Joint Nature Conservation Committee

The role and value of natural capital and development of indicators for use in disaster preparedness in the UK's Overseas Territory of the British Virgin Islands C19-0303-1361

Final Report

Wood Environment & Infrastructure Solutions UK Limited – April 2020

Report for

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Document revisions

No.	Details	Date
1	Draft Report	15/02/2020
2	Final Report	26/03/2020
3	Revised Final Report	30/04/2020

Contents

1. Background

1.1 Overview

The British Virgin Islands (BVI), like many of the UK Caribbean Overseas Territories, is highly dependent on the natural environment for its economic and social well-being. Tourism is a dominant economic sector with visitors on cruise ships and charter yachts drawn to the Islands by its landscape, beaches, coral reefs and rich biodiversity. The unprecedented events of 2017 demonstrated the Islands vulnerability to the natural hazards, the associated impacts to the population, damage to built infrastructure, natural capital assets and the resulting serious implications to the economy. As the natural environment also plays a key role in protecting built infrastructure and human well-being, it is important that it is also safeguarded against damage from human activities.

In recognition this, the Government of BVI, with support from the Joint Nature Conservation Committee's(JNCC) *Enhancing economic security through environmental resilience* in the UK Overseas Territories (OTs), CSSF funded programme, is taking steps to incorporate the socio-economic value of its natural capital into its policy and decision making. The JNCC, funded by the Conflict, Stability & Security Fund (CSSF) programme, 'Enhancing economic security through environmental resilience' in the UK Overseas Territories (OTs) is supporting the BVI in developing plans, policies and procedures to deal with natural disasters by enhancing their ability to prepare for and recover from the impact of storm events.

1.2 Project Objectives

Wood Environment and Infrastructure Solutions UK Ltd was commissioned by the JNCC to:

- Assess the role and economic value of the BVI's natural capital in the protection of vulnerable man-made capital from natural hazards. Specifically, to map the value of natural capital assets nationally, Objective 1.
- Further develop a framework of environmental indictors with a set of indicators required for new environmental legislation which monitor long term environmental change, a set of short-term disaster response indicators for monitoring the post-hurricane responses of and to the natural environment and a set of environmental economic indicators, Objective 2.
- Support the Government of BVI with the integration of indicators into the Environment Bill, Disaster and Needs Assessment (DANA) and for further national and international reporting, Objective 3.

The purpose of this report is to provide a summary of the outcomes of these three areas of work.

1.3 Project process

Essential to the delivery of this project was close working with the BVI Government. Following commission, the project team visited the BVI for a week of meetings with the Ministry of Natural Resources, Labour and Immigration to further clarify needs and priorities. These meetings focused on the environmental indicator framework related to Objectives 2 and 3 and specifically understanding requirements and developing the environmental economic indicators. During this visit, meetings were undertaken with the Ministry of Finance – Macro Fiscal Unit, Department of Disaster Management, Department of Central Statistics Unit, and the National Parks Trust. Following completion of the analysis and assessments related to Objective 1 the results and conclusions of the project were presented at a joint Government of the BVI, JNCC, UK Space Agency Data, indicators and reporting for disaster preparedness workshop held in Road Town 18th – 21st November 2019.

1.4 Structure of this document

This document comprises the following Sections:

- Section 2 responds to Objective 1, summarising the method followed and results related to mapping the value of natural capital assets for hazard protection;
- Section 3 responds to Objective 2, and presents the finalised three sets of indicators within the environmental indicator framework; and
- Section 4 provides conclusions and recommendations for further work.

2. Natural Capital Assessment

2.1 Natural capital asset register

A natural capital register is an inventory that holds details of the stocks of natural capital assets that are located within a specific geographic boundary. This contains the extent of the main habitats and can, if the information is available, include details of their condition or quality. The purpose of an asset register is to help track the changes/trends in overall extent and condition of habitats of a country.

For the BVI, two key datasets were available that provided information on habitat type. The first was a habitat/ land use dataset created by Environment Systems in 2016 and derived using earth observation data calibrated with the field data from the US Virgin Islands. The second, was a benthic dataset provided by the National Parks Trust which was created from UK funded field surveys undertaken in 2004/2005 by Warwickshire University. This dataset did include some comments on condition for some habitat entries, but these were not consistently available across the whole dataset so are not reported here. These two datasets were merged and the resulting habitat areas across the whole of the BVI are provided in Table 2.1 and how they support selected ecosystem services in Table 2.2.

Table 2.1 BVI national natural capital asset register baseline 2019

Habitat Class	Extent (m^2)
Algae	9,503,156
Agriculture	434,771
Bare ground	2,501,664
Beach	2,034,327
Coral Reef	120,236,505
Grassland	6,225,744
Mixed forest	37,753,616
Drought deciduous scrub	10,065,288
Evergreen forest	17,657,356
Semi-deciduous forest	14,171,865
Mangrove	3,858,090
Rock	8,060,312
Salt pan	3,462,736
Salt pond	6,441,697
Scrub	13,148,376
Seagrass	55,228,053
Sediment	133,691,133
Thicket	20,664,745
Urban	14,031,040
Total	**479,170,474**

Table 2.2 Habitats associated with supporting specific ecosystem services

Ecosystem Service	Habitat Class
Coastal flood protection	Coral reef, mangrove, seagrass, beach
Soil erosion regulation	Agriculture, grassland, mixed forest, drought deciduous scrub, evergreen forest, semi-deciduous forest, scrub, thicket

The two datasets above were created from one off studies and have/are not subject to regular monitoring to provide continuous update which presents a clear gap. The only regular monitoring that is ongoing is for terrestrial endangered species that has been carried out for the past 20 years and is currently supported by Kew. The UK Hydrographic office have recently completed a surveying exercise and have created two bathymetric datasets.

The gap in terms of regular monitoring of terrestrial and benthic habitats is a recognised issue. The Government of the BVI is currently looking at the potential regular acquisition of earth observation imagery that can be used to keep updating datasets for both terrestrial habitats and benthic habitats (recognising this is only able to do so up to a certain depth). In addition, the monitoring of a range of environmental indicators to support long term and short-term monitoring, which includes the extent and condition of habitats, is planned as part of the Environment Bill and DANA process and this is discussed further in Section 3.

2.2 Benefits of natural capital assets providing protection to built infrastructure

Ecosystem service focus

Aligned with the Objective 1 of the project, this section focuses on the natural capital assets which provide ecosystem services that protect built infrastructure against terrestrial and coastal hazards and contribute to disaster resilience and protection more generally. The hazards and mitigating ecosystem services identified and subject to more detailed assessment are:

- Erosion regulation. Natural capital that provide protective service against terrestrial sediment loss from extreme weather events; and
- Coastal flood regulation. Natural capital that provide a protection service against coastal flooding associated with extreme weather events;

These two areas are discussed in further detail in the sections below.

Erosion regulation

Objective

The objective of this component of work was to identify locations across the BVI which have the greatest risk of soil erosion and sediment delivery to near shore coastal environment and to examine how these overlap with the presence of coral reefs that provide coastal protection.

Soil provides critical ecosystem services. It supports the growth of arable crops, grassland and trees providing us with food, fibre for clothes, timber and fuel. It acts as a water filter, a buffer for temperature change and for the flow of water and provides a habitat for billions of organisms which cycle carbon and mineral nutrients. The loss of soil through erosion endangers these critical functions but can also lead to increased pollution and sedimentation in streams, rivers and the marine environment causing declines in fish and other species.

Impacts of sediment on coral reefs

The relationships between reefs and sediments has been observed and understood for centuries including Darwin noting that that "the deposition… of sediment, checks the growth of coral-reefs"[1]. Sediment run-off from the land and its deposition on coral reefs can significantly impact coral health by blocking light and inhibiting photosynthesis, directly smothering and abrading coral, triggering increases in macro algae, energy expenditure for surface cleaning by ciliary action, and inhibition of recruitment.[2] Pollutants which readily adhere to sediments such as heavy metals, pesticides and herbicides can also have a negative impact on coral health. As a result, reefs that are exposed to sediment runoff can have a decrease in coral growth rate, have a decrease in metabolic rate, can change population structure, morphology, reduce species richness and diversity[3] and so can take longer to recover from disturbances by storms, are more susceptible to coral bleaching and disease and outbreaks of coral predators.

Modelling the risk of sediment loss to the near shore coastal environment

A conceptual approach of sediment erosion and delivery to near shore coastal environment was developed comprising of two stages. Firstly, to quantify the potential risk of sediment erosion during storm events and secondly, the sediment delivery capacity i.e. how the mobile sediment could be moved across the land and delivered to the coast. Our conceptual approach made use of an updated 2-Dimensional ICM Infoworks hydraulic models that were previously developed at a national level for the BVI[4]. The ICM models were used assess the role of natural capital in terms of the protection offered by reducing the catchment response to a storm event; in slowing the passage of water through the catchment.

Soil erosion models can be used for indicating the severity of soil erosion, the best known of which include the Revised Universal Soil Loss Equation (RUSLE) (Renard *et al.*, 1991)[5].

$$A = R \; x \; K \; x \; L \; x \; S \; x \; C \; x \; P \qquad (1)$$

The RUSLE method for calculating the net detachment of soil (A) requires the calculation of factors for rainfall erosivity (R), erodibility (K), slope length (L), slope steepness (S), cover management (C) and supporting erosion control practices (P). The erosivity factor (R) of surface runoff is closely related to shear velocity. The ICM Infoworks model does not provide this information but does include peak discharge (m^3sec^{-1}). Given the steep slopes of BVI this was used as a proxy for (R). Slope steepness (S) is provided using the gradient information from the national lidar dataset. There is no spatial data on soils in the BVI and information on erosion control is not available so factors (K) and (P) were not included. Given the ICM model uses a consistent grid in its calculations factor (L) was ignored. The cover management factor (C) was factored in by undertaking two different model runs each representing a different land use: the existing baseline land use; and a hypothetical degraded land use scenario – where the vegetation cover and its protection is removed.

$$A = R \; x \; S \qquad (2)$$

The resulting proxy model for potential risk of sediment erosion A (which is assumed dimensionless) is shown in (2) where the model is run for both baseline and degraded land use scenario and the difference quantifies the erosion protection provided by the natural capital.

