

Vulnerability Mapping. The seven sets of data layers were digitized and were converted to raster data sets. These were then processed using Quantum GIS (Figure 1).

III. RESULTS AND DISCUSSIONS

A. Groundwater Vulnerability

The groundwater vulnerability map showed that most of the areas were highly and moderately vulnerable to contamination. This pattern is mainly dictated by the shallow water level and variation in soil media, aquifer media, vadose zone and topography. GIS analysis also aided in the calculation of the affected area. In Table 3, a total of 562.37 ha (56.01 %) in all three barangays of Boracay Island were highly vulnerable and a total of 410.28 ha (40.87 %) were moderately vulnerable to contamination. About 30.95 ha (3.08 %) were considered very highly vulnerable areas. It further showed that Brgy. Manoc-Manoc has the widest area (23.70 ha) that is very highly vulnerable to contamination, while most of the areas that is highly vulnerable are located in Brgy. Balabag (223.10 ha) and near the coastlines or low lying areas of the two other barangays.

These vulnerable areas are also the built-up areas where tourism developments had cropped-up. Health risks due to

TABLE I. AREAS (HA) VULNERABLE TO GROUNDWATER CONTAMINATION IN DIFFERENT BARANGAYS OF BORACAY ISLAND, PHILIPPINES

Barangay	Low	Moderate	High	Very High
Balabag	0.08	79.26	223.10	1.07
Manoc-manoc	0.18	144.27	142.20	23.70
Yapak	0.11	186.75	197.07	6.18
Total (ha)	0.37	410.28	562.37	30.95
Percent (%)	0.04	40.87	56.01	3.08

groundwater contamination from sewage pollution is highly probable in these areas since still many of the business establishments as well as residential areas do not have proper sewerage system or are not connected to the sewerage facility of the island.

The locations of the inventoried wells were also plotted into the vulnerability map to spot which among the wells were vulnerable to contamination. Results of the overlay showed that most of the existing wells used by the local people either for drinking, washing and other domestic chores were located in highly vulnerable areas as shown in Figure 2. Mitigation and control should therefore focus on these zones to avoid health problems due to groundwater utilization. It is then practical to demarcate and systematically study this vulnerable zones to facilitate any mitigation and control scheme proposed or considered necessary so as to avoid degradation of the groundwater resources and coastal waters which are important resources in attaining sustainable tourism industry and human well-being.

B. Policy Integration Towards Sustainable Coastal Tourism and Human Well-Being

The groundwater vulnerability map or the DRASTIC index map has intensely shown how vulnerable are the groundwater resources of Boracay Island. The establishment of sewerage treatment plant in the area to address groundwater contamination from domestic waste and other pollutants coming from commercial establishments and local residents is a good strategy in order to mitigate the contamination of groundwater resources. However, many if not majority of the commercial establishments and residents are not connected to the sewerage treatment plant for some other reasons aside from the possibility that the capacity of the treatment plant cannot cater to the needs of tourism industry in the island. Hence, a policy should be enforced to protect the groundwater resources of Boracay island so as not to enhance the proliferation of contaminants such as sewage pollution in aquifers given the fact that these aquifers are vulnerable to contamination based on this study.

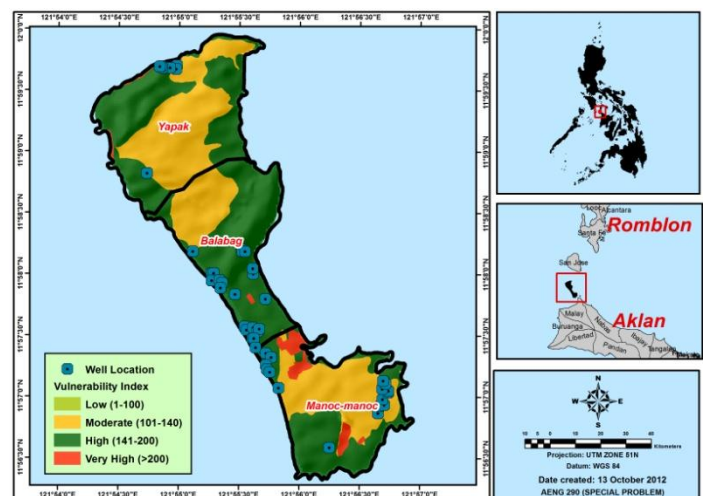


Figure 2. Groundwater vulnerability map showing the locations of the inventoried wells in Boracay Island

Groundwater also leads to coastal waters, thus, protection of groundwater resources will also preserve the integrity of coastal waters. Mitigation and control strategies can be based on the vulnerability map index developed. The highly vulnerable areas must be given the utmost attention and should be protected as soon as possible through an ordinance requiring a sewerage system to all establishments including those in the residential areas to ensure the sustainability of the Boracay tourism industry and human well-being. This is also to avoid the repeat of the incident that happened in 1997 when the waters of Boracay Island were declared unsafe for recreational activities due to the presence of very high levels of coliform.

IV. CONCLUSIONS AND RECOMMENDATIONS

The study has shown the effectiveness in the combined use of the DRASTIC model and GIS in assessing groundwater contamination vulnerability. The GIS technology has provided an efficient environment for analyses and high capabilities of handling spatial data in the study area which is in a small island setting. Furthermore, it provided a picture of the knowledge and information that the research wants its stakeholders to perceive.

Groundwater resources of Boracay Island were found to be vulnerable to contamination using DRASTIC MODEL which demonstrates an effective method to develop, improve and verify groundwater vulnerability maps. This study has also demonstrated the use of the model in a small setting, like Boracay Island. This method, with a little refinement, can be used throughout the country to create new groundwater vulnerability maps if none exists.

Special attention should be made to the areas having moderate to very high contamination vulnerability potential as shown in the vulnerability or DI map of Boracay Island. Decision makers can make use of this map in determining areas where groundwater monitoring and management is highly advisable because remediation of contaminated groundwater is prohibitively expensive and time-consuming. Prevention is particularly important in an effective groundwater management.

This study was limited to intrinsic vulnerability to groundwater contamination and no anthropogenic disturbance was considered. Future specific vulnerability assessments are recommended in order to delineate areas with high potential for specific contamination considering anthropogenic activities and land use pattern.

Developing a modified DRASTIC groundwater vulnerability map will be recommended if a specific contamination ensues. Sensitivity analysis of GIS-based DRASTIC model indices is further recommended so as to determine the significance of each DRASTIC parameter inclusion or exclusion as applied to a specific area.

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