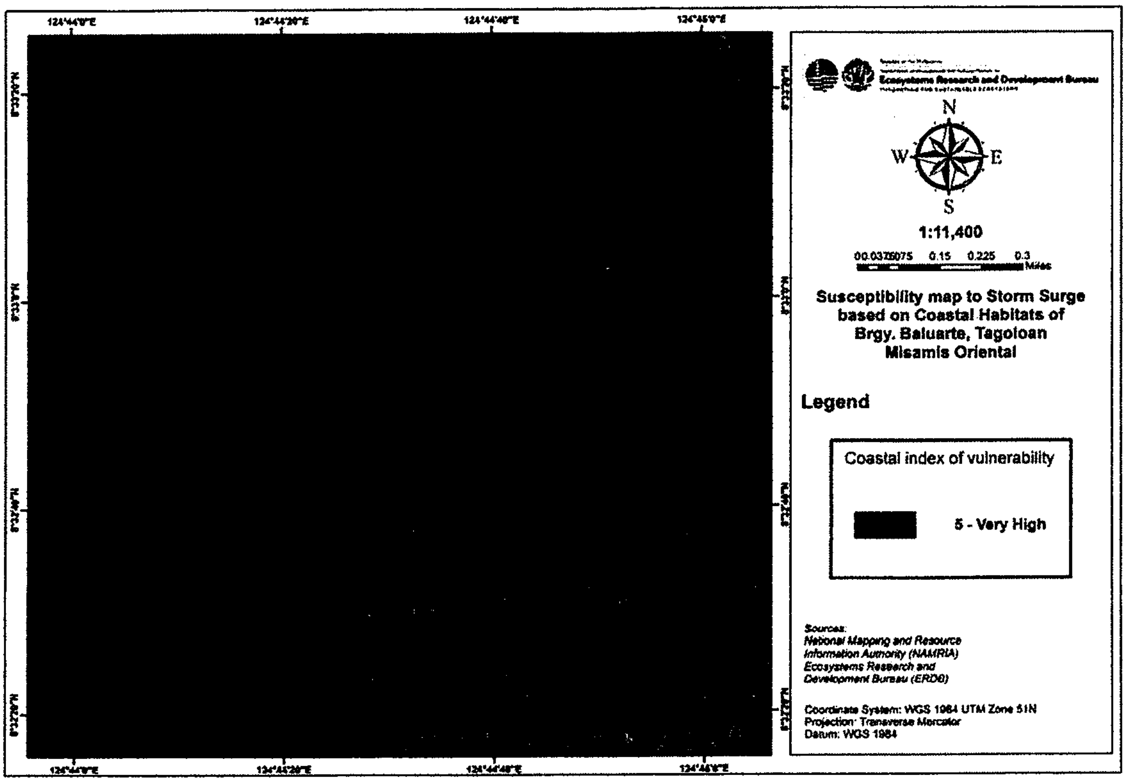


Fig. 69 Preparation of thematic map based on coastal habitat.



Sources:
National Mapping and Resource Information Authority (NAMRIA)
Ecosystems Research and Development Bureau (ERDB)

Coordinate System: WGS 1984 UTM Zone 51N
Projection: Transverse Mercator
Datum: WGS 1984

Fig. 70 Susceptibility map to storm surge based on existing coastal habitat.