The sediment delivery capacity was assessed by quantifying how sediment erosion risk aggregates over the land surface and the potential for it to be routed to the sea. A simplified approach was taken through slope

[1] Darwin, C.R (1842). The structure and distribution of coral reefs. London: Smith Elder.

[2] https://coralreefs.wr.usgs.gov/sediment.html

[3] https://www.researchgate.net/publication/278716776_Impacts_of_Sediment_on_Coral_Reefs

[4] Wood (2019) An assessment of the value of natural capital in the protective service against coastal and inland flooding in the UK Overseas Territory of the British Virgin Islands. A report for the JNCC. https://hub.jncc.gov.uk/assets/c8e46472-2bfc-4a70-b6e8-573f1807c158

[5] Renard, K.G., Foster, G.R., Weesies, G.A. and Porter, J.P., 1991. RUSLE: Revised universal soil loss equation. Journal of soil and Water Conservation, 46(1), pp.30-33.

routing between the grid cells and cumulative summing of sediment risk. The output of this process is a dataset of sediment delivery capacity.

ICM Infoworks Hydraulic model

The Infoworks national scale models developed in the previous NCA assessment[4] were used for this assessment with the 1:100 year return flood event. The models were updated using the latest gridded Lidar data was used (rather than the slope derived from a 2m contour data) and the baseline land use data was also included.

Results

The updated national scale Infoworks models were simulated for the baseline and degraded land use scenarios and post processing undertaken to calculate potential sediment erosion risk and subsequent cumulative sediment capacity delivery. The sediment capacity delivery results for Tortola and zoomed into Cane Garden Bay in Figure 2.1 - Figure 2.4.

