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# High Resolution Application of the Technology Development Index (TDI) in State Waters South of Block Island

## for the Rhode Island Ocean Special Area Management Plan 2010

**by**

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### *Executive Summary*

A technology development index (TDI) was developed by Spaulding et al. (2010) for the Rhode Island Ocean Special Area Management Plan (RI OSAMP). The TDI is an estimate of the technical challenge for siting wind farms in any state or federal waters and includes technology type, seabed geology, cable distance, and wind power in its calculation. TDI values of one are optimum, while higher values indicate increasing siting challenge and decreasing return. The relatively low-resolution study of Spaulding et al. (2010) show the values of the TDI in state waters south of Block Island are about 2.25 to 2.5 compared to values of 2.75 in state waters adjacent to the southern Rhode Island coastline. This mostly reflects the much higher wind power available at the Block Island site.

In this work we extend the TDI to higher resolution in the Block Island area employing meterological simulations for discrete directions, a wind frequency rose based on wind hindcast data from a station located immediately south of Block Island, and a newly determined construction effort map (sub-bottom geology). A high-resolution map of the TDI was constructed and shows values of TDI of 2.1 adjacent to the south coast of Block Island, with increasing values going south (2.0 to 2.3) and then decreasing to 1.6 to 1.8 in a band several kilometers wide SE and SW of the island near the state waters boundary with federal waters. The lowest TDI values are found S to SSW or S to E of the island depending on which wind speed data set is used (meterological model or AWS TrueWinds data, respectively), due to the lee effects of Block Island from NW winds.

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### *Abstract*

A technology development index (TDI) was developed by Spaulding et al. (2010) for the Rhode Island Ocean Special Area Management Plan (RI OSAMP). The TDI is an estimate of the technical challenge for siting wind farms in any state or federal waters and includes technology type, seabed geology, cable distance, and wind power in its calculation. TDI values of one are optimum, while higher values indicate increasing siting challenge and decreasing return. The relatively low-resolution study of Spaulding et al. (2010) show the values of the TDI in state waters south of Block Island are about 2.25 to 2.5 compared to values of 2.75 in state waters adjacent to the southern Rhode Island coastline. This mostly reflects the much higher wind power available at the Block Island site.

In this work we extend the TDI to higher resolution in the Block Island area employing meterological simulations for discrete directions, a wind frequency rose based on wind hindcast data from a station located immediately south of Block Island, and a newly determined construction effort map (sub-bottom geology). A high-resolution map of the TDI was constructed and shows values of TDI of 2.1 adjacent to the south coast of Block Island, with increasing values going south (2.0 to 2.3) and then decreasing to 1.6 to 1.8 in a band several kilometers wide SE and SW of the island near the state waters boundary with federal waters. The lowest TDI values are found S to SSW or S to E of the island depending on which wind speed data set is used (meterological model or AWS TrueWinds data, respectively), due to the lee effects of Block Island from NW winds.


### *1 Introduction*

Spaulding et al (2010) applied a technology development index (TDI) to the RI Ocean SAMP study area to assist in siting of wind farms in state and federal waters. The TDI estimates the technical challenge (technology type plus cable distance) in extracting offshore wind energy to the amount of wind energy (wind power) available at a given location. To facilitate comparisons and eliminate dependence on the units used in the analysis, the TDI is divided by the optimum TDI in the region to generate a non-dimensional TDI. Figure 1 shows the non dimensional TDI for the RI Ocean SAMP study area, including consideration for the seabed geology. Optimum sites have a TDI of one and those less desirable have values increasingly larger than one. The analysis was performed on a 100 m grid system. Bathymetric data was obtained from the NOAA

Electronic Navigation Charts (ENC) data set. Mean annual wind speed (power) data was obtained at hub height (80 m) from AWS True Winds data set for the Ocean SAMP study area (Brower, 2007). A lattice jacket support structure, with piles driven into the seabed, was assumed to support the tower and wind turbine. The cost of the lattice jacket structure, as a function of water depth, was provided by Roarke (2008) and confirmed by Hensel (2009). The impact of the glacially dominated subsea bed geology on construction effort (pile driving operations) was estimated using a construction effort (CE) map. The CE ranged from 1 (lowest effort) to 5 (highest effort). The map was generated by University of Rhode Island geology experts: Jon Boothroyd, GeoSciences and John King, Graduate School of Oceanography based on their analysis of existing data sets and literature resources. Chris Baxter, Ocean Engineering, a geotechnical engineer, recommended a scaling parameter to relate the construction effort to the challenge of pile driving or drilling operations. These scaling factors (SF) were applied directly to the technology type costs. (CE- 1 scale factor of 1 to CE-5 with a scale factor of 2.2).