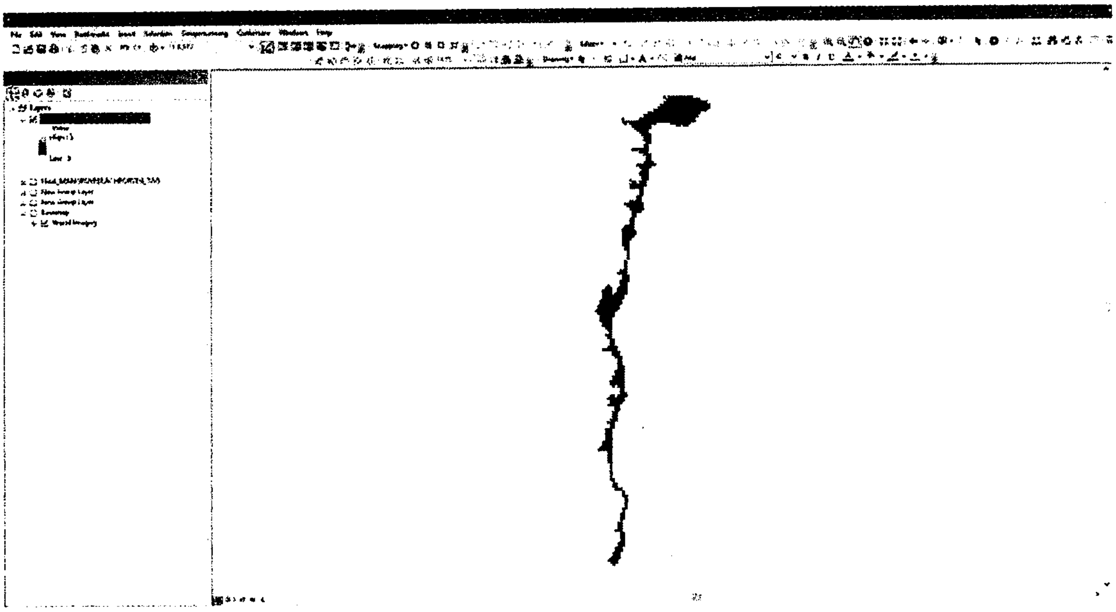


Fig. 73 Preparation of thematic map based on width of the reef flat.

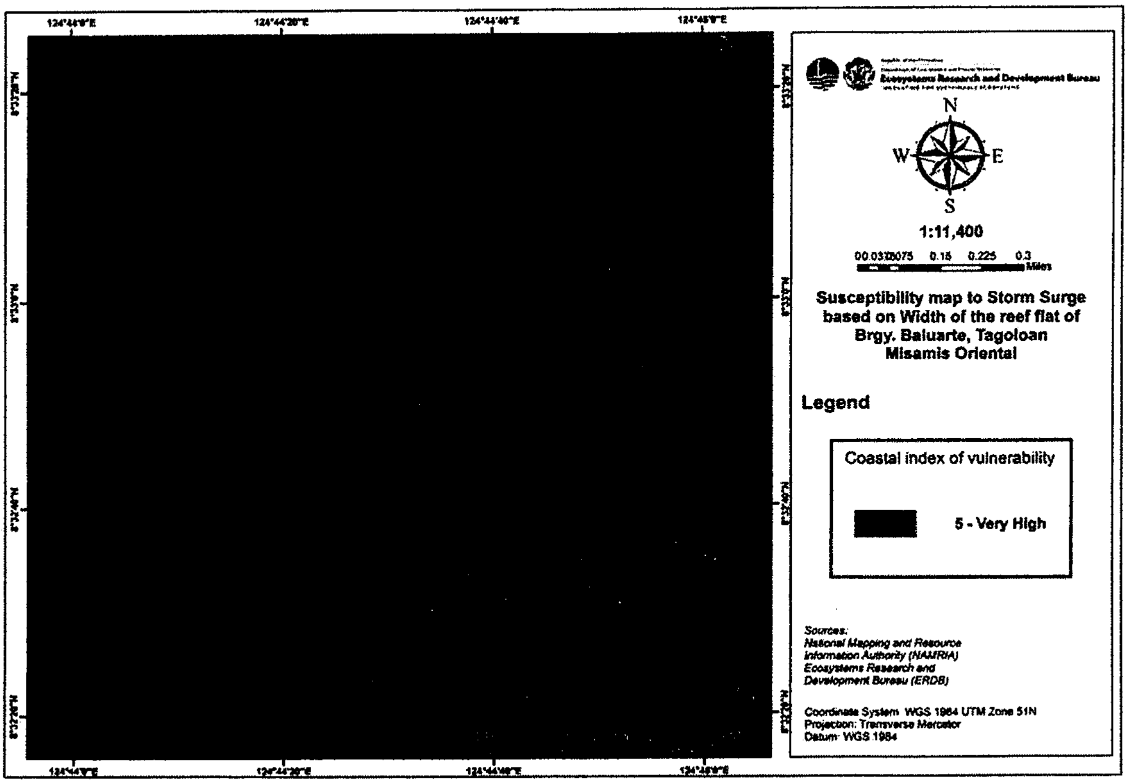


Fig. 74 Susceptibility map to storm surge based on width of the reef flat.