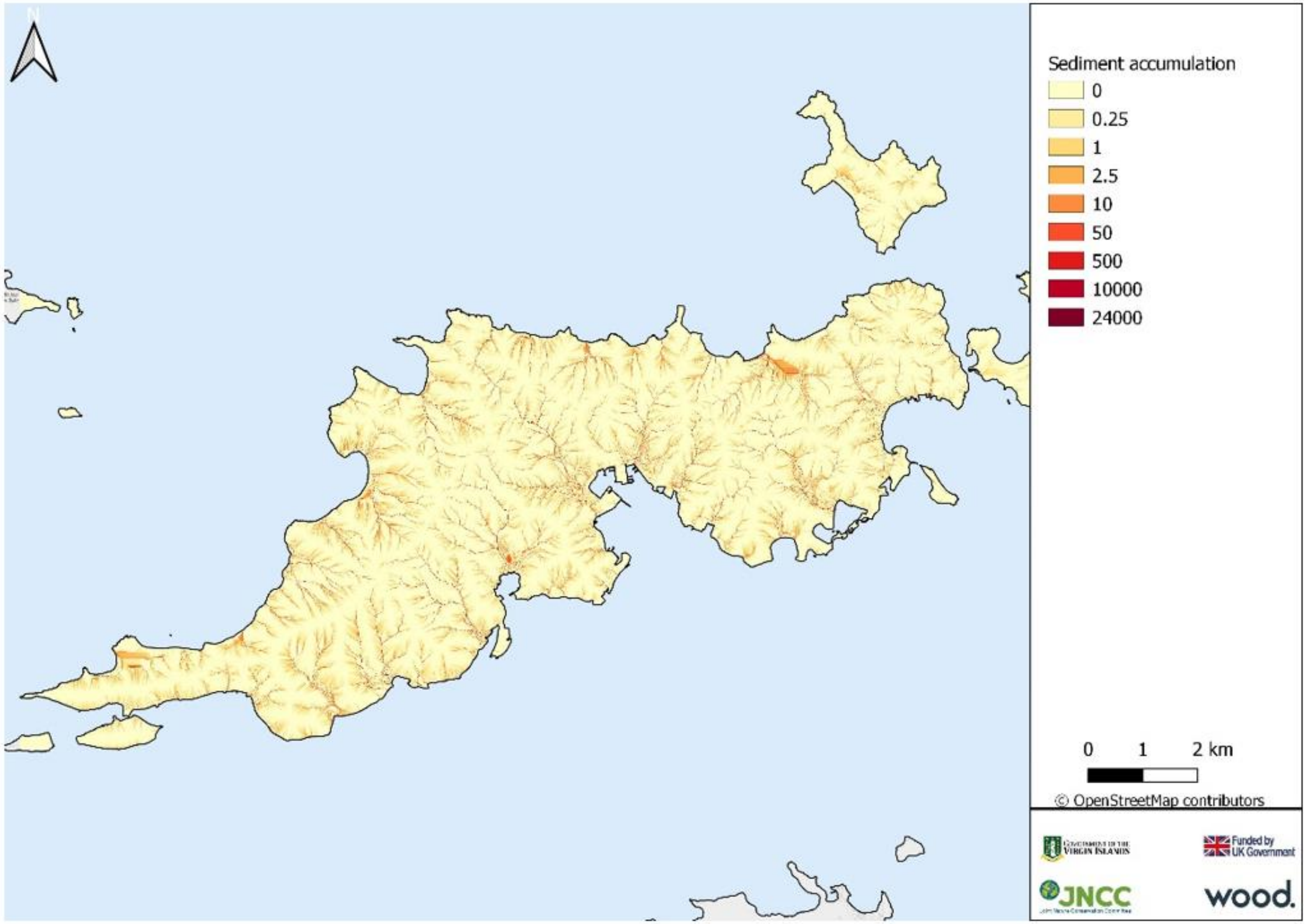


Figure 2.1 Sediment delivery capacity – Tortola – baseline scenario

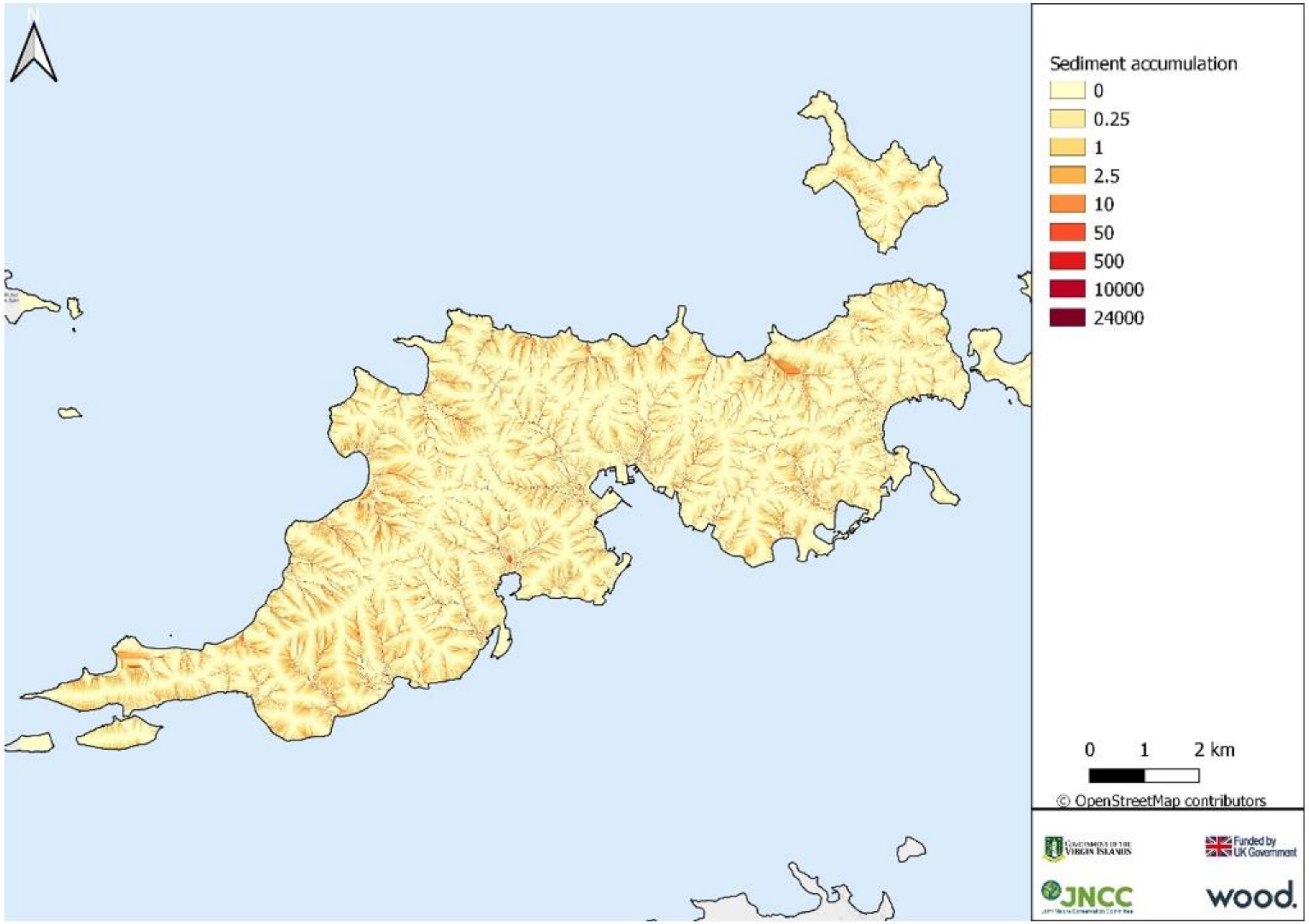


Figure 2.2 Sediment delivery capacity – Tortola – degraded scenario

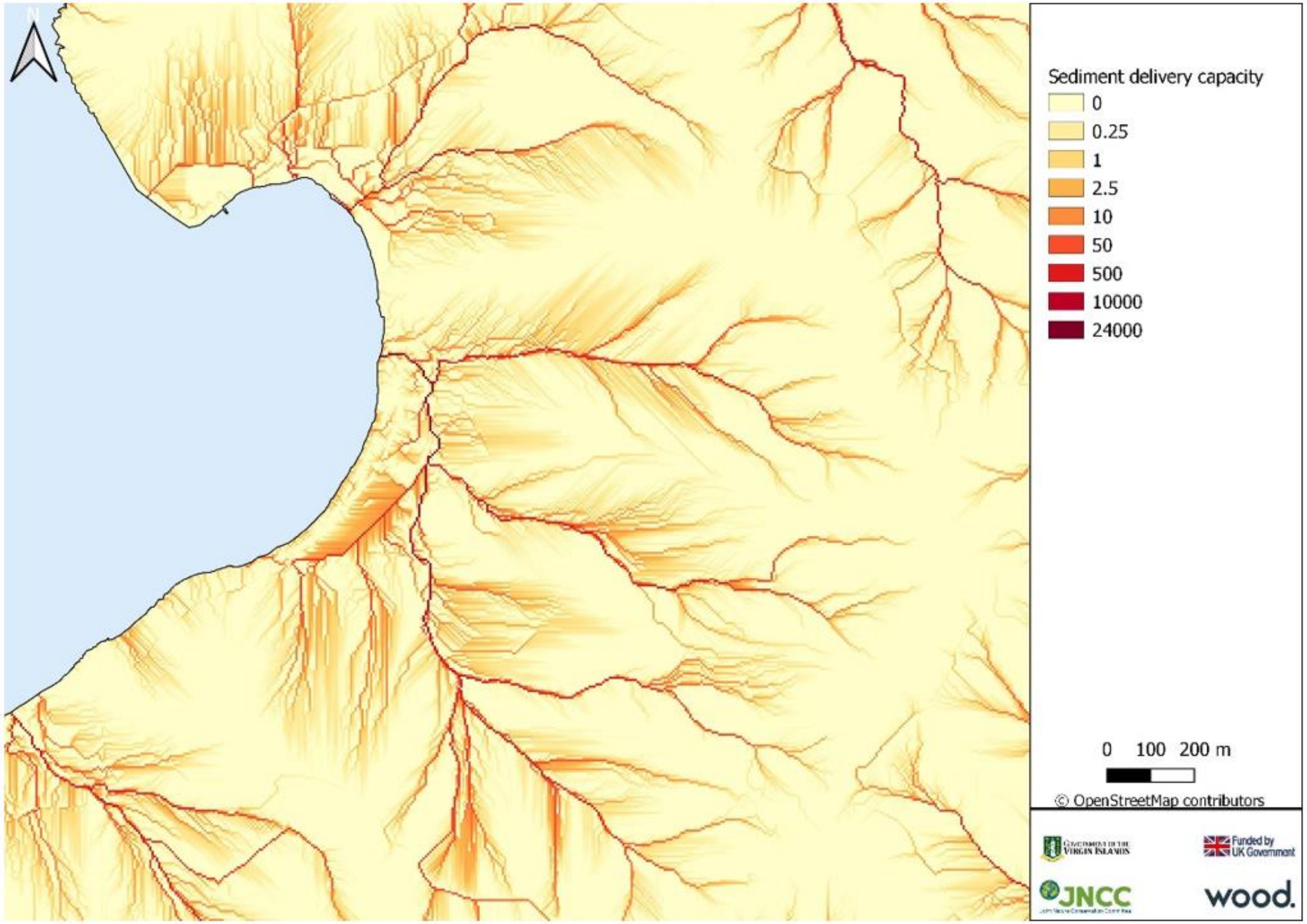


Figure 2.3 Sediment delivery capacity – Cane Garden Bay – baseline scenario

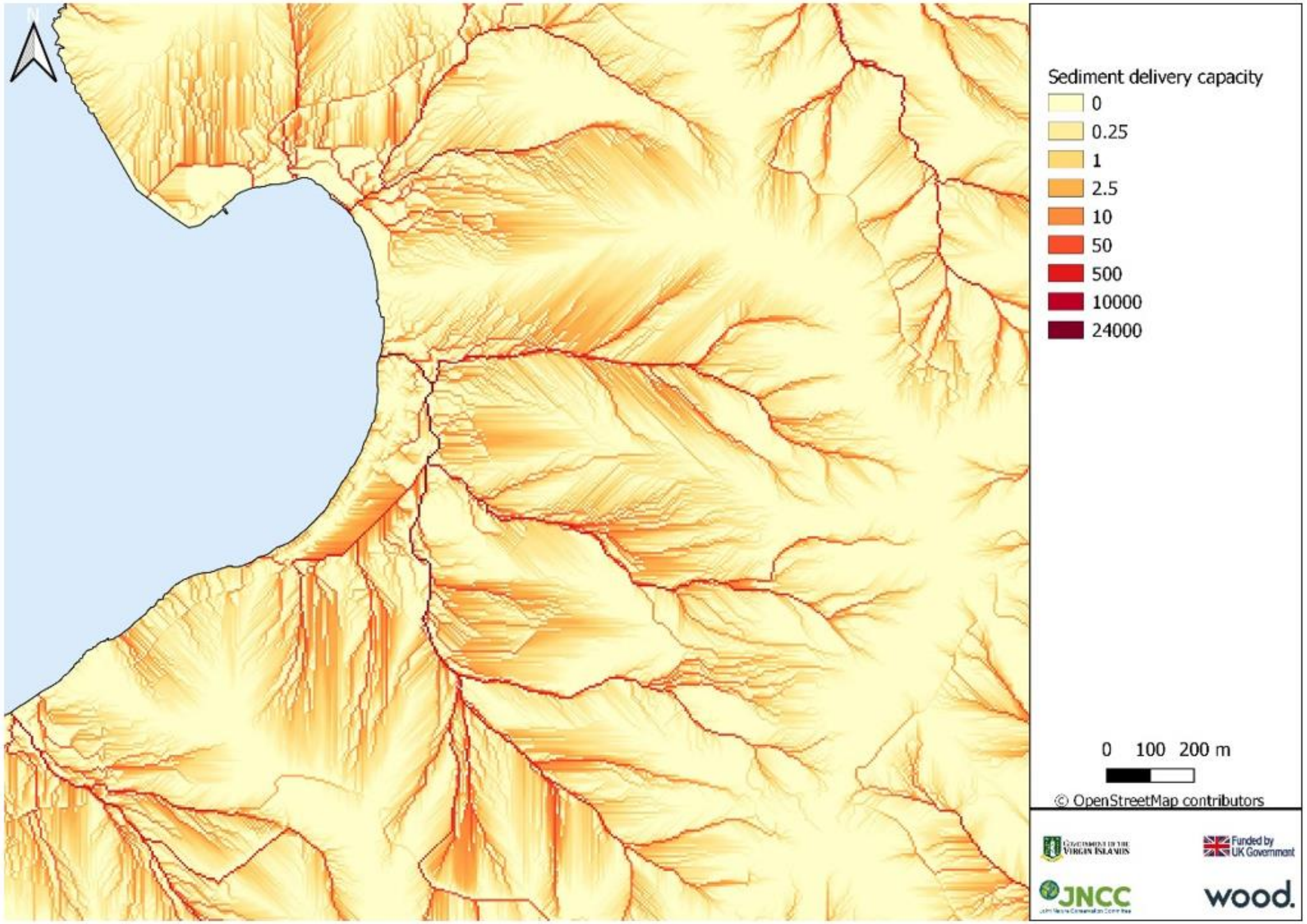


Figure 2.4 Sediment delivery capacity – Cane Garden Bay – degraded scenario

In the degraded scenarios (Figure 2.2 and Figure 2.4) the increased sediment delivery over the baseline can be clearly observed (both in extent and magnitude), reflecting the loss of vegetation and subsequent increase in peak flow velocity which would mobilise the sediment.

Figure 2.5 shows the spatial distribution of baseline sediment delivery capacity for different Bays around Tortola. For each Bay the baseline sediment delivery capacity is the first figure quoted with the % increase the second figure.

The largest baseline sediment delivery capacity is shown to be on the south coast, with the potential for high levels of sediment to enter coastal waters at Road Town, Pockwood Pond, Nanny Cay, Paraquita Bay and Sea Cows Bay. In addition to the function of topography and landcover, the size of catchment area will be a key contributing factor to this. The loss of vegetation in the degraded scenario and resulting increase in peak flow velocity provides an increase in sediment delivery capacity over baseline ranging from 39%-93%. This highlights the importance of vegetation in increasing the surface roughness and slowing the water flow and reducing the ability to entrain sediment.

Figure 2.6 highlights, in pink shading, the location of coral reefs surrounding Tortola. Coral reefs provide important ecosystem services including coastal flood protection through dissipation of wave energy. Communities, infrastructure and the related economy situated in locations behind these coral reefs benefit from maximum flood protection where these are in a healthy condition.