A review of the results of the TDI analysis, with a focus on potential sites for offshore wind development in state waters ( within 3 miles of the RI coast line or around island, yellow line in Figure 1), shows that the best location is south of Block Island. The value of the TDI in this area is about 2.25 to 2.5. This compares to values of 2.75 or higher in state waters adjacent to the southern RI coastline. In this region, while water depths are generally low, and hence the technology challenge is low, the wind power is low given the proximity to land and its enhanced roughness. South of Block Island the water depths are deeper but the wind power is considerably higher and hence is the preferred site in state waters, based on the TDI analysis.

## *2 High Resolution Application of TDI*

In the interest of assessing the area south of Block Island for siting of a small wind farm ( 5 to 8 wind turbines) and taking advantage of new data generated by studies of wind resources and seabed geology in the Ocean SAMP, a high resolution TDI was performed. Figure 2 shows the study area for the high resolution analysis and the associated bathymetry. The bathymetric data set was once again obtained from the NOAA Electronic Navigation Charts (ENC) charts. The location of the state water boundary is shown. A 65 m grid was selected for this application.

Two wind data sources were considered for this study. The first (Figure 3) uses the same data employed in the SAMP wide study area at 80 m elevation obtained from AWS True Winds (Brower, 2007). The second (Figure 4) is based on a four level, nested, high resolution meteorological simulations for discrete directions (eight points of the compass) and dates (performed by Titlow and Morris, 2010) and then scaled using a wind frequency rose based on wind hindcast data from the US Army Corp of Engineers Wave Information Study (WIS) (http://chl.erdc.usace.army.mil/wis), station 101, located immediately south of Block Island.

The construction effort map (Figure 5) was generated by John King and Rob Pockalny, Graduate School of Oceanography and Jon Boothroyd and Brian Oakley, Geosciences. The map is based on high resolution (250 m track line spacing) side scan and sub-bottom profiling data collected by King, with interpretation of seabed surface geology by Boothroyd and Oakley and sub seabed geology by King and. Pockalny. The construction effort ranged from 1 to 5, to be consistent with the prior effort (Spaulding et al , 2010). There is no data for several areas south of the state water boundary and hence construction effort has been estimated for these locations based on the large scale glacial geology. Chris Baxter, Ocean Engineering reviewed data from boring logs (typically 65 m in depth) that DeepWater Wind (DWW) collected at eight sites in the study area, SE of Block Island. Based on this data and his review of the construction effort maps he has developed a scaling factor of 1 for CE 1-2, 1.5 for CE-3, 1.8 for CE 4-5, and 2.2 for CE 5.

High resolution TDI maps (non dimensional) for the study area were prepared, once again assuming lattice jacket support structure, and are shown in Figures 6 and 7 for the two wind cases (Figures 3 and 4), respectively. Both maps show the same basic characteristics. High TDI (2.1 or greater) areas are located adjacent to the southern coast of Block Island with tongues protruding offshore. These are directly related to the construction effort (Figure 5) (areas with CE of 4-5). As one moves further south, the TDI progressively increases (2.0 to 2.3) due to increasing water depths. There is a band of low TDI values (1.6 to 1.8) several kilometers wide from approximately SE to SW of Block Island following the state line boundary. If AWS True Winds data is used (Figure 3), the lowest TDI (Figure 6) spans, in an arc, from the E to S. If the meteorological model scaled winds (Figure 4) are used, the areas (Figure 7) from the S to SSW of Block Island have the lowest TDIs. This difference is a direct result of the difference in wind speed contours to the SE of Block Island. AWS TrueWinds analyses show the wind speed contours wrapping around the southeastern side of the island, while those based on the meteorological model results show lower wind speeds in the area due to lee effects of Block Island from NW winds. Buoy based wind observations are currently being collected due south of Block Island at the state water boundary (Latitude - 41.1 and longitude - 71.56; October 2009 to present). This data will help partially resolve the difference between the two approximations of the wind fields in the area.