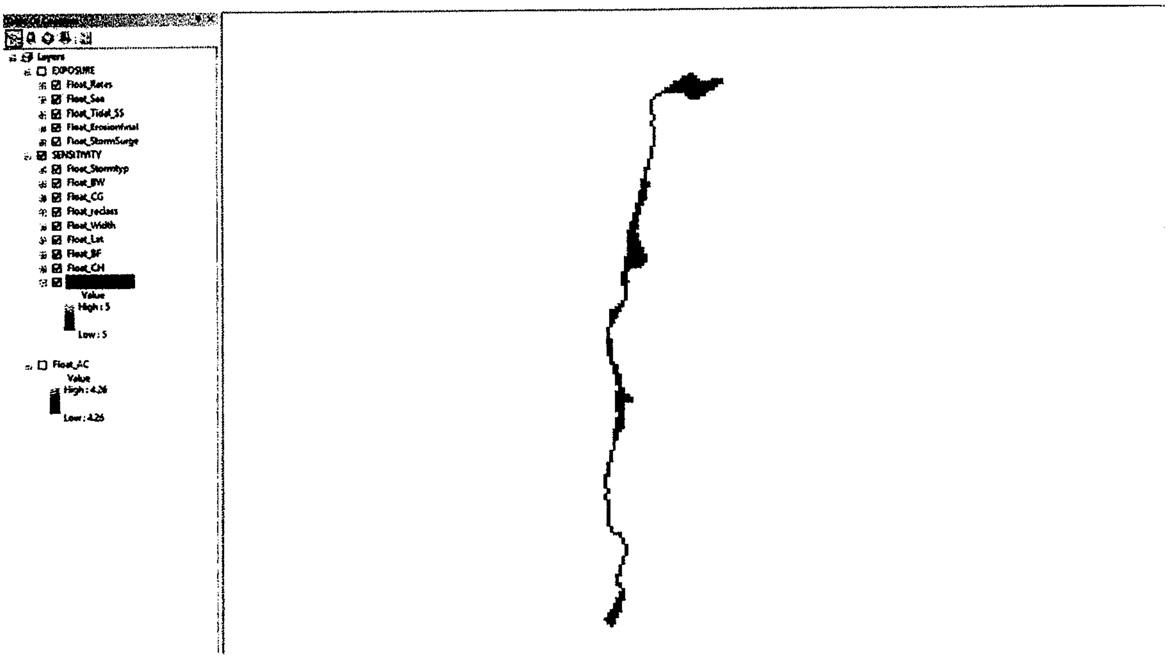


Fig. 77 Preparation of thematic map based on manmade structures.