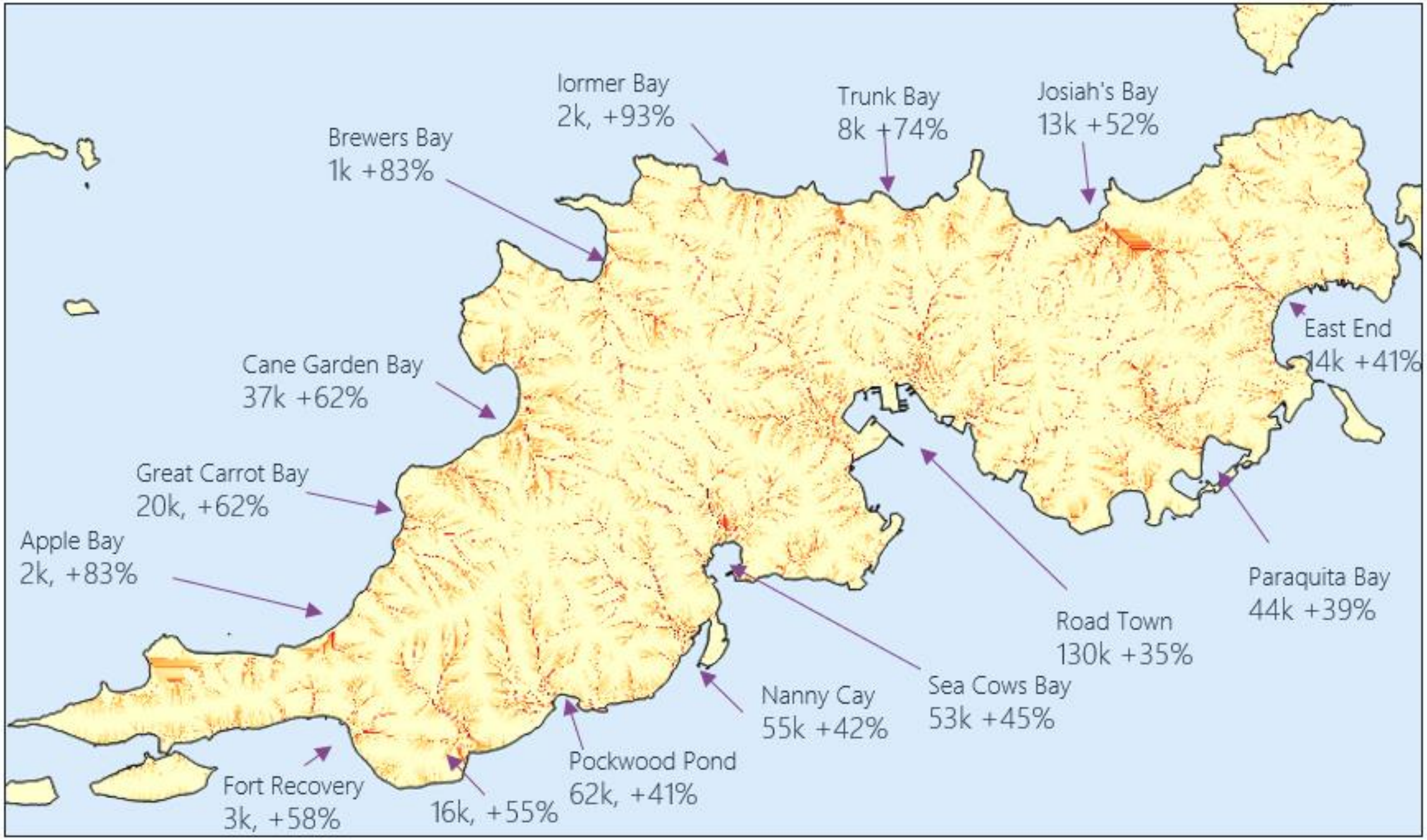
Locations with both coral reefs and high sediment delivery capacity are also highlighted in Figure 2.6. Reefs located at Sea Cows Bay, Pockwood Pond, Paraquita Bay, Cane Garden Bay, Nanny Cay and offshore from Road Town are most vulnerable from sedimentation (ringed in red on Figure 2.6). Economic activities related to tourism at Nanny Cay, Cane Garden Bay, Paraquita Bay (hurricane yacht shelter) and commercial activities at Road Town are correspondingly vulnerable to reduced coastal protection through sedimentation and are areas where sediment management practices in upstream catchment areas are most likely to deliver economic benefits.

An economic assessment of the role of natural capital in protecting infrastructure against flooding has previously been undertaken in the BVI[4]. Unit values ($\$/m^2$) of the protection value provided by coral reefs were derived for buildings with different use types at different locations. A review of the literature undertaken as part of this study looked to identify whether research had reported evidence of additional economic impacts where floodwater had higher levels of turbidity and the entrained sediment had caused additional damage. No such evidence was identified.

A study in St Lucia[6] considered the issue of coral reef degradation due to sedimentation. It reports that sedimentation was the second largest contributor to coral reef losses (after storms) but also highlights that sediment pollution is one of the most serious future threats to reefs as it inhibits their recovery from other impacts. Degradation of reefs from sedimentation has led to dive sites being abandoned and future losses were estimated as leading to annual economic losses of between EC$430,000-750,000 per site.

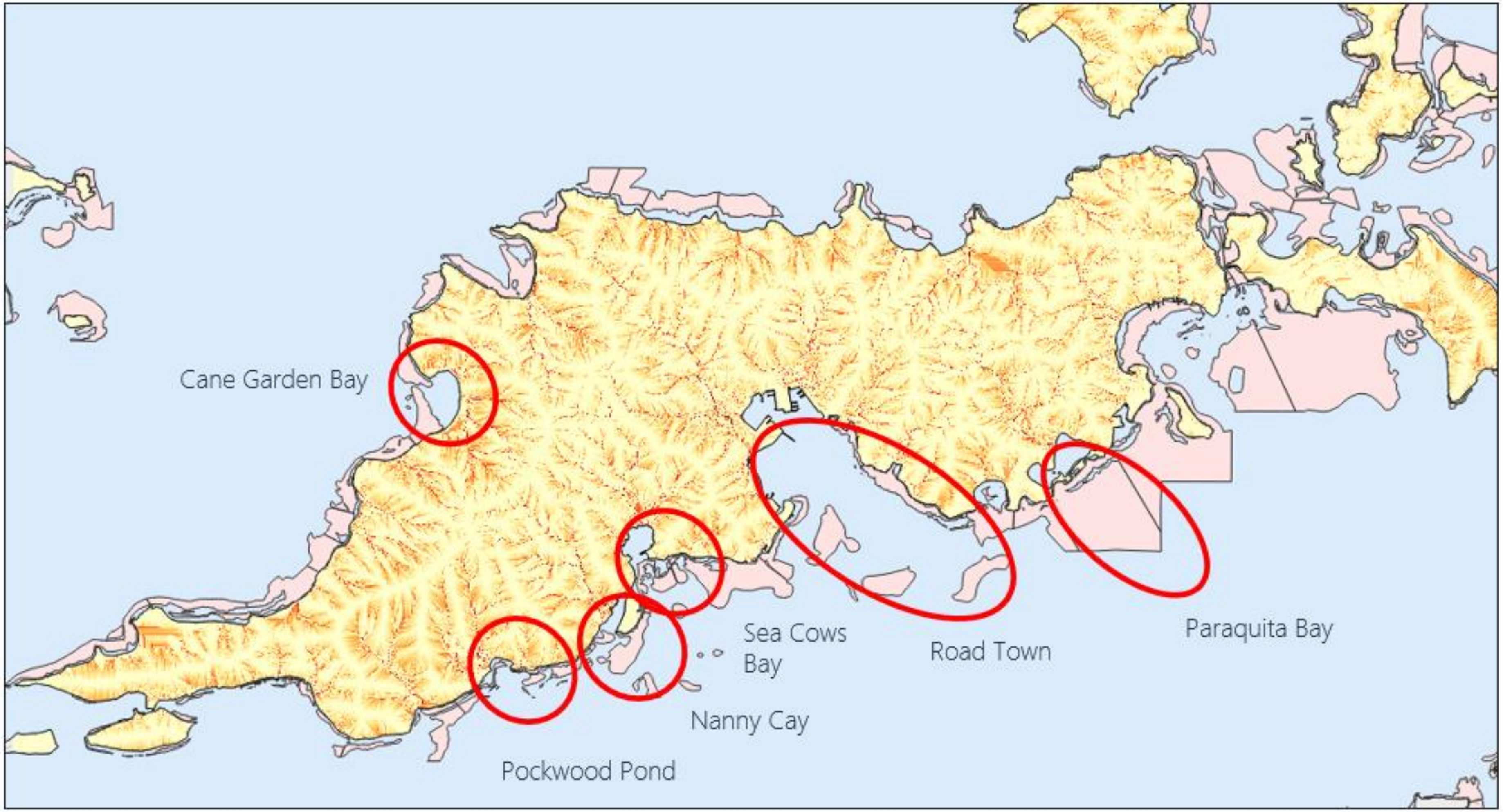
In this study we have not made a quantitative or monetary estimate of the link between increased transport of sediment to the marine environment and the level of economic impacts. However, the chain of effects identified here from sedimentation would also be expected to occur in the BVI resulting in reduced coastal protection as well as reduced marine tourism.

[6] Roberts *et al.* (2003). R7668 Impact and amelioration of sediment pollution on coral reefs of St. Lucia, West Indies. https://www.gov.uk/dfid-research-outputs/impact-and-amelioration-of-sediment-pollution-on-coral-reefs-of-st-lucia-west-indies



Note: Figures shown are (baseline sediment delivery capacity; % change in degraded scenario).

Figure 2.5 Sediment delivery capacity – Tortola – baseline scenario and % change for degraded scenario.



Note: Coral reefs are highlighted in pink shading.

Figure 2.6 Locations of coral reefs and areas of high vulnerability from sedimentation – Tortola

Coastal flood protection

Objective

The objective of this component of work was to characterise locations of built infrastructure across the BVI which are dependent on coral reefs (natural capital) to provide coastal flood protection and to map the flood protection value that these natural assets provide.

Overview

Coral reefs provide physical barriers to waves and dissipate wave energy through friction to flows over their surfaces. In particular, the rugosity of live coral provides an increased surface area and hence increased energy dissipation. The net effect is a reduction in maximum water level which leads to less on-shore flooding and so reduces economic losses from physical damage and business disruption. Degraded coral reefs provide less friction and so do not reduce as much wave energy. The overall method of assessment used here aims to link the natural capital assets to the economic value derived from them. Changes in natural capital condition will then cause corresponding changes to economic impact.

Scope of assessment

This method looks at short term impacts from flooding to existing properties in existing locations and the repair and disruption costs of continuing to use them. There are no costs attributed to abandoning properties for example, though climate change and sea level rise are factors which might mean that structural solutions are eventually better. The assumption of the continuation of existing uses is also similarly extended to cover changes in value from future expectations. In particular, no account is taken of the possible fall in value of a property because people expect it to flood more often than it has in the past.

The method also takes a specific approach to economic growth. The pattern of greatest growth in the BVI is for this to occur at lower elevations which are inherently more exposed to coastal flooding. Further growth could expand the built infrastructure at risk, and this would correspondingly increase the value of natural capital assets providing protection. Here, the assessment is made against the current pattern of settlement and economic activity. In particular, sections of coastline protected by reefs but without built infrastructure implicitly cannot experience damage to the non-existent infrastructure and so the protective function of reefs does not contribute to economic value.