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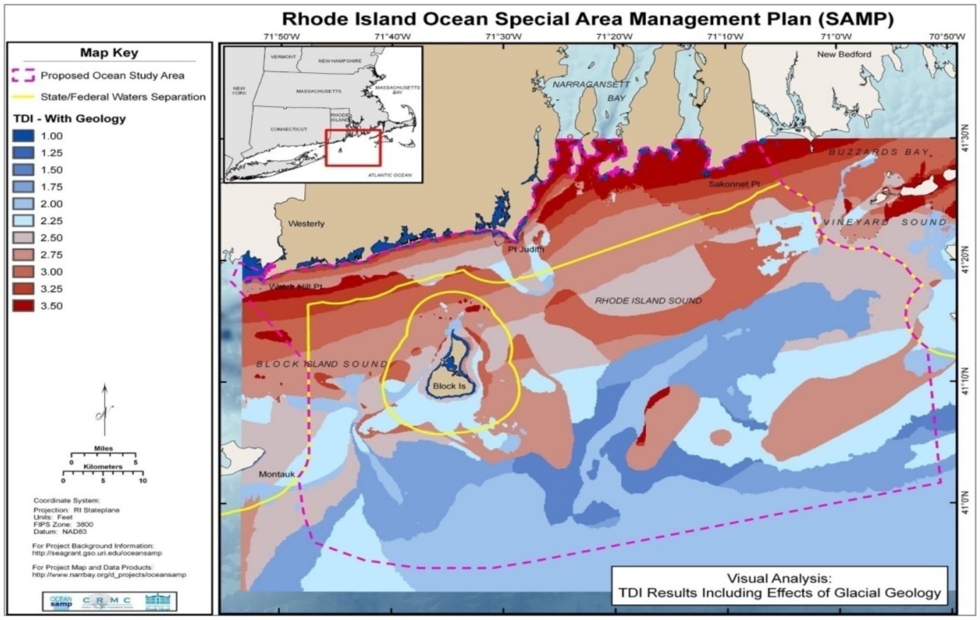


**Figure 1 Contours of non-dimensional *TDI* for the Ocean SAMP study area, with glacial geology (Spaulding et al, 2010).**