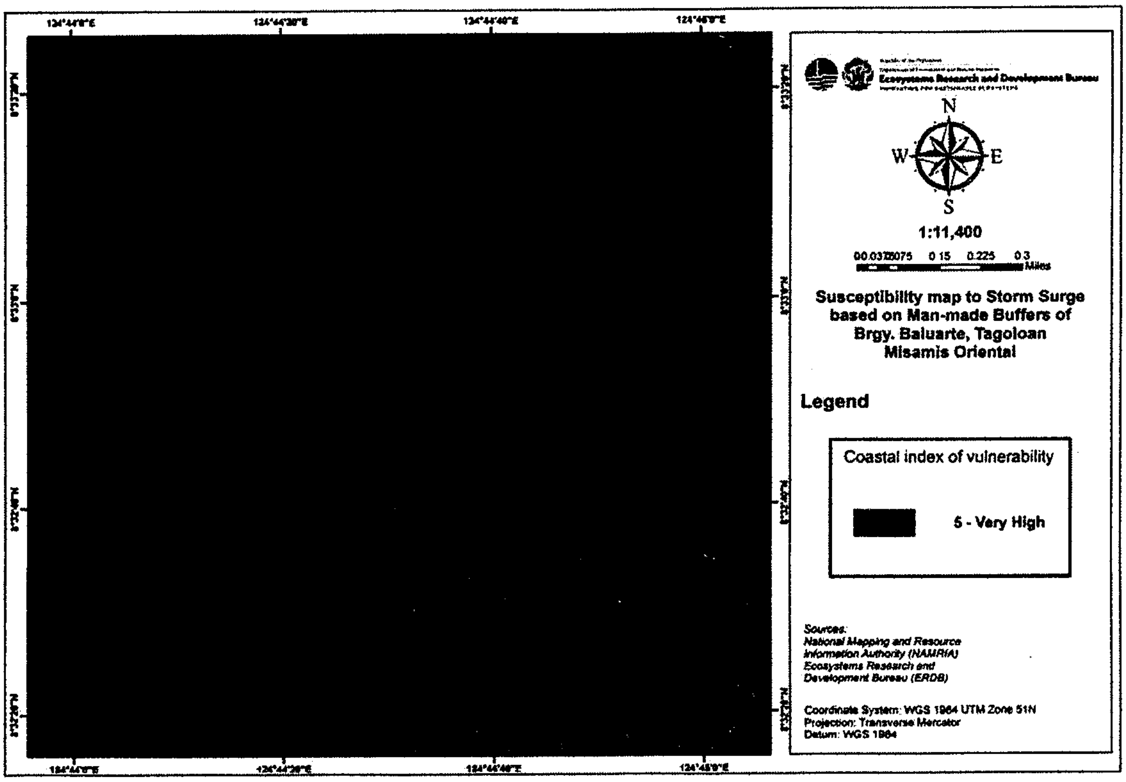


Fig. 78 Susceptibility map to storm surge based on man-made buffers.

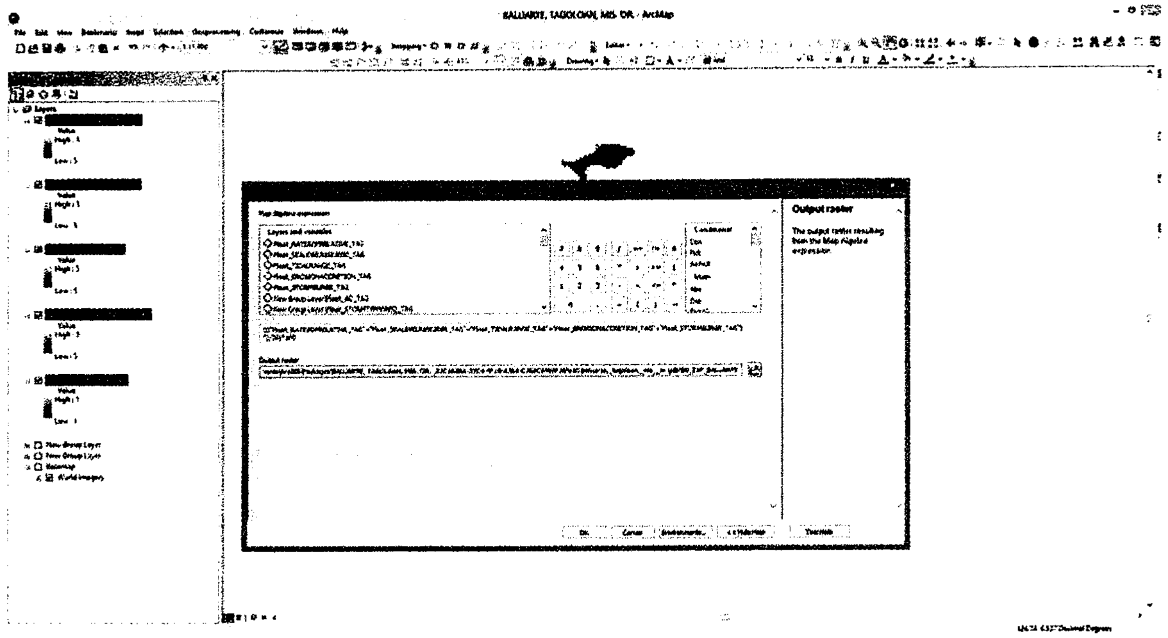


Fig. 81 Computation of exposure index.