Methodological elements

The links between natural capital and economic activity can be characterised and analysed as a sequence:

- The physical characteristics of the natural capital assets - comprising the identification of natural capital assets, their properties and the effects of changes in them;
- The events which have the potential to cause damage and their interaction with the natural capital assets; and
- The value of the level of economic activity affected by the net physical impacts of the events and the protection provided.

A more detailed description of these is provided in earlier reporting[4] and the steps and quantitative elements of the valuation summarised below. BVI reefs are predominantly shallow 'low density' (SLD) reefs. The effect on flooding depth to different reef types in the hypothetical situation of degradation (1) or destruction is shown in Table 2.3.

Table 2.3 Predicted relative wave energy dissipation before reaching the shore per reef type during a 100 year probability event and increased flooding levels without coral reef protection in flood zones

Reef Type	Coral friction energy dissipation	(1) Increased flooding without coral friction (m)	Total reef energy dissipation	(2) Increased flooding without coral reefs (m)
SHD	5.5%	0.33	95.5%	5.82
SLD	3.5%	0.21	90.0%	5.49
DHD	10.5%	0.64	38.0%	2.32
DLD	4.5%	0.27	32.0%	1.95

Reproduced from van Zanten *et al.* (2014)[7] SHD = shallow high-density reefs; SLD = shallow low density reefs; DHD = deep high density reefs; DLD = deep low density reefs.

The geographic distribution of reefs across the BVI are shown Figure 2.7.

The events that result in coastal flooding are predominantly severe tropical storms (hurricanes). Records analysed in earlier work are summarised in Table 2.4 and show the annual probability of different category hurricanes and associated storm surge height. These are based on observations from 1851 to 2010 for tropical storm systems passing within 60 nautical miles of Tortola. The probabilities sum to 0.19 which indicates that once every 5 years a hurricane of an intensity between 1 and 5 would be expected to affect the BVI.

Table 2.4 Predicted Probability of hurricane and associated storm surge estimates

Saffir Simpson Hurricane Categories	Average storm surge (m)	Frequency in 160 years	Annual Probability of occurrence (100% = certain)	R3i modelled (m)	R3i + Degraded (m)	R3i + reef destruction (m)
H1	1.35	6	3.8%			
H2	2.2	12	7.5%			
H3	3.25	6	3.8%			
H4	4.75	6	3.8%	1.26	1.47	4.8
H5	6.3	1	0.6%			

Source: R3i scenario from the Regional Risk Reduction Initiative for the GoBVI (2013) and stormcarib.com

The level of economic activity was characterised by attributing it pro-rata to the footprint area of buildings of different types. Two categories of building type were identified and unit values estimated reflecting losses from disruption to bars and restaurants (commercial) and through lost welfare for residential properties, as show in Table 2.5. These values were validated against BVI Government GDP estimates for the hospitality sector and estimates of costs of flood events by Van Zanten *et al.* (2014)[7]. These unit values were then used to represent values for properties with other types of use based on a rationalisation which reflected the equivalence (in terms of their earning potential) of properties with more than one potential use.

[7] Van Zanten *et al.* (2014) *Coastal protection by coral reefs: A framework for spatial assessment and economic valuation.* https://www.researchgate.net/publication/262921102_Coastal_protection_by_coral_reefs_A_framework_for_spatial_assessment_and_economic_valuation

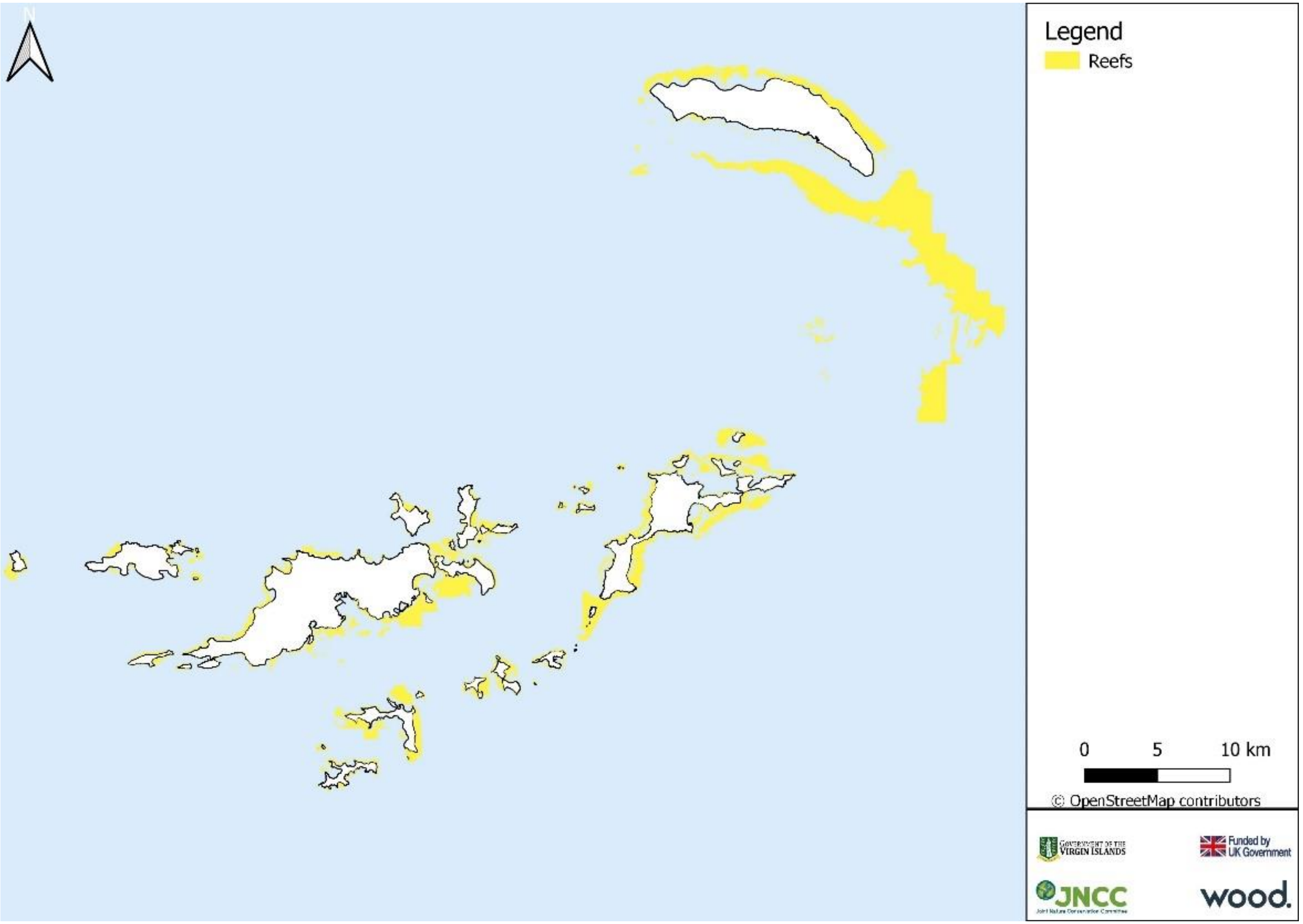


Figure 2.7 Geographic distribution of these reefs across the BVI

Table 2.5 Unit values of different building types in the BVI

Building type	Unit value (US$/m^2/yr)	Basis of valuation
Residential property	US$415/m^2	This represents the rental value of property and was derived from current market prices. Residents who live in their own property are assumed to experience personal benefits equivalent to the profits that would be made from renting the property and so would experience a loss in welfare equivalent to these lost profits if they were displaced.
Bars and restaurants	US$1400/m^2	This represents the value of the net margin (profit) earnt from bars and restaurants per unit area and has been estimated for the BVI specifically. This was calculated by modelling annual revenue for bars and restaurants by estimating the seating capacity of each business and occupancy rate modelled over the year, reflecting seasonality of tourist arrivals to the BVI.

Events typically result in transient effects and a period of recovery. For coastal flooding, interruption to business activities was assumed, for an event of any severity, to be one year, while disruption to residential occupancy is assumed to be 6 months. In addition to disruption, physical damage was also estimated. The repair costs are modelled assuming only the repair costs from the additional properties which become flooded are included in the aggregate estimate. The repair cost is based on American Federal Emergency Management Agency (FEMA) estimates from 2011 and amounts to 15% of the construction value.

The buildings within the BVI are all individually identified within the GIS mapping system. The buildings affected and the associated economic losses from disruption from flooding could be identified by their elevation, compared to the estimated coastal flood depth. Based on the property type, a unit value of loss could be determined.

There is established evidence that direct impacts recorded in an economy, such as expenditure in a shop or hotel, is causally associated with wider economic impacts in supply chains and from induced impacts due to knock-on spending in these supply chains and elsewhere. These additional impacts increase the overall economic effect and are typically represented using an economic multiplier which is applied as a factor on the direct impacts and expressed in terms of expenditure or employment. The economic multiplier is assumed here to be 1.65 based on a number of sources for what is an inherently difficult number to establish. This increases a direct level of loss of $100 to $165 in terms of the overall economic impact.

Through this sequence, the methodology links the reef characteristics, to the severity of events, and then to the economic impact: firstly, directly to residents and business operators and secondly, to the overall economy. The assessment comprised a characterisation of the change in levels of coastal flooding and resulting economic impact using a baseline scenario compared with two hypothetical scenarios of reef degradation and reef destruction.

Results

The assessment methodology was applied across the whole of the BVI using individual models of each bay and their associated reef structures. For each bay the estimated flood water level can be equated with a corresponding level of economic loss. In the baseline scenario, the expected economic loss in a single Category 4 tropical storm event is shown in Figure 2.8. This indicates the level of loss assuming the coral reefs are in their current condition. The greatest levels of expected loss are around Road Town as the area has concentrations of economic activity (public sector, commercial and industrial uses). These areas are also those where reef degradation has the greatest impact because it increases coastal flooding at higher elevations where there are also concentrations of economic activity.