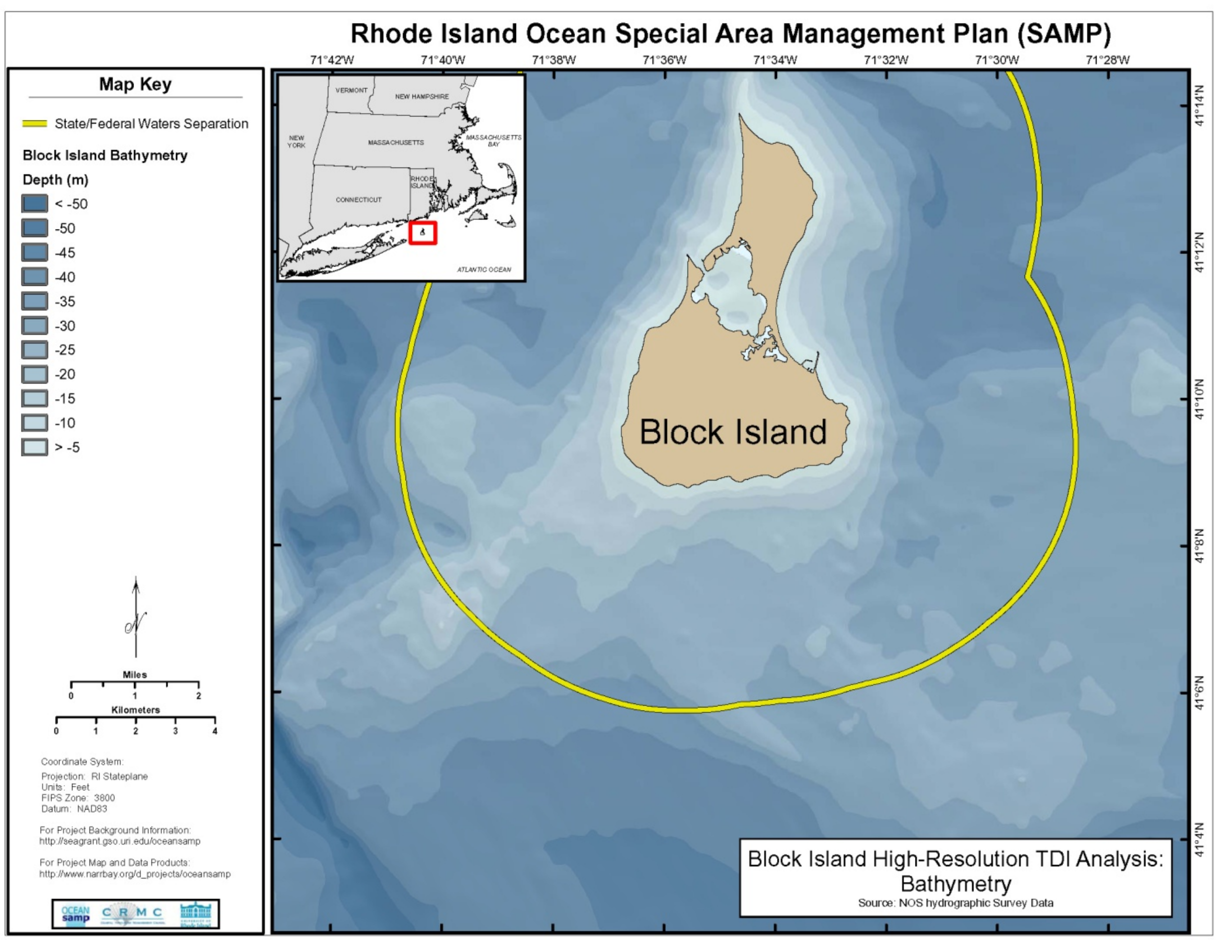


**Figure 2 Block Island study area with NOAA ENC bathymetry.**

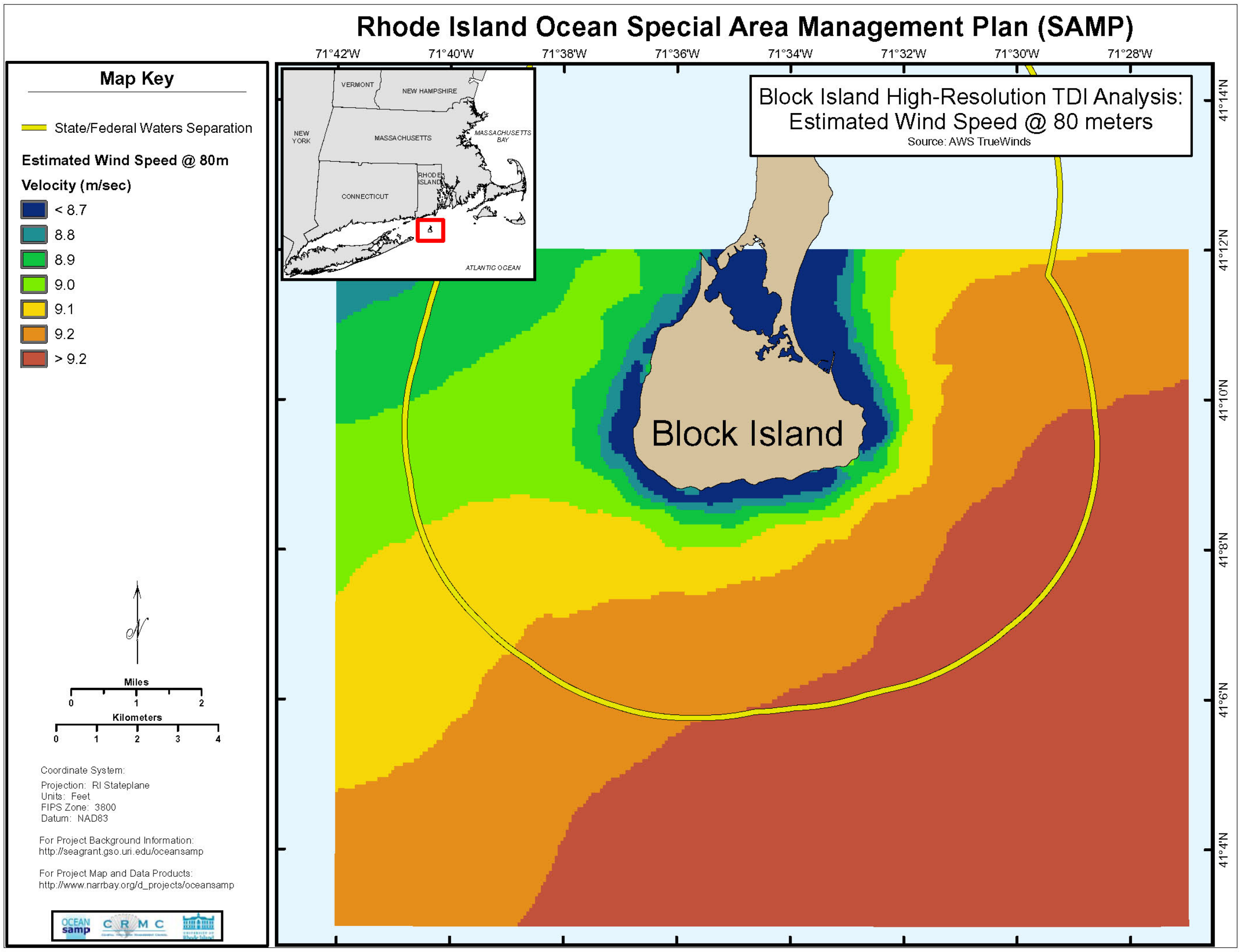


**Figure 3 Estimated mean annual wind speed at 80 m from AWS TrueWinds data (Brower, 2007) for Block Island study area.**