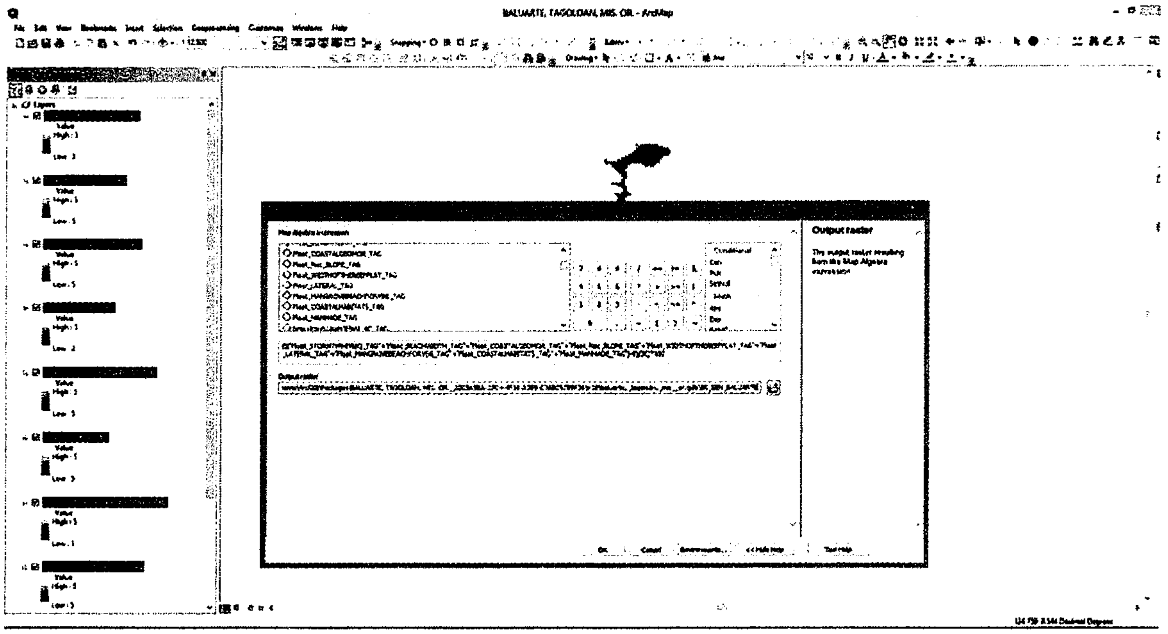


Fig. 82 Computation of sensitivity index.