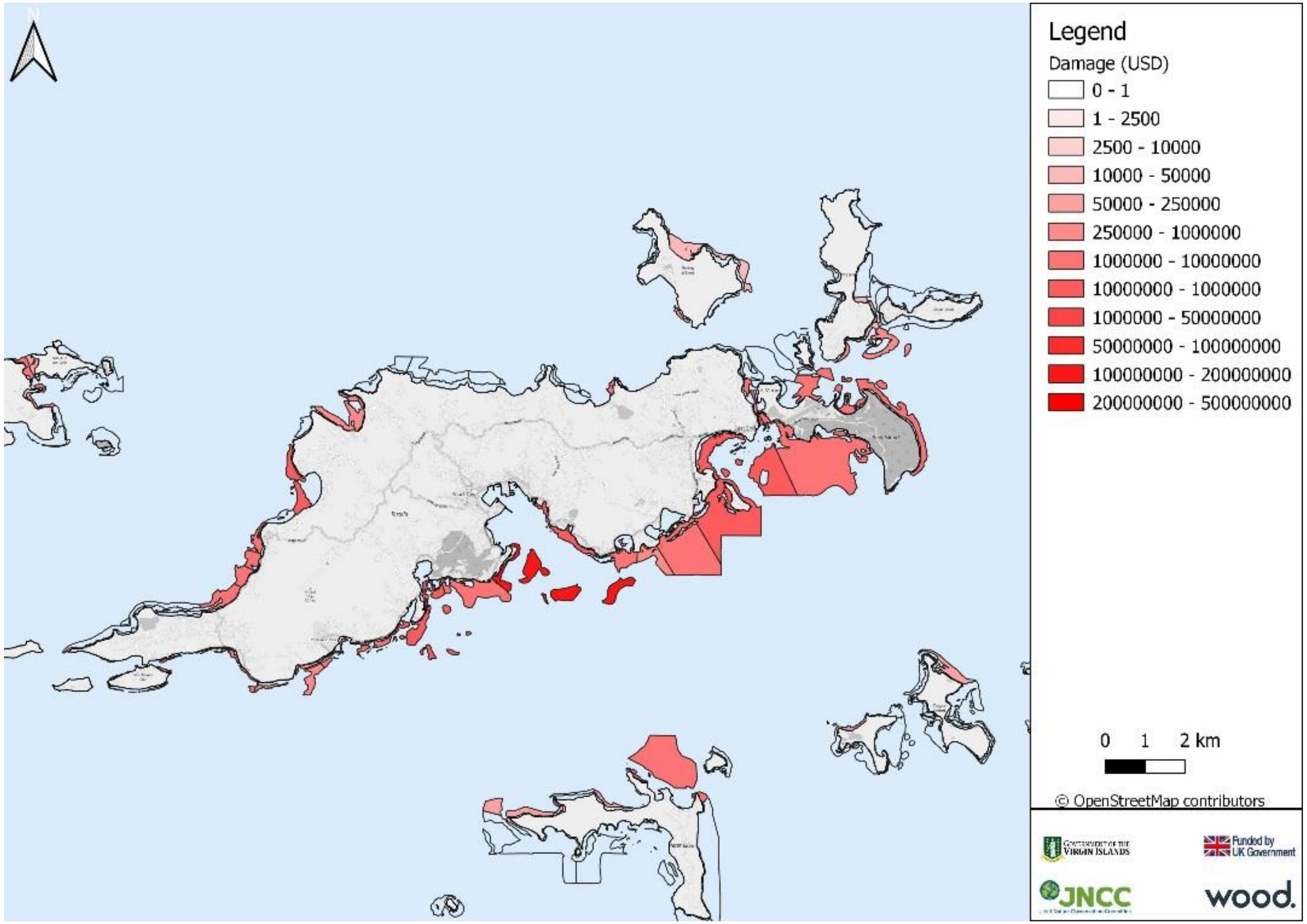


Figure 2.8 Estimated levels of economic loss in the baseline scenario shown as values attributed to the nearest protective reefs – Tortola

For each bay a water depth-damage curve was developed which showed the economic losses for storm events according to the increase in water level. Figure 2.9 shows the results for Road Town. The red vertical lines show the difference in losses for a Category 3 tropical storm event with and without reef protection. Each line corresponds to a different scenario for the reef's health and existence. The solid red line (labelled 'Cat 3 base') is positioned at 0.6m along the horizontal axis showing that the water level rise in a Category 3 event at baseline. To the right is the dotted line (labelled 'deg.') at 0.85m on the axis the showing the water level rise in a scenario with degraded reefs. Further to the right, the dash-dotted line shows a water level rise of 4m in a scenario where the reefs were no longer present (labelled 'no reef)'. In each of these scenarios, the intersection of the red lines with the curves indicates the level of economic impact[8]. For example, if coral reefs were destroyed and no longer present in the Bay beyond Road Town, the dash-dotted line indicate that almost USD$120m of damage would be caused in the Retail and Office sector of the economy. In addition, there would be almost USD$20m of losses in the residential sector, shown by the dark purple curve on the graph.

For this Category 3 event, the value of coral reef protection can be seen as the difference between the losses in the baseline scenario with healthy reefs and the losses in the no-reef scenario. For Road Town, the losses in a Category 3 event are relatively small but rapidly increase for scenarios with reef loss and in storm events that would result in water levels rising above 1m.

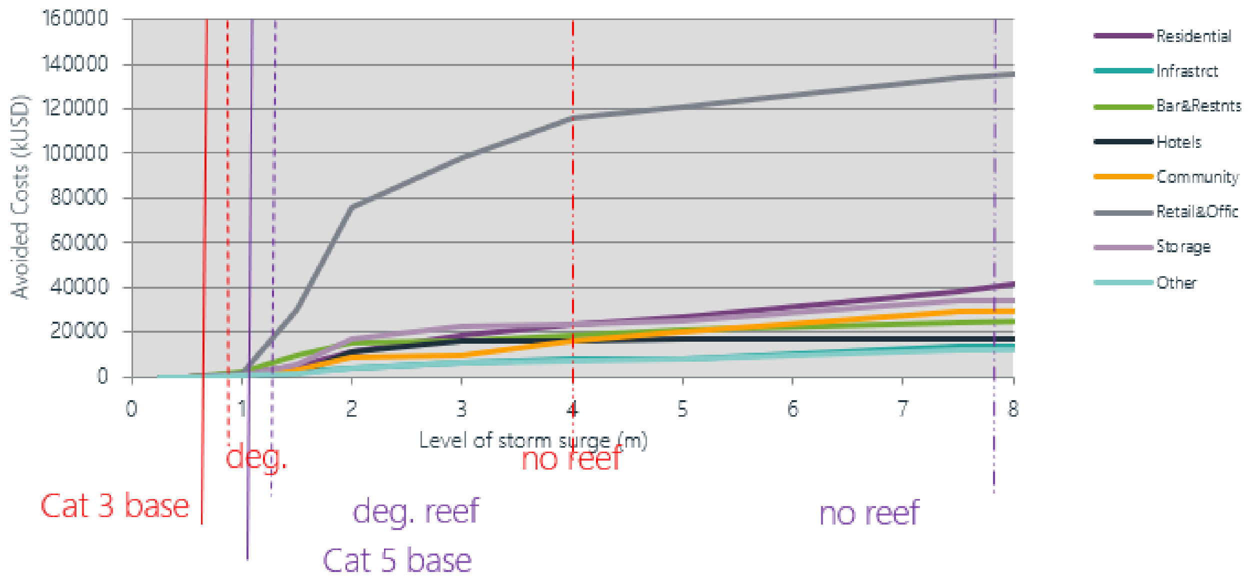


Figure 2.9 The levels of damage avoided by the natural capital of reefs at Road Town

The situation for a Category 5 hurricane event is shown by the set of purple lines. The damage in the baseline scenario (solid line) is still relatively small, corresponding to a water rise of just over 1m, but in a scenario with reef degradation (dotted line) there are aggregate losses of over USD$20m (for the sum of all sectors). The protective function of the reefs around Road Town is complex to and the assignment of values to specific reefs is notional. However, the general estimation of economic values and the operation of methodology is chosen to be illustrated here as Road Town has the greatest economic values and hence is particularly important to consider.

[8] The benefit from a healthy reef arises because it allows economic losses to be avoided that would arise if the reef were degraded or destroyed. The graph shows the avoided costs (i.e. benefits) that would be lost for different levels of flooding.

As well as showing the effects of tropical storms and the mitigating effects of coral reefs, these curves show a general 'depth-damage' relationship linking flood water depth and economic value in each bay on the coastline of the BVI. They provide the capability to:

- show the economic value exposed at different water levels and elevations in each location and the value of natural capital in preventing water-level rise in these locations;
- translate estimates of physical damage assessment to estimates of economic impacts to support rapid short-term requirements of DANA; and
- compare and quantify the economic value at risk in one bay compared to others across the BVI.

Wider use of depth damage curves

The curves show a measure of the 'value at risk' for different water level rises and are therefore 'depth-damage functions' for each bay. While coral reefs mitigate water level rise, mangroves provide similar protection against coastal flooding and as such if a depth mitigation figure can be estimated the curves can be used to derive a flood protection value.

A further use of the curves is in understanding the maximum value that coral reefs could ever provide in a single location which can be calculated in terms of a maximum rate of loss per increase in water level (the steepness of the curve), the implication being that the natural capital would, according to the conditions of the baseline and scenario, sometimes provide this.

This metric is potentially useful to identify and compare the benefits of natural capital at different parts of the coastline. It could be used to prioritise the enhancement and maintenance of natural capital so that it continues to maintain its function of coastal protection at the places on the coast where this is most valuable.

These more general uses of these curves are explained below using examples for Cane Garden Bay and Nanny Cay below. **Error! Reference source not found.** and **Error! Reference source not found.** show the depth damage curves for Cane Garden Bay Nanny Cay respectively.

In Cane Garden Bay the sector most exposed is 'Bars and Restaurants' (the green curve). Furthermore, this curve rises most steeply between water levels of 2m and 3m. It implies that the value of natural capital is greatest when it prevents a 2m coastal flood becoming a 3m metre flood. When it prevents this condition occurring, it saves almost USD$10m by avoiding losses. This situation would occur in a Category 5 event if the reef was partially destroyed.