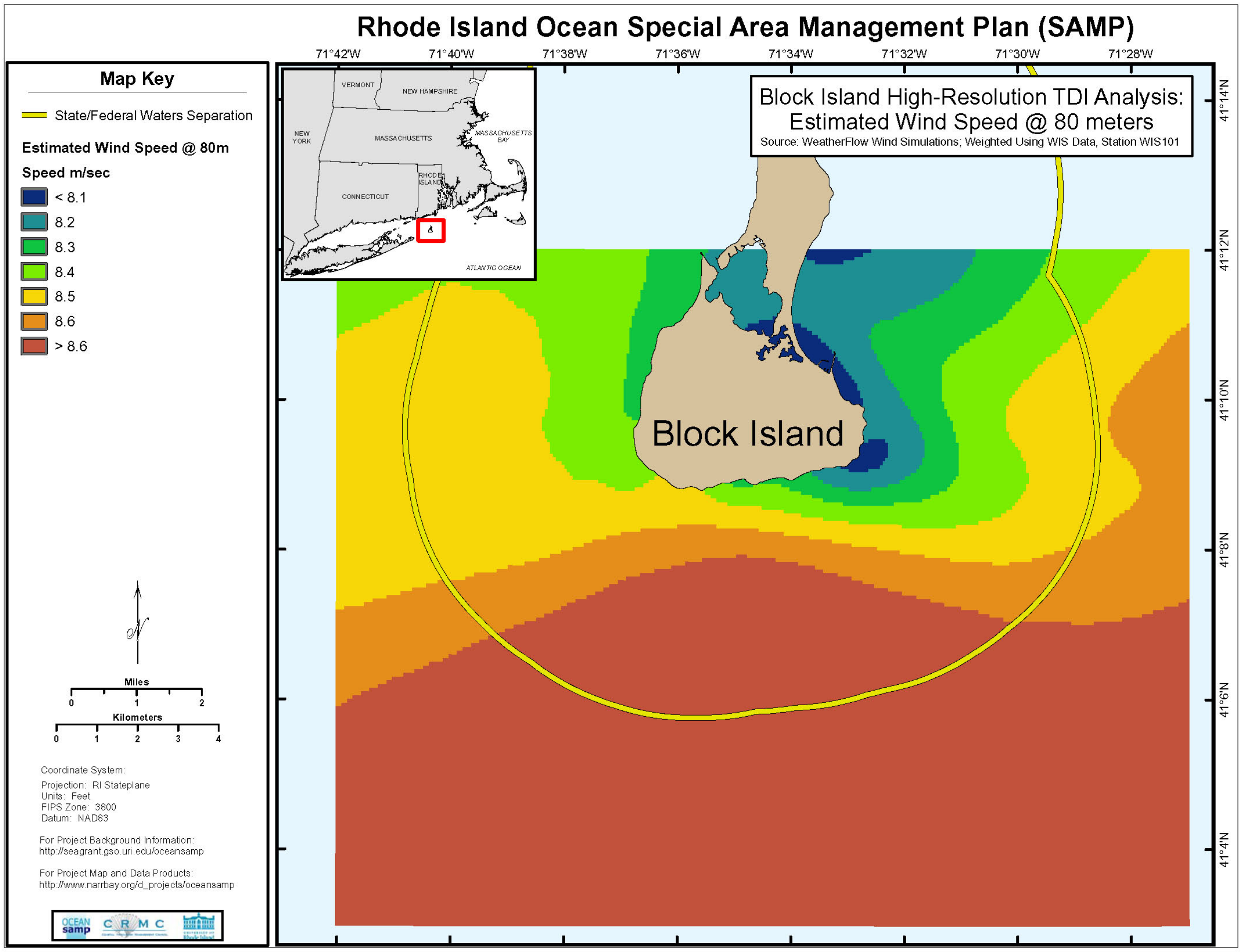


**Figure 4 Estimated mean annual wind speed at 80 m with using meteorological modeling based strategy and US Army Corp of Engineers, Wave Information Study, WIS 101 wind rose for Block Island study area.**