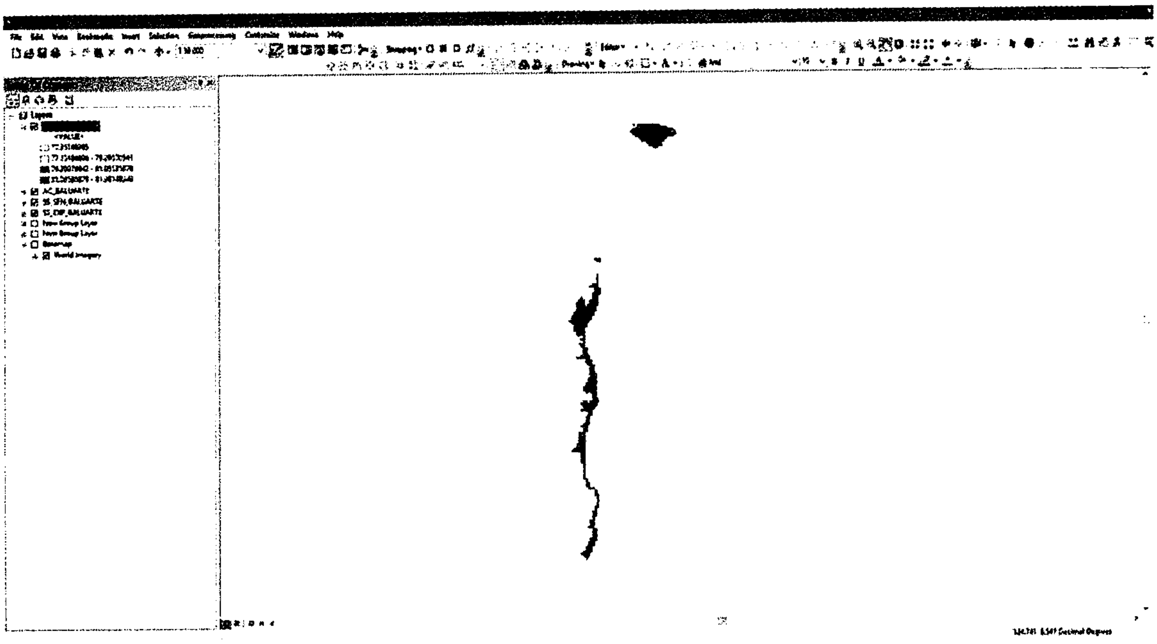


Fig. 85 Generated vulnerability model on storm surge.

Table 10. Color scheme for vulnerability map generation.

Degree	CIV Index
■	80-100
High vulnerability	60-80
■	40-60
■	20-40
■	0-20

CLIMATE CHANGE VULNERABILITY ASSESSMENT FOR COASTAL AND MARINE ENVIRONMENT

Name:________________________
Sex/Civil Status/Age:_______________
Length of stay in the area:___________
Educational attainment:_____________

Indicator/Variable			Rating		
1. No. of ordinaces relative to beach/sand mining law	☐ Absent 1(Very Low)	☐ 1 2 (Low)	☐ 2 3(Moderate)	☐ 3 4(High)	☐ 4 5 (Very High)
2. Proximity of settlement to coastline	☐ <100 1(Very Low)	☐ 100 to 400 2 (Low)	☐ 401 to 700 3(Moderate)	☐ 701 to 1000 4(High)	☐ >1000 5 (Very High)
3. Coastal protection structure	☐ No structure 1(Very Low)	☐ Temporary structure (sandbag/ light materials) 2 (Low)	☐ Concrete breakwater 3(Moderate)	☐ Concrete armors and boulders 4(High)	☐ Seawall 5 (Very High)
4. Land use pattern/coastal development	☐ Commercial/ industrial 1(Very Low)	☐ Unclaimed 2 (Low)	☐ Agricultural/open space 3(Moderate)	☐ Settlement/residential 4(High)	☐ Protected 5 (Very High)
5. Guidelines on setback zones in CLUP 5.a. Integration and Implementation of Coastal Zoning Plan in the CLUP	☐ Not integrated and implemented (presence of settlements in seawater) 1(Very Low)	☐ Integrated but not implemented (presence of settlements within 3m zone) 2 (Low)	☐ Limited implementation (presence of settlements within 20m zone) 3(Moderate)	☐ Partially implemented (presence of settlements within 40 m zone) 4(High)	☐ Fully implemented (no presence of settlements within the set back zone) 5 (Very High)
5.b. Awareness of community on the guidelines in setback zone	☐ Not aware 1(Very Low)	☐ Low level of awareness 2 (Low)	☐ Average level of awareness 3(Moderate)	☐ High level of awareness 4(High)	☐ Very high level of awareness 5 (Very High)

Indicator/Variable	**Rating**				
11.b. Community knowledge on geohazard maps	☐ No knowledge on the presence of geohazard maps 1(Very Low)	☐ <=25% of the total respondents have knowledge of geohazard maps 2 (Low)	☐ 26%-50% of the total respondents have knowledge of geohazard maps 3(Moderate)	☐ 51%-75% of the total respondents have knowledge of geohazard maps 4(High)	☐ at least 76% of the total respondents have knowledge of geohazard maps 5 (Very High)
11. c. Alternative or supplemental livelihood	☐ not available all throughout the year 1(Very Low)	☐ available only for 1 to 3 months 2 (Low)	☐ available for 4-6 months 3(Moderate)	☐ available for 7 to 11 months 4(High)	☐ available all throughout the year 5 (Very High)

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