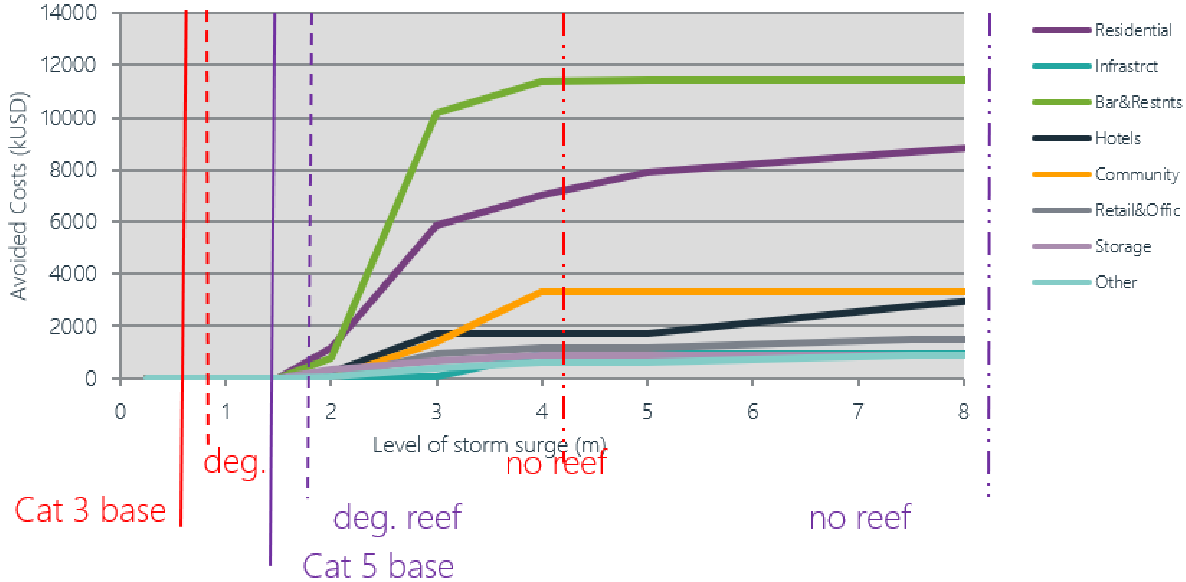


Figure 2.10 The levels of damage avoided by the natural capital of reefs at Cane Garden Bay

In contrast, at Nanny Cay, the most exposed sector is 'Residential' (the purple curve) with the curve rising most steeply between 1m and 1.5m. Correspondingly, coral reefs which reduce water levels have most value when they prevent a coastal flood of 1m becoming a flood of 1.5m. Note that in a Category 5 event, the residential flood depth in the baseline is already 1.5m and so the reefs only prevent further losses which are of a lower magnitude than those already incurred.

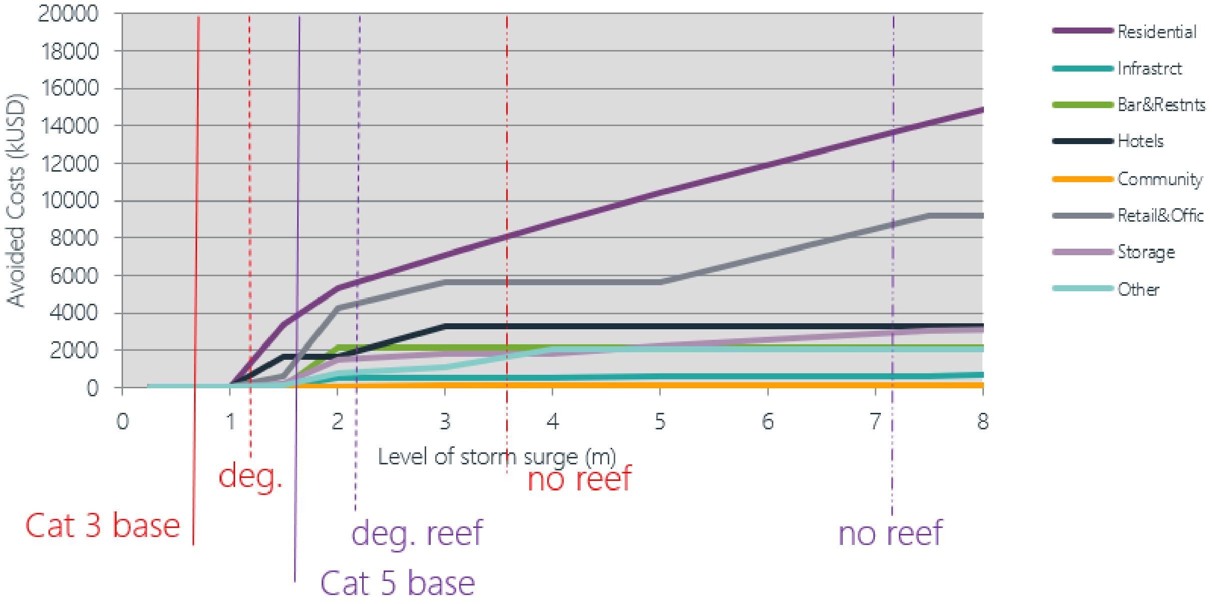


Figure 2.11 The levels of damage avoided by the natural capital of reefs at Nanny Cay

Appendix A provides curves for all the bays identified as protected by reefs or mangroves in the BVI and a table of the maximum rates of loss avoidance in terms of USD per metre of flood water level.

2.3 Methodology to quantify post event loss or gain

The quantification of post-event loss or gain uses the depth-damage curves. The curves are presented in Appendix A and their general interpretation is described in Section 2.2 above. In summary, the observed water level rise along the horizontal axis can be used to identify the corresponding level of damage reported on the vertical axis for a particular economic sector, or by adding them, for all sectors in aggregate.

The physical damage to natural capital needs to be assessed in order to use the curves and an estimate made of the physical effect in terms of the impact on water level rise. These judgements have been made in this project and the precursor project for hypothetical damage to reefs and expressed in terms of scenarios for 'degraded reefs' and 'no reefs' (reef destruction). In a practical situation damage is likely to fall on a spectrum between these scenarios and will need to be judged at the time. This is called the 'scenario of damage' and allows an estimate to be made of the increase in the water level that would now be expected to occur if another event were to occur in the future, compared to the level had the reefs remained intact (the baseline scenario).

There are then two options for using the curves to estimate the difference such damage has made:

- Firstly, to use the maximum rate (in terms of USD$ per metre of water level rise) and multiply it by the increase in expected water level rise due to the physical damage –this corresponds to assuming the increase in damage is at the steepest parts of the curve;
- Secondly, to calculate the difference between the new (higher) water level expected in the scenario of damage and the baseline (equivalent to the difference between the solid vertical line (baseline) and a new more specific version of the dotted and dashed-dotted lines as shown in the graphs above).

The benefit of the first option is that it is simpler to calculate but assumes the protective function provided by natural capital that has been lost is the maximum it could have been supplying, because it uses the steepest part of the curve. The second option instead represents the level of protective function as being represented by the section of the curve explicitly between the baseline and the scenario of damage. The second estimate will always be lower but is only representative for the selected baseline, and the baseline will be at different positions according to the event that is modelled. The first method avoids this by selecting the maximum and so does not need to specify the event baseline. The choice of method depends on the purposes of the assessment, in particular, whether the estimates are to be made relevant to a specific event.

3. Environmental indicators

3.1 Background

The development of indicators which provide consistent environmental monitoring is strongly related to the development of effective environmental policy. Wood was previously commissioned by the JNCC to develop a set of indicators for long term environmental monitoring and short-term disaster response for the Government of the BVI. The resulting draft set of environmental indicators used as a basis the latest UK practice (the indicators in the Defra 25 Year Plan), consultation with Government of BVI stakeholders and further refinement from feedback received during a workshop consultation with specialists from the Overseas Territories of the BVI and Turks and Caicos[9].

Structured under 11 Headline Areas groups (see Table 3.1), the first iteration of indicators comprised 68 environmental indicators to monitor long term environmental change. Of these, a subset of 15 were identified for use for short-term disaster response. For each indicator, information was further characterised using a set of criteria including: a potential metric, methodological approach, spatial coverage, cost, frequency of monitoring, potential data source and whether it could be measured using earth observation data.

Table 3.1 Headline Indicators

Headline Areas	
Air	Impacts of exotic disease and invasive species
Freshwater	Resource Efficiency and waste
Marine, estuarine and coastal	Exposure to harmful chemicals
Land	Production and harvesting of resources
People enjoying and caring for the natural environment	Greenhouse gas emissions from the natural environment
Resilience to natural hazards	

In a subsequent visit to the BVI, the JNCC and Government of BVI undertook an additional review of the draft environmental indicators and wider consultation. This resulted in a further prioritisation and rationalisation to form a second iteration of environmental indicators: 25 long-term environmental indicators over six headline areas (freshwater, marine, land, resilience to natural hazards, impacts of exotic disease and invasive species, and production and harvesting of resources); and 13 short-term environmental indicator over five headline areas (as above but excluding impacts of exotic disease and invasive species). Of these 13, 4 indicators were exclusive to the short-term indicator framework. An additional 6 indictors (covering air, land and exposure to harmful chemicals) were identified as having future priority.

A key outcome of this JNCC/Government of BVI review was the need to develop environmental economic indicators to support BVI macro-fiscal reporting.

Wood visited the BVI in September 2019 for meetings with the Government of BVI. During these discussions, the key priority related to project Objective 2 was the development of environmental economic indicators. This, therefore, became the focus of work related to this objective.

[9] Wood (2019) Development of environmental indicators for the British Virgin Islands

3.2 Environmental economic indicators

Overview

The specification of environmental economic indicators was centred around the development of key 'Programme Strategies'. Programme Strategies are a method used for planning and budgeting by the BVI government. Associated with each Programme Strategy are "Outcome indicators" which focus on the broad desired outcomes of the programmes and "Output indicators" which describe impacts of specific outputs generated in delivering the outcomes.

Programme Strategies of the Ministry of Natural Resources, Labour and Immigration (MNRLI) were developed in order to respond to pressures on the environment and to support the Environment Bill. Their selection responds to the need to define government action over the short to medium term in the context of the overall objective to deliver long term enhancement and sustainability of natural resources.