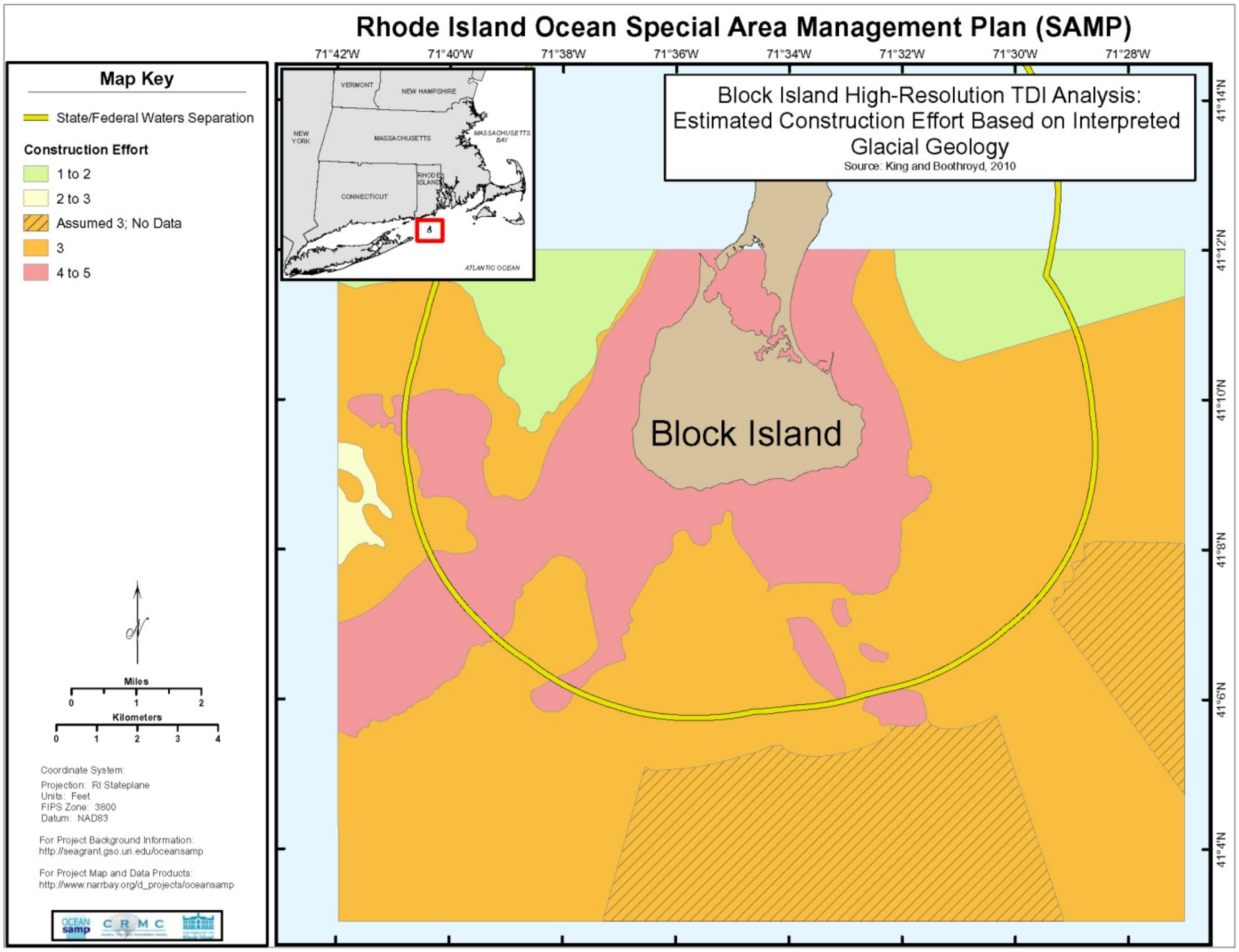


**Figure 5 Construction effort map for Block Island study area (generated by John King, Rob Pockalny, Graduate School of Oceanography,and Jon Boothroyd and Brian Oakley, Geosciences.)**

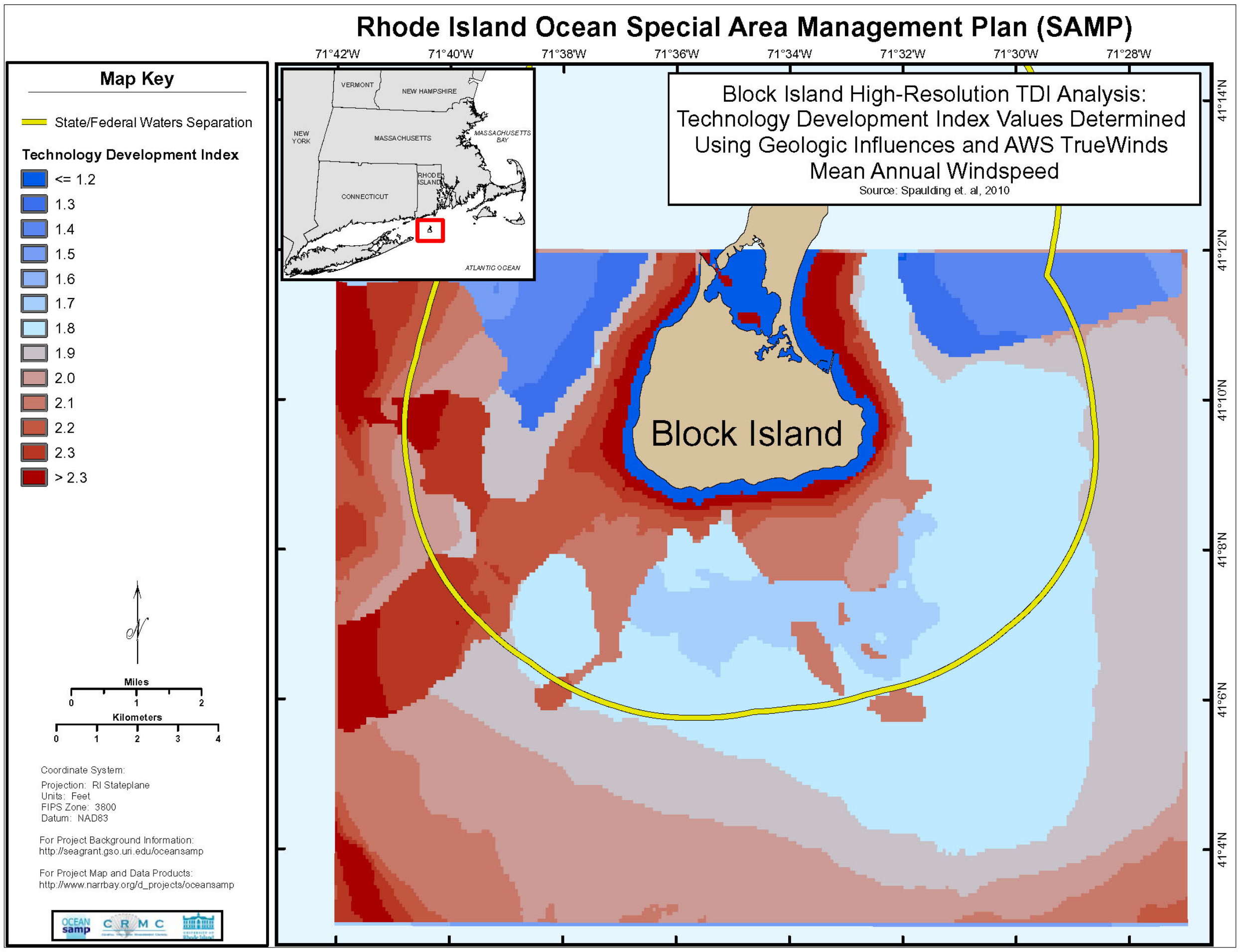


**Figure 6 TDI for Block Island Study area with geology using AWS TrueWinds mean annual winds (Brower, 2007).