Programme Strategies were chosen following consultation across the MNRLI led by the Deputy Permanent Secretary Joseph Smith-Abbott and Minister Honourable Vincent O. Wheatley and reflect environmental priorities for funding for 2020. The indicators for each Programme Strategy were formulated to meet the needs, processes and following consultation with the Ministry of Finance Macro-Fiscal Unit.

Programme Strategies and Indicator development

The Programme Strategies and related 'Output Indicators' and 'Outcome Indicators' developed are presented in Tables 3.2 – 3.4. Appendix B provides further detail characterising each Programme Strategy including the pressure associated with it. Programme Strategies are each focused on natural capital and the ecosystem services they provide.

In developing these indicators, the following factors were considered:

- Data availability;
- Ease and cost of measurement;
- Whether an indicator, while not directly capturing the effect of interest, is a suitable proxy for it;
- Whether an indicator is more or less capable of manipulation in reporting (such as a project count indicator with a single large project represented as many smaller projects)

Indicators were selected which were inherently quantitative (e.g. number of days or projects). As a result, features of the environment often considered using qualitative considerations are not represented. The advantage is that the indicators overall are more quantitatively based and so can provider a clearer picture while the disadvantage is that they are less representative. This aspect of the choice of indicators reflects the quantitative requirements of the BVI government planning process.

Table 3.2 Draft Key Programme Strategies

#	Key Programme Strategies
1	To establish an environmental legislative and regulatory framework.
2	Establish a framework for environmental data collection and management to provide evidence to support the implementation of the Environment Bill.
3	To establish environment enforcement capability.
4	To develop and implement a marine water quality policy and strategy to support improvements to natural capital assets that enhance biodiversity and provide coastal flood protection services.
5	Establishing yacht sewage collection infrastructure and introduce incentives for yacht modification to install effluent tanks to reduce pollution into the marine environment.
6	Creation, maintenance and restoration of natural capital assets (coral reefs, mangroves, beaches) to reduce coastal flooding.
7	To develop and implement a policy and strategy prevent illegal reclamation and future loss of salt ponds to protect against flooding, biodiversity degradation and beach erosion.
8	The establishment of a beach management policy and strategy to support and enhance biodiversity and coastal protection.
9	Develop and implement a management plan to address impacts from mass sargassum events.
10	To develop and implement a policy and strategy to promote the use of natural capital for climate change adaptation.
11	To develop and implement an air quality policy and strategy to reduce significant emissions of pollutants with local impacts (e.g. NOx, SOx, soot, fine particulate matter (PM2.5)).
12	To establish an implement a policy and strategy to ban the use of specific hazardous substances (e.g. specific paints, sun cream containing oxybenzone and octinoxate) to protect natural capital assets (e.g. coral reefs).
13	To develop and implement a policy and strategy to reduce the use of single use plastics to increase resource efficiency and reduce litter.

Table 3.3 Draft Output Indicators

Programme Strategy #	Output indicators
1	Number of Cabinet Papers for the Environment Bill prepared for Cabinet {Assumed included in generic Ministry performance criteria}.
2	Number of environmental aspects being monitored.
2	Number of ecosystem services with natural capital valuation estimates.
3	Available hours for enforcement.
4	Number of water quality samples taken at specific locations.
6	Number of projects focusing on coral reef creation, maintenance and restoration.
6	Number of projects focusing on mangrove creation, maintenance and restoration.
6	Number of projects focusing on beach creation, maintenance and restoration.
7	Number of projects focusing on salt pond restoration
7	Number of salt ponds with legal protection.
8	Number of beaches with management plans.
8	Number of leatherback turtle hatchlings observed.
9	Response capacity to sargassum per event ($, man days).

Table 3.4 Draft Outcome Indicators

Programme Strategy #	Outcome indicators
1	Environment Act enacted.
2	Number of ongoing sampling programmes with routine data collection.
2	% of GDP being spent on environmental monitoring, reporting and verification.
3	% of GDP linked to natural capital.
4	No. of prosecutions.
6	Number of days marine water quality at locations meets or exceeds standards.
6	Percentage of territorial marine water within standards.
6	Area (m^2) of natural capital assets affected by projects.
7	Economic value of built infrastructure protected by natural capital.
7	Area (m^2) of functioning salt ponds.
8	% of beaches without negative human impacts.
8	Population of leatherback turtles.
9	No. of days where sargassum is causing negative impacts after mass events.

Programme Strategies 5, and 10-13 were included with a view into the future beyond the 2020 budget process. As a result, specific Indicators were not developed for these.

Result of indicator selection adopted by Government

The draft set of Programme Strategies and Indicators were successfully presented to the Ministry of Finance in draft form to ensure that their description and quantification met their needs. Following additional refinement by the MNRLI[10] a subset of Programme Strategies was successfully submitted as part of the budgetary process.

The Key Programme Strategies which are present within the BVI Budget 2020 are:

- Establish comprehensive legislation to:
  - Introduce an environmental, climate adaptation and sustainable development framework for the management of natural resources and advance the sustainable development agenda,
  - Convert the existing Territory's Exclusive Fisheries Zone to an Exclusive Economic Zone to better manage and control marine affairs and resources, and
  - Enacting the bill to control the illicit trade of Endangered Species (CITES) to better control the movement of species in and out of the Territory by end of first the fourth quarter of 2020.

[10] Smith Abbott, J. Policy relevance of the indicator framework for environmental management, climate adaptation and disaster resilience for the Virgin Islands, presented 19th November 2019.

- Restore and conserve of coastal habitats by establishing and maintaining coral nurseries and restoring mangroves and ponds throughout the Territory to create healthy coastal ecosystems by partnering with NGO's.
- Establish the ecological, economic and financial value that ecosystems, habitats and natural capital render to reduce the impact of disasters and hazard events to human settlements, critical infrastructure and environmental assets driving the economy of the Territory.

Associated output and outcome indicators that were derived by MNRLI are summarised in Table 3.5 and Table 3.6

Table 3.5 Output indicators

Output indicators
Area of coral reef under direct restoration
initiatives (sq. m)
Area of mangrove creation or restoration (sq. m)
Number/area of salt ponds reinstated
No. of days water quality at beaches exceed safety standards
Number of development projects assessed and undertaken by established environmental standards and safeguards

Table 3.6 Outcome indicators

Outcome indicators
Percentage of land and marine space being declared as protected areas
Number of environmental and climate adaptation projects delivered at the community and national levels
Change in value of protected economic assets directly linked to natural capital

3.3 Long-term priority environmental indicators

The purpose of the long-term indicators are to support the new Environmental Bill, fiscal planning and reporting including as input to deriving an Environment Sensitivity Index (ESI). Since the development of the 2nd iteration of long-term environmental indicators no additional amendments had been made the MNRLI.

The long-term indicators were presented to the Department of Disaster Management (DDM) and Department of Central Statistics Unit. No further amendments to indicators or potential metrices were suggested during these discussions.

Outcome

During the November 2019 visit it was confirmed that the long-term indicators had been included as a key component of the Environment Bill that is in its final revision stage and should be introduced by Q3/Q4 2020. These indicators are presented in Appendix C.

3.4 Short-term environmental indicators

Short-term environmental indicators have been derived to meet the requirements of the Disaster and Needs Assessment (DANA) and to support short term disaster response. Since the development of the 2nd iteration of short-term environmental indicators only one amendment had been made by the MNRLI, this was an extra potential metric to measure the erosion/loss of soil: 'The frequency of landslides/slope failures'.

During the visit to the BVI in September 2019 the short-term indicators were presented to the Department of Disaster Management (DDM). During this discussion it was noted that an indicator for the 'Extent of sustainable fisheries' had been included by mistake so was removed. No further indicators were identified to be added.

Outcome

DDM were fully supportive of the third iteration of the short-term environmental indicators and they met the requirements for DANA. These indicators are presented in Appendix C.

4. Conclusion and recommendations

Conclusions

The environmental indicator development was a positive process of participation and collaboration which has generated results that have been incorporated into government planning and environmental monitoring at a policy and strategy level. This has resulted in:

- the inclusion of long-term environmental indicators in the new Environment Bill;
- short-term environmental indicators that have been approved by DDM for use as part of DANA; and
- the inclusion of selected economic indicators into the BVI government 2020 budget.

We note that the selection and specification of indicators can and will change over time in response to changing pressures on the environment and current priorities. The current focus on monitoring sargassum and containing its effects is an example where the level of monitoring may be matched according to the levels of occurrence in a particular year.

A quantitative assessment of the soil erosion regulation and coastal flood regulation provided by natural capital was provided. This study has identified the key catchments with the largest estimated sediment delivery capacity and as a result the coral reefs that are most vulnerable to sedimentation. These catchments should be the focus of sediment management practices to ensure coral reef health to increase resilience of coastal protective services.

Coral reefs provide a coastal flood protection benefit quantified in terms of avoided economic losses. These benefits were estimated for 120 individual sections of the BVI coastline related to the specific built infrastructure and economic activities at each. There are wide variety in levels of exposure and levels of economic losses but, in general, reefs that protect low lying population centres are of particular value. Depth damage graphs showing the specific exposures and values at each location for different levels of coastal flooding (that coral reefs mitigate against) are presented in the appendices. These graphs allow the value of the impact of different storm events to be assessed locally and different locations to be compared. They provide the basis for assessing the cost of damage including for use in Damage and Needs Assessments (DANA).

Recommendations

Implementation of protocols for deploying indicators - The implementation of the monitoring of indictors requires methodologies to be agreed and protocols to be developed. Organisational responsibility for different indicators is required and specification of methods for the technical aspects of data collection, recording and reporting.

Regular review of indicator selection – Regular reviews of indicator selection is required to ensure the selected set meet fitness-for-purpose tests within an overall context of environmental monitoring. Such reviews might be accomplished by revisiting the process and stages of indicator selection used in this project and confirming the up-to-date relevance of indicator selection according to current environmental priorities.

Review indicators on 'resource efficiency and waste' – An initial review might include an early consideration of the implementation of indicators on 'resource efficiency and waste', which have not currently been selected, given the importance of these issues in the BVI and across the Caribbean more widely.