**

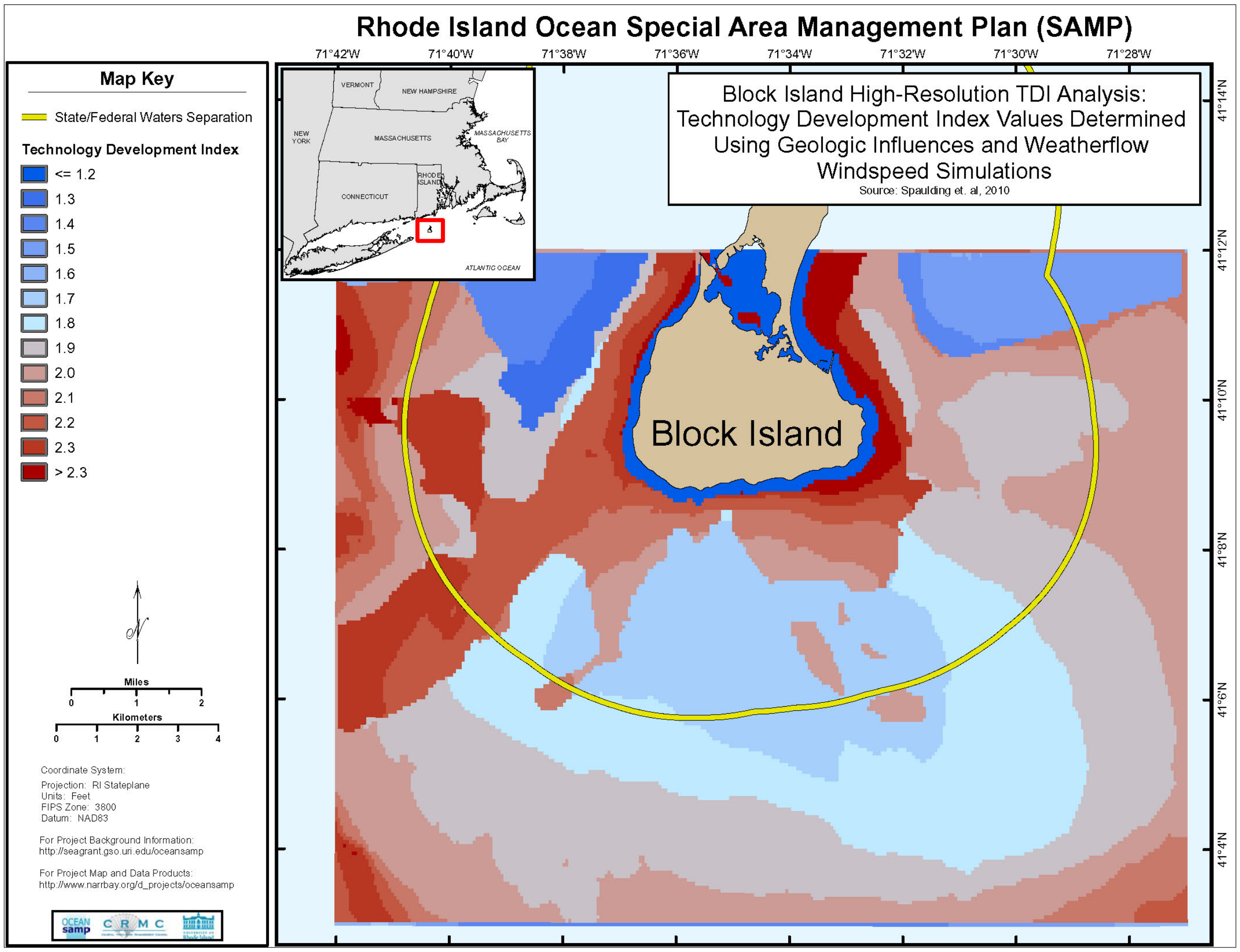


**Figure 7 TDI for Block Island Study area with geology with model scaled winds based on WIS 101 wind rose.**